Airport Risk Assessment. A Probabilistic Approach

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Synopsis

The purpose of this paper is to describe and analyse the problem of safety aspects at airports. Special attention is given to the following aspects:

- A strategic approach to improve airport safety, which includes the use of failure and hazard analysis techniques and fast time simulation modelling;
- Safety of land side operations;
- Certification aspects.

This research looks at an extremely small part of that network, picks out a few hazards, introduces a new modelling tools that have been used in their analysis, and discusses some mitigating strategies.
A risk is "the combination of the probability, or frequency, of occurrence of a defined hazard and the magnitude of the consequences of the occurrence". The air traffic control system is in place to monitor and maintain both vertical and horizontal separation; also, many aircraft have radar based collision avoidance systems installed.
The goals of risk assessment are:

- To derive the values of likelihood and severity of consequence for each hazard;
- To use that information as a means of prioritising actions, i.e. which hazard requires the most work and so should be tackled first?
- To specify mitigating features as appropriate to each hazard;
- To predict the effectiveness of those features in reducing the risk.

To stand any chance of achieving these goals we first need a list hazards analyzing report of air accident or incident assembled in every Government from 1980 to 2003. We relived in the accident data that currently the general number of events in the world (accident, incident, serious incident) it is, for the commercial aviation, equal to around 50 a year, which correspond to in average 1300 deceased. The number of annual catastrophic accidents (accident) in the world it is, instead, around equal to 25. The model provides equations with which to determine either the impact or wreckage location of an aircraft following an accident. Several equations are described which cater for all permutations of: aircraft operation (approach or departure); crash from flight, or runway run off, veer off and, crash location (before or after the prepared runway surface). These equations form a set of probability distribution functions of a crash occurring per unit area. The probability of an aircraft being struck by debris due to an accident has five components. The product of these components gives the desired result:

- P(accident) or the proportion of aircraft within the airport vicinity that have an incident that causes it to crash, or run – off, veer – off, short land the runway;
- P(accident type) that represent the type of accident the aircraft will have (short landing, overrun, run off, veer off etc.). These components derive by the statistic analysis conduct beginning from real data deducted by accident reports;
- P(aircraft type) that represents the probability of an aircraft type occurs in an accident. This value is relate with actual and estimate number of aircraft operation, landing and take – off;
- P(point of occurrence) or the region that will be affected by the resulting crash or run – off;
- P(final point) that represent the region that will be affected by debris or the entire aircraft due to accident occurs in take – off or landing manoeuvres.

With this model we determine the region around airport that will be interested by the incident. In other words we determine the area affected by different probability occurrence of incident (*frequency of occurrence of a defined hazard*). To determine the risk we will be multiplied by the magnitude function that will be determine with reference to an accident and the operation of aircraft types.

The final product of this research will be a quantitative tool that can be utilized both in airport project and in the operation management, assessing in the first case an useful tool to the infrastructure realization of determinate capacity in the other case a "limit" to the airport capacity.

Airport risk assessment.
A probabilistic approach

Reduction of risk and consequent death injury and damage is the key objective of policy for transport safety. The systematic assessment of risk, the setting of targets for its reduction in the context of safety strategies, and the monitoring of progress towards such targets are playing an increasing role in the formulation and implementation of transport safety policy across the modes.
Risk assessment ranges from the interpretation of data concerning numerous and frequent occurrences to the estimation of the likelihood of very rare events, combined in each case with the quantification of exposure to risk. Target setting requires forecasting of exposure, levels of risk, and the acceptability and effectiveness of policies and measures for risk reduction, in order to identify targets which strike a balance between challenge, achievability, and public and political acceptability. Risk and safety have always been important considerations in civil aviation. This is particularly so under current conditions of continuous growth in air transport demand, frequent scarcity of airport and infrastructure capacity, and thus permanent and increased pressure on the system components. The purpose of this paper is to describe and analyse the problem of safety aspects at airports. Special attention is given to the following aspects:

- A strategic approach to improve airport safety, which includes the use of failure and hazard analysis techniques and fast time simulation modelling;
- Safety of land side operations;
- Certification aspects.

An airport is a multifunction distributed system that is apart of a much larger system. You can think of it as being at the centre of a dynamic network made up of all the sources of cargo, passengers and the other people who travel to and from the airport. But that is just the ground system; a large number of these networks are interconnected to form a huge communications network: the nodes are the airports with their hinterlands and the dialogues are made up of aircraft.
This research looks at an extremely small part of that network, picks out a few hazards, introduces a new modelling tools that have been used in their analysis, and discusses some mitigating strategies. Airports are centers for air traffic in the air transportation system. Consequently, their presence causes a convergence of air traffic over the area surrounding the airport. For those people living in the vicinity of an airport, this implies involuntary exposure to the risk of aircraft accidents. Actual local risk levels are higher than might be expected. Although the probability of an accident per flight is very low (typically in the order of 1 in 1.000.000), accidents tend to happen mostly during take – off and landing phases of a flight and hence, close to an airport, as we may seen in the previous paragraph. The low probability of an accident per movement combined with large number of flight operations (typically several hundreds of thousands) may suggest the probability of one accident per year near a large airport. This probability is of course much higher than the better known and smaller probability of being involved in an aircraft accident as a passenger. Local risk levels around large airports are, in effect, of the same order of magnitude as those associated with participation in road traffic. Because an increase in airport capacity usually involves changes to runway layouts, route structures and traffic distributions, which in turn effect the risk levels around the airport, *third party risk* is an important issue in decision making on airport development. To realize this model objective and accurate risk information is necessary to provide guidance to local and national authorities, the population around the airport, and the airport operator. The method and its derivative may be used to calculate risk contours.

1. DEFINITION

A risk is "the combination of the probability, or frequency, of occurrence of a defined hazard and the magnitude of the consequences of the occurrence". This definition comes from the United Kingdom's Regulator of Air Traffic Services. It is possible to interpret the "combination" of parameters in this definition of risk to mean the formation of a two dimensional quantity. So, if the risk is to be reduced, it can be either be done in the severity axis, or in the likelihood axis, or both. To effect a decrease on both axes may be considered the best approach to risk reduction; but it is not always possible. For natural hazards such as an earthquake, typically we cannot do anything to reduce the likelihood, but there is much that can be done to reduce the consequences. For example, special building regulations can be put in place and general public can be encouraged to keep “earthquake kits” to hand that contain emergency food, water, etc. Alternatively, there is much that can be done to reduce the consequences of a mid – air collision of two aircraft, but there is much that can be done to reduce the chances of it happening: the air traffic control system is in place to monitor and maintain both vertical and horizontal separation; also many aircraft have radar based collision avoidance systems installed.

The goals of risk assessment are:

- To derive the values of likelihood and severity of consequence for each hazard;
- To use that information as a means of prioritising actions, i.e. which hazard requires the most work and so should be tackled first?
- To specify mitigating features as appropriate to each hazard;
- To predict the effectiveness of those features in reducing the risk.

The subject of risk has become very popular in the last few years and is much talked about at all levels of industry. We shall first give a definition of risk in qualitative terms and then translate it in quantitative terms. A first, intuitive observation comes from the fact that there is *risk* if there exists a potential source of *damage*, or *hazard*. When an hazard exists, e.g. posed by a system which in certain conditions may cause undesired consequences, *safeguards* are typically devised to prevent the occurrence of such hazardous conditions and its associated undesired consequences. However, the presence of an hazard does not suffice itself to define a condition of risk. Indeed, inherent in the latter there is the *uncertainty* that the hazard translates from potential to actual damage. Thus, the notion of risk involves some kind of loss or damage that might be received and the uncertainty of its transformation in an actual loss or damage:

risk = damage + uncertainty

This qualitative analysis is reflected in the various Dictionary-definitions of risk, such as “possibility of loss or injury and the degree of probability of such loss”. Let x and p denote a given damage and the probability of receiving such damage, respectively. From a quantitative point of view, it is common to the define a measure of the associated risk R as:

$$R = x \cdot p \tag{1.1}$$

In practice, often, the perception of risk is such that the relevance given to the damaging consequences x is far greater than that given to its probability of occurrence p so that eq.(1.1) is slightly modified to:

$$R = p \cdot x^k \text{ with } k > 1 \tag{1.2}$$

By so doing, numerically larger values of risk are associated to larger consequences. When considering complex systems, the above quantitative definitions must be extended to account for the fact that typically more than one undesirable events exist. With n undesirable events associated with the operation of a given system, eq. (1.1) is usually extended to the following definition of *composite risk* which accounts for all hazards present, in an integral way:

$$R = \sum_{t=1}^{n} x_t \cdot p_t \tag{1.3}$$

and similarly for eq. (1.2).

These quantitative definitions of risk, eq. (1.1-1.3), are easily shown to be little informative for the purposes of risk analysis, management and regulation. Suppose you were considering two different systems A and B of equal risk $R_A = R_B$ as defined by (1.1). Let the risk of A be due to a potentially large consequence x_A occurring with small probability p_A and vice versa for the risk of B. Then, if we wish to intervene on the design, operation and regulation of the two systems in order to reduce the associated risks, we act differently knowing the different natures of the risk in the two cases. To reduce R_A we would implement emergency systems which mitigate the accident (*mitigation*) and containment systems which limit its consequences to the outside environment (*protection*), on the contrary, if we were to reduce R_B we would allocate additional redundancies and improve the reliability of the system components so as to reduce the probability of an accident (*prevention*).Thus, if we simply know the value of R, we may not be effective in reducing it by limiting its probability part or by mitigating its consequences; hence, the importance of keeping separate the constituents of risk, p and x. Note also how the key concepts of the *defence-in-depth* approach, characteristics of the nuclear safety world, i.e. *prevention, mitigation, protection*, come into play in the management of risk. The situation is even worse in the case of the composite risk of eq. (1.3) where the probabilities and consequences of all potentially dangerous events are combined together in a single risk value. From the above said, an informative and operative definition of risk should allow answering the three fundamental questions of any risk analysis:

- Which sequences of undesirable events transform the hazard into an actual damage?
- What is the probability of each of these sequences?
- What are the consequences of each of these sequences?

The answers to these questions lead to a definition of risk in terms of a set of triplets:

$$R = \{s_t, x_t, p_t\} \tag{1.4}$$

where s_i is the sequence of undesirable events leading to damage, p_i is the associated probability and x_i the consequence.

In relationship to the type of events it is possible to define three typologies of risk:

- *Conventional risks*: they are relative to very frequent events and they interest one or two people;
- *Specific risks*: they are relative to continuous or very frequent events with modest damages in brief times;
- *Great potential risks*: they are connected to very rare events with serious damages.

These are the last risks, object of the analysis, that is illustrated in the pages that follow and that for, simplicities of language, will synthetically come suitable as *risk of accident*.

In the case in which the risk of accident, defined through the relationship 1.1, is not considered tolerable in relationship to the benefits attended by the activity to which refers, it will is necessary to put to attenuate its intensity into effect. The research of smaller risk conditions (with greater safety degree) it behaves interventions aimed to decrease:

- the entity of the consequence, protection action;
- the frequency of the dangerous events, prevention action;
- both last intervention.

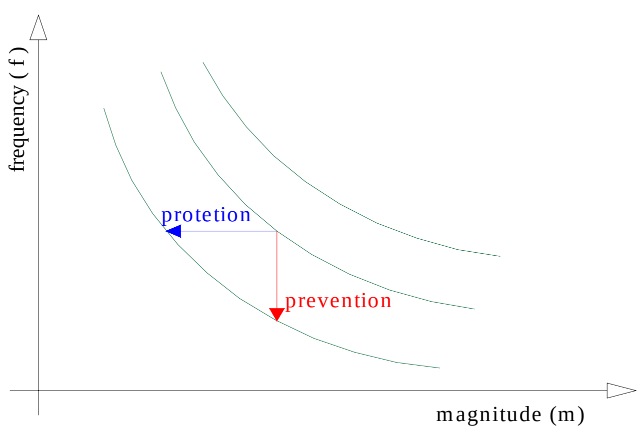

Figure 1.1.: Isorisk lines. Scheme of Prevention and Protection Actions.

Events in this publication are classified according to the following definitions. These definitions are consistent with those of the National Transportation Safety Board (NTSB) and the International Civil Aviation Organization (ICAO).

Airplane accident: An occurrence associated with the operation of an airplane that takes place between the time any person boards the airplane with the intention of flight and such time as all such persons have disembarked in which:

- Airplane sustains substantial damage.
- Death or serious injury results from: Being in or upon the airplane;
- Direct contact with the airplane or anything attached thereto;
- Direct exposure to jet blast.

Hull loss (Serious Incident): Airplane damage that is substantial and is beyond economic repair. Hull loss also includes events in which:

- Airplane is missing.
- Search for the wreckage has been terminated without it being located.
- Airplane is substantially damaged and inaccessible.

Substantial damage (Incident): Damage or structural failure that adversely affects the structural strength, performance, or flight characteristics of the airplane and would normally require major repair or replacement of the affected component. Substantial damage is not considered to be:

- Engine failure or damage limited to an engine if only one engine fails or is damaged.
- Bent aerodynamic fairings.
- Dents in the skin.
- Damage to landing gear.
- Damage to wheels.
- Damage to tires.
- Damage to flaps.

Fatal accident: An accident that results in fatal injury.
Fatal injury: An injury that results in death within 30 days as a result of an accident.
Serious injury: An injury sustained in an accident that:

- Requires hospitalization for more than 48 hours that begins within 7 days of the date of injury.
- Results in a fracture of any bone (except simple fractures of fingers, toes, or nose).
- Produces lacerations that result in severe haemorrhage or nerve, muscle, or tendon damage.
- Involves injury to any internal organ.
- Involves second or third degree burns over 5 percent or more of the body.
- Involves verified exposure to infectious substance or injurious radiation.

To stand any chance of achieving these goals we fist need a list of hazards; a necessary precursor is thus hazard identification. When building a large system from a number of smaller ones we find that many of the hazards arise from the intra – system interfaces. When performing a risk assessment, then, we can start off by identifying those interfaces and the hazards arising from them. Where a system is made up of subsystems from different suppliers their domains of influence also need to be considered. The overall system owner needs to be able to coordinate and disseminate hazard identification information. An airport has a lot of interfaces with outside world, air traffic control has radio and telephones; there are navigational aids that communicate with aircraft, such as a distance measuring beacons and instrumental landing systems; there are road links; there may be rail links; etc. We will consider an airside interface, the runway. It is the interface between the air navigation system and the ground handling area.

2. THE SAFETY DATA RECORDS

The airport risk assessment includes a series of connected activity among them and following lists:

- the historical of the events analysis;
- the determination of the accident frequencies;
- the evaluation of the magnitude and the risk.

This study has involved the information acquisition among which the most important are:

- investigating causes of aircraft accidents;
- the accident location;
- the accident consequences.

Accident data are obtained, when available, from government accident reports. Otherwise, information is solicited from operators, manufacturers, various government and private information services, and press accounts.
Such information, as already illustrated in the next chapter, is been inferred by a historical analysis of the events object of the study, making reference to two types of files:

1) local files (ANSV);
2) world files (AAIB, AAIU; ATSB; NTSB; TSB, etc.).

In order to determine a tool that allows, with few lines, to have a brief and exhaustive description of the aircraft accidents that have been analyzed, as well as a support on which to bring the first news of an investigation, a report has been compiled:

Tab. 2.1.: A synthetic scheme to collect a principal factors concerning aircraft accident.

<table>
<tr><td>ID_NUMBER:</td><td colspan="2">DATE AND HOUR:</td><td>LOCATION:</td></tr>
<tr><td colspan="2">AIRCRAFT_TYPE:</td><td colspan="2">CLASS:</td></tr>
<tr><td>FLIGHT_CONDITION:</td><td colspan="2">MANOUVRE_CONDITION:</td><td>EVENT_TYPE:</td></tr>
<tr><td colspan="4">FLIGHT PLAN:</td></tr>
<tr><td>ORIGIN:</td><td colspan="2">INTERMEDIATE_SCALE:</td><td>DESTINATION:</td></tr>
<tr><td colspan="4">Flight_ID:</td></tr>
<tr><td colspan="4">METEREOLOGICAL_CONDITION:</td></tr>
<tr><td colspan="4">SYNTETIC EVENT DESCRIPTION:</td></tr>
<tr><td colspan="4">PROBABLE CAUSES:</td></tr>
<tr><td colspan="4">DANNI A PERSONE</td></tr>
<tr><td></td><td>Flight crew</td><td>Passengers</td><td>Others</td></tr>
<tr><td>DEADS</td><td></td><td></td><td></td></tr>
<tr><td>INJURIES</td><td></td><td></td><td></td></tr>
<tr><td>UNINJURIEDS</td><td></td><td></td><td></td></tr>
<tr><td>TOTAL</td><td></td><td></td><td></td></tr>
<tr><td colspan="4">DAMAGE:</td></tr>
<tr><td colspan="2">AIRCRAFT:</td><td colspan="2">OTHER:</td></tr>
<tr><td colspan="4">AIRPORT FEATURES INTERESTED:
Description:</td></tr>
<tr><td colspan="4">EVENT_SCHETCH:</td></tr>
</table>

where:
ID_NUMBER is the code of the analyzed report;
DATE AND HOUR are the date and the time when the accident is verified. This last, in conformity with the prescriptions of the ICAO Annex 13, it will be express in now local or coordinated universal schedule UTC (Universal Time Coordinated).
LOCATION is the place in which the accident is occurred (airport in this search).
AIRCRAFT_ID: the typology of aircraft interested by the accident. In the case in examination the commercial airplanes interested to the cargo and people transport, among which, for instance, the whole typology of Boeing, Airbus, Mac Douglas, Fokker, Antonov, BAe, etc.
CLASS: the class of the aircraft defined in relationship to its maximum take-off weight (MTOW), particularly identified with following letter code:

- A: aircrafts with maximum take-off weight smaller than 15.000 lbs (6.750 Kg) with an only motor;
- B: aircrafts with maximum take-off weight smaller than 15.000 lbs (6.750 Kg) and two motors;
- C: aircrafts with maximum take-off weight included among the 15.000 (6.750 kg) and the 300.000 lbs (136.000 kg);

- D: aircrafts with maximum take-off weight greater than 300.000 lbs (136000 Kg) and more than two motors.

FLIGHT_CONDITIONS are the flight meteorological conditions before and during the accident event distinguished in:

- VFR (Visual Flight Rules): it deals with a flight performed with the visual references aid, for instance to establish the flight direction they are used points of the ground surface of note location; naturally the possibility to effect visual flights is tied up to the existence of an enough visibility, that is of meteorological conditions VMC (Visual Meteorological Condition). In the checked aerial spaces the "least" VMC (that is the least values of the parameters that define the conditions of VMC) are: flight visibility in 8 Km; distance from the clouds: 1,5 Km in horizontal direction and 300 ms in vertical direction. In Italy the visual flight rules are forbidden in the nighttimes hours and the flight have to sustain under the 600 ms of height; cannot be landed in VFR with visibility to the ground lesser than 8 Km and with ceiling lesser than 450m;
- IFR (Instrument Flight Rules): when the flight is performed using radio – frequency aids (VOR, NDB, DME, TACAN, etc.).

MANOUVRE_CONDITIONS: are the manoeuvres that the aircraft was performing during the accident (landing and take – off, in IFR or VFR conditions, taxing, etc.).

EVENT_TYPE: is the typology of aircraft accident. In the specific case the main typologies are:

- run off: it is frequent in the case of long landing or aborted take-off;
- veer off: it is relative to an aircraft side off and can happen both in take-off phase and landing; it can be due to an elevated value of the wind transverse component, to a mechanical breakdown, etc;
- short landing: it is relative to a touchdown happened before the runway threshold and as it suggests the name it happens in phase of landing. It is due, mainly, to bad meteorological conditions;
- run incursion: it occurs both in take-off phase and landing and can concern both aircrafts and other vehicles.

FLIGHT PLAN: a synthetic description of the flight plan is brought that the aircraft interested by the accident has performed or it had to perform. Particularly we record: the departure airport and his id code (in ICAO, IATA or FAA coding); possible intermediary airports; the destination airport with his code and finally the flight typology.

METEOROLOGICAL_CONDITIONS are the conditions recorded in the place of the accident during the event. Particularly they regards: the presence and height of the clouds (ceiling); visibility; wind direction and intensity; precipitation presence or absence; temperature and dewy point.

SYNTETIC EVENT DESCRIPTION: a brief but exhaustive description of the accident dynamics. For the finalities of the conducted study, in such description are underlined:

- in landing phase: the touchdown point, in which the accident is verified and the stop point in which the aircraft or your eventually debris are reinvented;
- in take-off phase: the point in which the accident is verified and the stop point in which the aircraft or your eventually debris are reinvented.

PROBABLE CAUSES: are the probable causes that have brought to the accident. We would remembers that an aerial accident is essentially due to three factors:

- Human factor;
- Mechanical factor;
- Environmental factor;

These are not among them interdependent, but they interact among each and they can be considered as causal factor of the other. The mechanical and environmental factors are obviously unchangeable the brief period and the man cannot intervene in some way to modify them. The only possibility of intervention consists in the evaluation of the human errors and in the application of preventive measures that aim to reduce the accident. In to examine the typology of errors, the following classifications can be made:

- active failures (errors or active drawbacks): they are errors or drawbacks that an immediate negative effect caused;
- latent failures: they are failures existing before the event.

AIRPORT FEATURES INTERESTED: a description of the features interested by the accident: RWY, TWY, Apron or also the zone where the accident is occurred, as well as the state in which was found during the accident. In the case in examination, the airport features interested is the runway and of the last we consider:

- a synthetic description that understands the geometric characteristics: length, width, longitudinal and transversal inclination, presence of stop way (SWY) and his dimensions, the STRIP width, declared distances, what: TORA (Take Off Run Available); TODA (Take Off Distance Available) distance, ASDA (Accelerate and Stop Distance Available), LDA (Landing Distance Available). The runway

Instrumentations. Particularly the ILS system for landing. In relationship to the runway visual range (RVR) and to the decision height, the ILS is divided in: ILS of 1° category (CAT I): it allows an approach of precision until to a height of decision of 60 mt and a RVR of the 800m; ILS of 2° category (CAT II): it actually allows an approach of precision to a decision height of 30 mt and a RVR of the of 400 ms; ILS of 3° category (CAT III): it allows an approach of precision without some decision height and a RVR between the 200 and 50 mt. The typology and intensity of the Visual AIDS;

- the pavement state conditions during the accident. To define said conditions is made reference to the ICAO terminology. In the eventuality in which on the runway there is water the followings terms we have been used: damp to point out that the surface shows changes of color because of the damp; wet to point out that the surface is full water, but there is no puddles; water patches (presence of puddles) to point out that on the surface they are visible puddles; flooded to point out that on the surface they are visible ample zones covered of water. Instead to point out the presence of ice on the runway the terms that we have been used are: rime or frost covered normally to the millimetre; dry snow; wet snow; slush; ice; compacted or ruled snow; frozen ruts or ridges.

EVENT_SCHETCH is a graphic accident representation in which the points in the synthetic description of the accident and a possible photographic documentation are underlined.

In the late 1990s the world's airline fleet consists of more than 15 000 aircraft flying a network of approximately 15 million km and serving nearly 10 000 airports. The sector directly employs more than 3.3 million people, with over 1.4 million in USA (Air Transport Action Group, 1996). Some 12 billion people and 23 million tonnes of freight are being moved per annum. The freight figure represents approximately one third of value of the world's manufactured exports. Total accidents are closely related to the scale of civil aviation operations. A variety of international institutions, organisations and agencies deal with forecasting future trends, including International Civil Aviation Organization (ICAO) and International Air Transport Association (IATA). The airspace manufacturers such as Airbus Industry, Boeing and Rolls Royce also make projections. Some idea of projected growth can be seen in Table 2.2. (International Civil Aviation Organization, 1994). The broad range of predicted growth rates vary between 5 and 6.5% across particular forecasters with the exception of the low figure from Fokker. Historically, when there has been relatively rapid growth in air transport, it has often been followed by a series of accidents. The occurrence of such events has stimulated the introduction of technical and operational measures. As a result, overall safety has improved over time. ICAO, for example, has shown the fatality rate for international and domestic schedule aviation operations has been consistently decreasing over time. Between 1970 and 1993 the fatality rate fell from 0.18 to 0.04 fatalities per 100 million passenger kilometres with particularly marked reductions recorded between 1970 and 1977. During the period 1984 - 1993, the trend was relatively stable. The same analysis indicates that the number of fatal accidents during this 23-yr period varied between 16 and 31/yr. The average number of accident per annum was 25 and the average annual number of passenger fatalities was 741/anuum.2 At the same time the output of the sector rose from 1971 to 389 billion passenger-kilometres which is over a 500% increase (International Civil Aviation Organization, 1992,1994). Some are arguing that the scope for further improvements in safety are becoming exhausted implying that if the accident rate remains the same, while air travel increases, the number of accidents will inevitably rise.

Tab. 2.2.: Example of air traffic forecasts. Source ICAO (1994) – ATAG (1996)

Forecaster	*Period*	*Average annual growth Rate (pkm) (%)*
Airbus Industry	1992-2001	5,8
	2002-2011	5,1
Boeing	1993-2013	5,2
Rolls - Royce	1993-2012	5,2
AcDonnell Douglas	1990-2000	6,5
Fokker	1994-2013	3,5
ICAO	1992-2003	5

2.1. Experimental analysis: acquisition and elaboration data

To every accidental event, relieved trough the government or others operators accident reports, we have compiled the files determined in the previous paragraph. An elaboration of the general data, has allowed to establish that of the 1.174 commercial airplanes involved in accidents the 46,4% concern the airport; the 18,1% the approach paths; the 35,4% different locations from those previously lists.

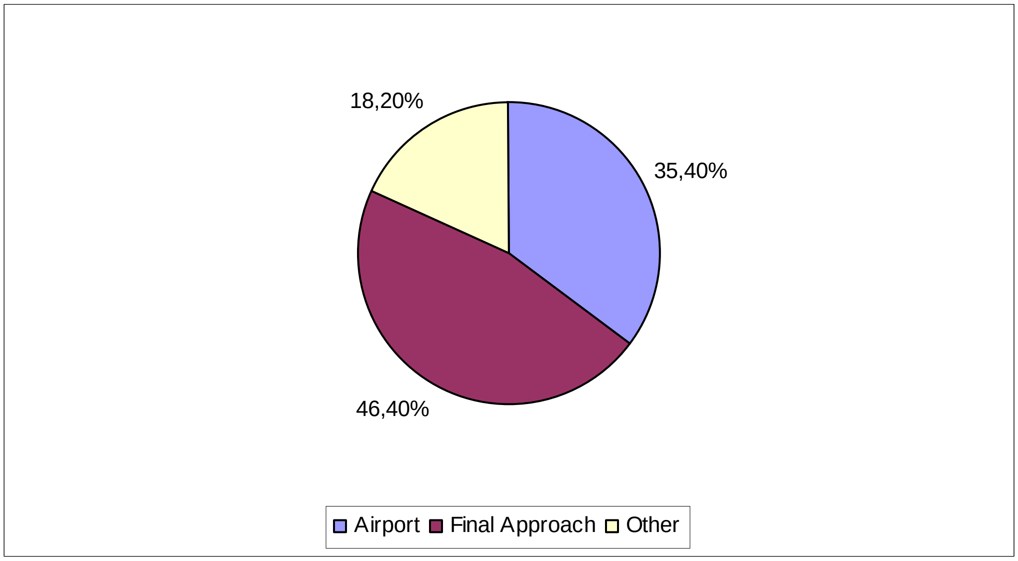

Figure 2.1.: Aircraft accident events from 1995 to 2004: different location distributions

Of this last the 40,1% are *accident*, the 54,7% are *incident* and the 5,2% are *serious incident.* As for the accidents that have interested the airport: the 58,5% concern the RWY, the 33,6% the apron and the7,9% the TWY.

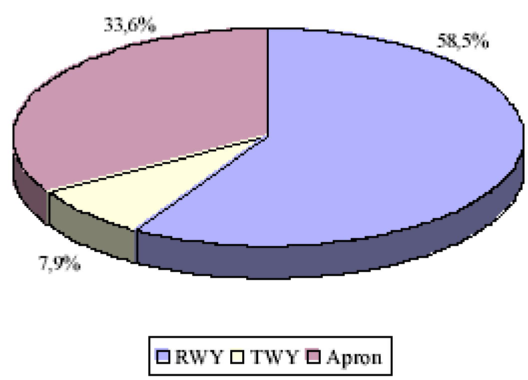

Figure 2.2.: Accidents of commercial airplanes in the airport: distribution among the different airport features

In the following figures is illustrated, for every ICAO features typology, the distribution of the accidents.

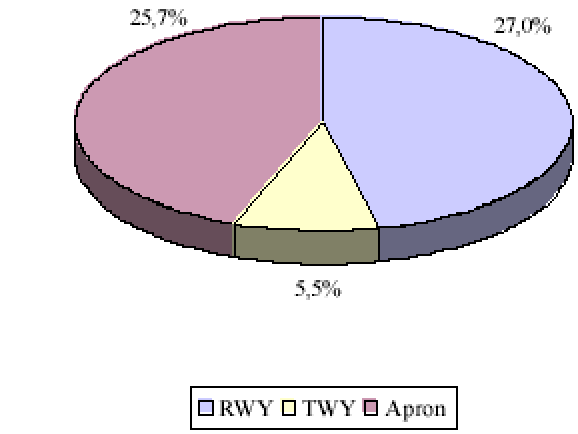

Figure 2.3.: *Accidents* of commercial airplanes: distribution among the different airport features

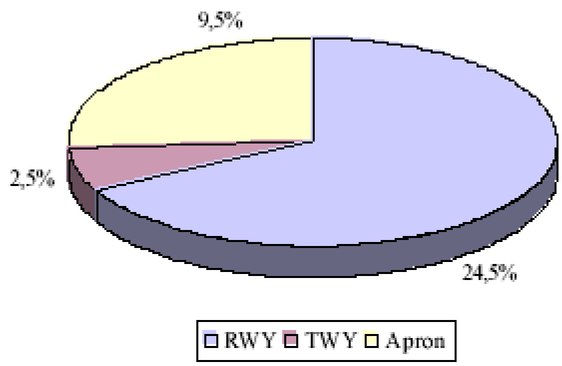

Figure 2.4.: *Incidents* of commercial airplanes: distribution among the different airport features

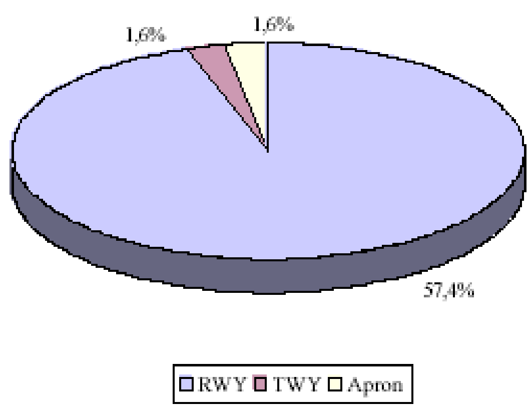

Figure 2.5.: *Serious Incidents* of commercial airplanes

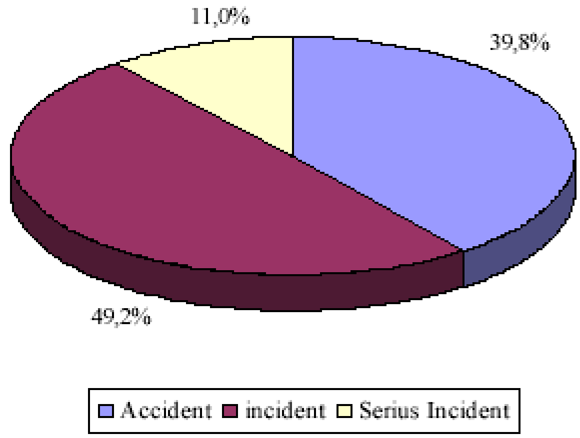

Figure 2.6.: Typology distribution of accident events in the runway infrastructure.

From these first results emerges that during the taxing manoeuvres from and for the runway and those of standstill in the terminal area, the aircraft, also causing damages to things, it doesn't produce some damage to the people except a strong fear or light injuries. For against, the accidents during the take-off phase and, particularly, in that landing, they are characterized by an elevated percentage of injuries and deceased. Therefore in this research they have not been considered the "slow manoeuvres" because of can be held it departs specific risk category, but only those on the runway.
Investigating causes of fatal aircraft accidents is difficult because they generally stem from a complex system of mutually dependent, sequential factors. These factors can be classified in several ways. First, according to the current state-of-knowledge they can be categorized into known and avoidable and unknown and unavoidable causes. The former should be considered conditionally in the sense that immediately after an accident the real causes are seldom fully known but as the investigation progresses they become known and avoidable. The causes of some accidents are never uncovered. Second, with respect to accident type, the main causes of air accidents can conditionally be classified into human errors, mechanical failures, hazardous weather, and sabotages and military operations.
The analysis of the general statistic data related to the accidents happened on the runway has allowed to underline that the 75% of these happen in the landing phase and the 25% in the take-off manoeuvre. Of these, 62% are due to human errors; 13% to the meteorological conditions; 25% to the mechanical failures.

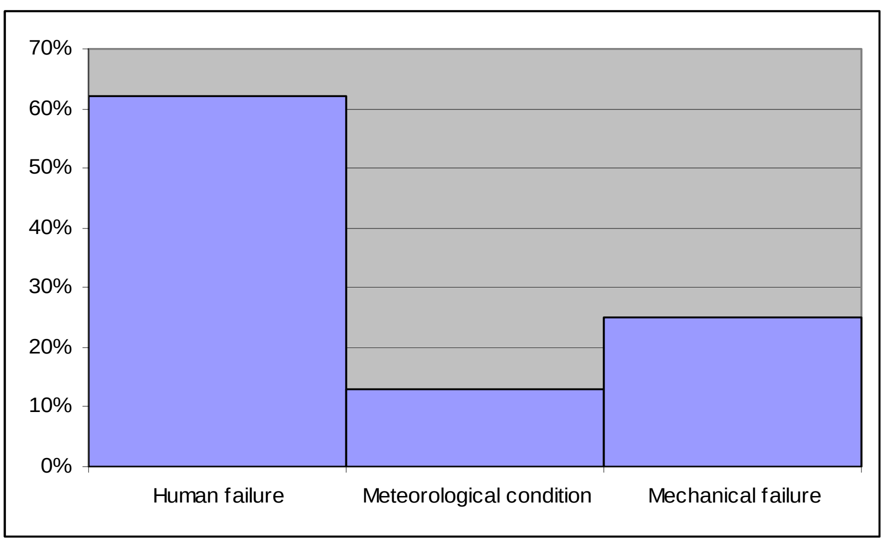

Figure 2.7.: Factors causing air accidents.

Considering single maneuvers has been possible to notice that:

- in the landing phase, the 66% of the accidents are due to the human error, 20% to the mechanical failures and the 14% to the meteorological conditions;

- in the take-off phase, instead it is due the 45,5% to human error, 45,5% to the mechanical failures and the 9% to the meteorological conditions.

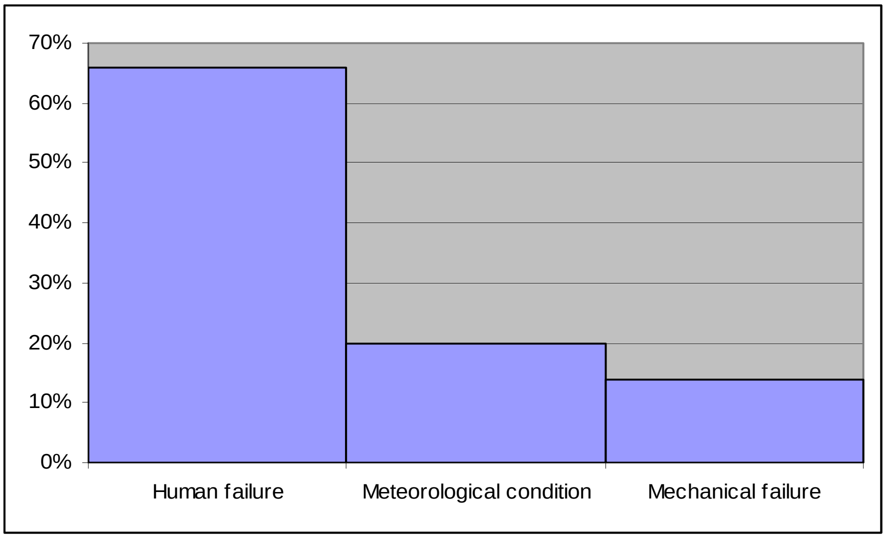

Figure 2.8.: Factors causing air accidents in the landing phase.

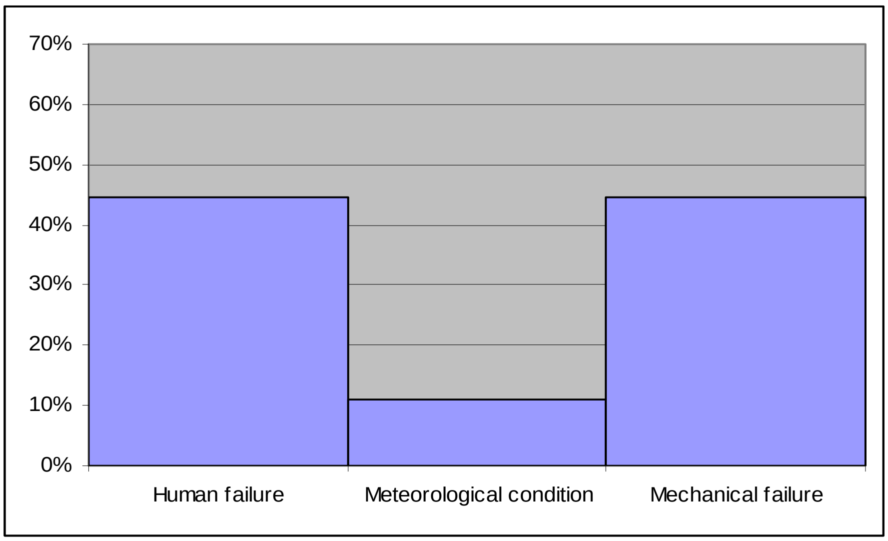

Figure 2.9.: Factors causing air accidents in the take - off phase.

Therefore, while in landing phase the predominant cause is represented by the human error, in the take-off there is an equilibrium between mechanical failures and d human error.

3. A METHODOLOGY FOR ASSESSING THE RISK

Basic element to conduct a statistical analysis of an event is the sample data description and determination. In the case study the sample elements are the commercial aircrafts involved in runway accidents in the takeoff manoeuvre and in landing phase. In this work we have not been considered:

- the missed collisions in the runway among two aircrafts or among these and an any other vehicle;
- the damages of the aircrafts in take-off phase that has not brought to some effect; particularly when the aircraft has missed the take-off arresting itself inside the runway, without problems, or has also continued the take-off unloading the excess fuel and, after circling around the airport, is landed without further accidents;

- the aircrafts that, during the landing phase has suffered a failures and went out the runway without further problems.

The model used to calculate airport risk accidents consists of three main elements: the probability model of an occurrence of aircraft accident and the accident location probability model to determine the frequency of an occurrence (*p* in the 1.1. equation); the accident consequence model (to determine the *x* variable in the 1.1. equation).

3.1. The aircraft accident probability model

Objective of this phase of the study has been the subdivision of the surrounding area runway in isofrequency lines or rather zones characterized by the same probability to individualize to their inside a commercial aircraft, of one determined aircraft class, following the accident.
The idea and the model as a result was born from a careful analysis of the incidental phenomenon, particularly of the various phases that have brought to the arrest of the aircraft to the outside of runway, both in take-off phase and in landing. It has emerged that the interested events (the touchdown point or take-off interruption phase; the accident causes; the aircraft or debris stop point) may be considered, everyone, of an event can occur at random and at any time or any point in space. Past aircraft accidents have possessed this characteristic. They occurred in a random manner in different parts of the world. Therefore it is possible to determine the frequency of an occurrence through a partial shares model. Particularly we have fixed a Cartesian reference, (x,y) with origin on the runway axle and axle x coincident of this last, and we have discredited the study object area (and the area around the airport) through a grid squared or rectangular. It will be possible to estimate the probability p that the airplane or debris, involved in a generic accident, belonging *i* class, stop in a determined point (B) centre of the generic unit grid in which is hypothesized assembled the probability of stop related to the whole unit grid. This probability will be related to the probability that define touchdown or aborted take – off point (A), for the same airplane, also defined similarly as the probability of centre of the generic unit grid in which is hypothesized assembled the probability of stop related to the whole unit grid. As we say may be synthesize by the following relationship:

$$Pr_I^i\{B\} = \frac{n_i}{\sum n_i} Pr^i\{I\} \cdot Pr^i\{A\} \cdot Pr^i\left\{{}^{B}\!/\!_{A}\right\} \qquad (3.1)$$

where

$\frac{n_i}{\sum n_i}$ is the percentage of airplanes related to *i* weight class that landing or take off from the airport object of study;

$\frac{n_i}{\sum n_i} Pr^i\{I\}$ this figure represents the proportion of aircraft within the airport vicinity that have an incident that causes it to crash, or run – off of the runway, ect. The I variable represent the type of accident the aircraft will have (i.e. crash short of runway on approach, or run off the side of the runway, etc.);

$$Pr_I^i\{B\} = \frac{n_i}{\sum n_i} Pr^i\{I\} \cdot Pr^i\{A\} \cdot Pr^i\left\{{}^{B}\!/\!_{A}\right\}$$

$Pr^i\{A\}$ this figure represents the probability that the airplane of *i* class touches in the landing phase or aborts the take-off in the determined point A;

$Pr^i\left\{{}^{B}\!/\!_{A}\right\}$ is the probability that the airplane of *i* class, departing from the point A comes to stop themselves in the point B.

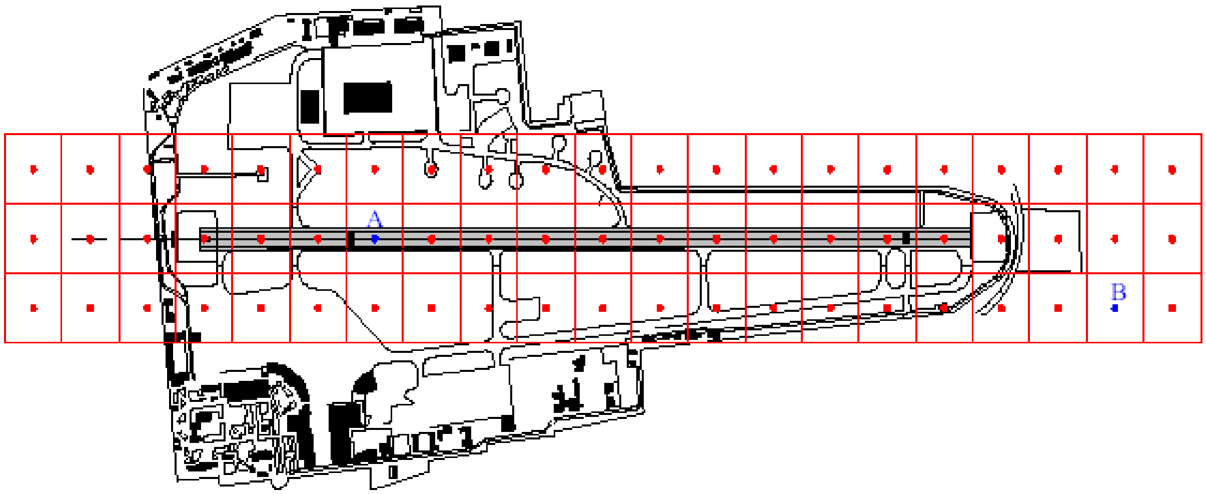

Figure 3.1.: Discredited area object of study. *Naples International Airport*.

Adding, for every point B, the probabilities determined with the preceding relationship, relatively to every category in which the sample will be divided, total probabilities are gotten. Enveloping the points characterized by the same total probability the above mentioned areas we are obtained.
Since the examined accidents interested different measures of runway, to give a correct interpretation of the statistic data related to the distances has been necessary to make adimensional the distances information. To such purpose we have introduced "standard runway" that has a length equal to 10.000 ft and a width equal to 150 ft. Dividing these lasts dimensions for the real dimensions of the runways interested by the relieved accidents, the values of two homogenized coefficients (C_x and C_y) have been obtained. Multiplying dictates values for the real length and width, may be possible to define the accidents schemes of the "standard runway", on the base of which the study has been conducted then. For example the 11/07/2001 in Fiumicino Rome Airport accident has interested a type MD-11 airplane. In such case the runway 16C dimensions are 9.850 ft, of length and 150 ft, of width. Dividing the measures of the "standard runway" to these the following values of the coefficients Cx and Cy are obtained:

- C_x= 1,015;
- C_y= 1,000.

Multiplying the valued distances according to the aces x and y, for said coefficients we are obtained some homogenized values on the base of which the study has been conducted. Particularly results that the aircraft MD-11 has touched the runway to a distance of 914 ft and it is arrested to 3665 ft from this. We have proceeded in analogous way for all relieved accidents and for every manoeuvres (landing and take-off).
The model provides equations with which to determine either the impact or wreckage location of an aircraft following an accident. Several equations are described which cater for all permutations of:

- Aircraft operation (approach and departure);
- Crash from flight, or runway run off;
- Crash location (before or after the prepared runway surface.

These equations form a set of probability distribution functions of a crash occurring per unit area.

3.1.1. The proportion accident type model

This approach model involves the statistical modeling the occurrence of air accidents over time; a Poisson sequence or Poisson process is often deployed. Such a process is based on the following assumptions:

- an event can occur at random and at any time or any point in space. Past aircraft accidents have possessed this characteristic. They occurred in a random manner in different parts of the world;
- the occurrence of an event in a given time or space interval or segment is independent on what happened in any other non-overlapping intervals or segments. Air accidents, except very rare mid-air collisions, have occurred as the series of independent events in time and space;

- the probability of an event occurring in a small interval Δt is proportional to Δt and can be estimated by $\lambda \cdot \Delta t$ where λ is the mean rate of occurrence of the event. It is assumed constant and equal to $\lambda = {}^{1}\!/_{T_a}$, where T_a is the average time interval between consecutive events. The probability of two or more occurrences in Δt is negligible (of higher order of Δt). From empirical evidence, as Δt is assumed to be a sufficiently short period, the probability of an occurrence of more than one aircraft accident will normally be negligible.

In Poisson processes the time intervals between successive events is exponentially distributed, indicating no-memory property in the process. This means that future events do not depend on the number or time of previous events. This would logically seem to be the case with air accidents. Mathematically, let *T* be the random variable representing the time between any two consecutive events. This variable is exponentially distributed. The probability that no accident will occur in time period *t* is

$$P(T > t) \cong P(X_t = 0) = e^{-\lambda \cdot t} \qquad (3.2.)$$

where, X_t is the number of air accidents in time *t* and ë is the average accident rate. Similarly, the probability of the occurrence of at least one event in time *t* is

$$P(T \le t) = 1 - P(T > t) = P(X_t \ne 0) = 1 - e^{-\lambda \cdot t} \qquad (3.3.)$$

The probabilistic assessment of accidents uses a sample of 101 accidents over the period 1995 - 2003. The distribution of time intervals between these events is shown in Figure. 3.2. A simple calculation provides an estimate of the average accident rate: $\lambda \cong$ 7.851 accidents per year or $\lambda \cong$ 0.0215 accidents per day. An analysis of the time intervals between accidents, independent of aircraft type, indicates they have been independent and exponentially distributed (a χ^2 test confirms the hypothesis matching the empirical and theoretical data: $\chi^{2(10)}_{0.05} = 16.9191;\ \chi^2 = 15.706 \Rightarrow \chi^2 < \chi^{2(10)}_{0.05}$. This offers confirmation that the observed pattern of accidents can be treated as Poisson process. Using the exponential distribution seen in Figure 3.2., it is possible to assess the probability of an occurrence of an air accident.

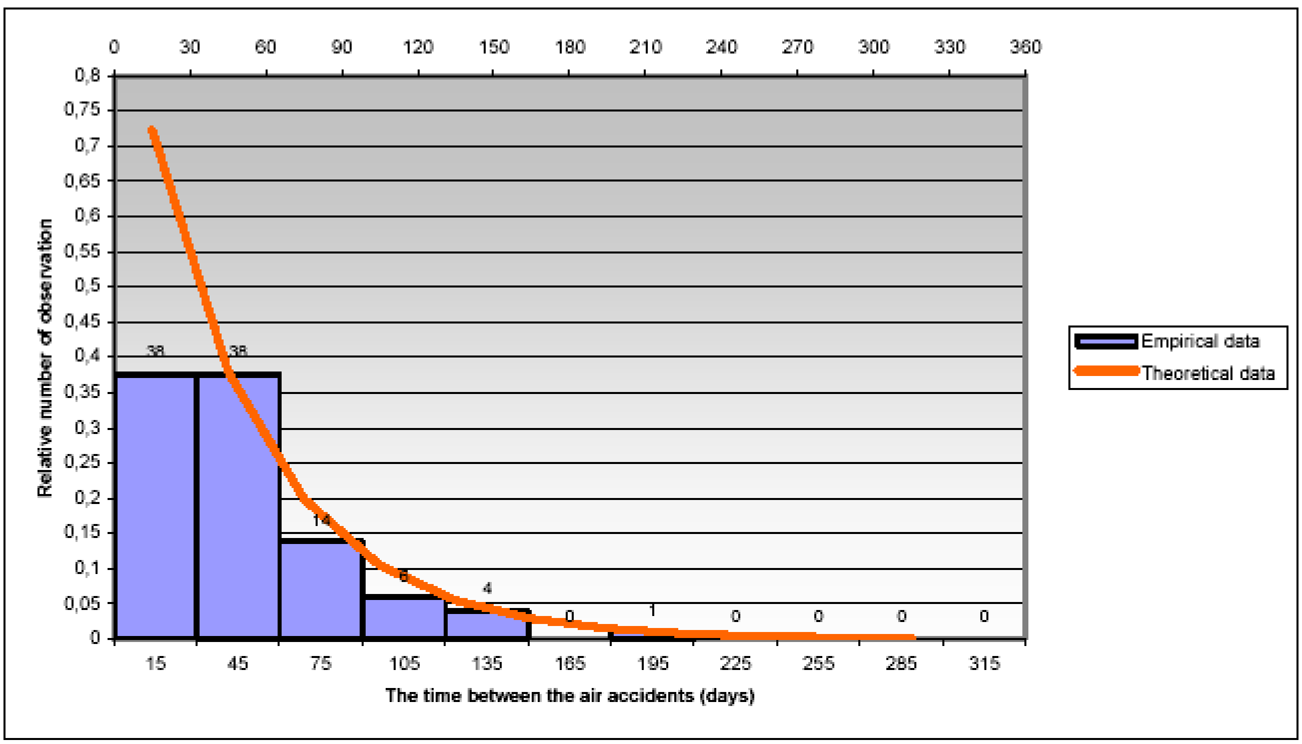

Figure 3.2.: Distribution of time intervals between consecutive air accidents (1995 – 2003)

If there is unlikely to be any improvement in safety features then this distribution can be used for assessing the probability of future events. Figure 3.3. illustrates the probability of the occurrence of at least one air accident per period *t*. This probability rises over time until the event. For example, the probability of at least one accident by the following day from now is about 0.0215, by next month 0.5207, by six months 0.974, and by next year 0.999.

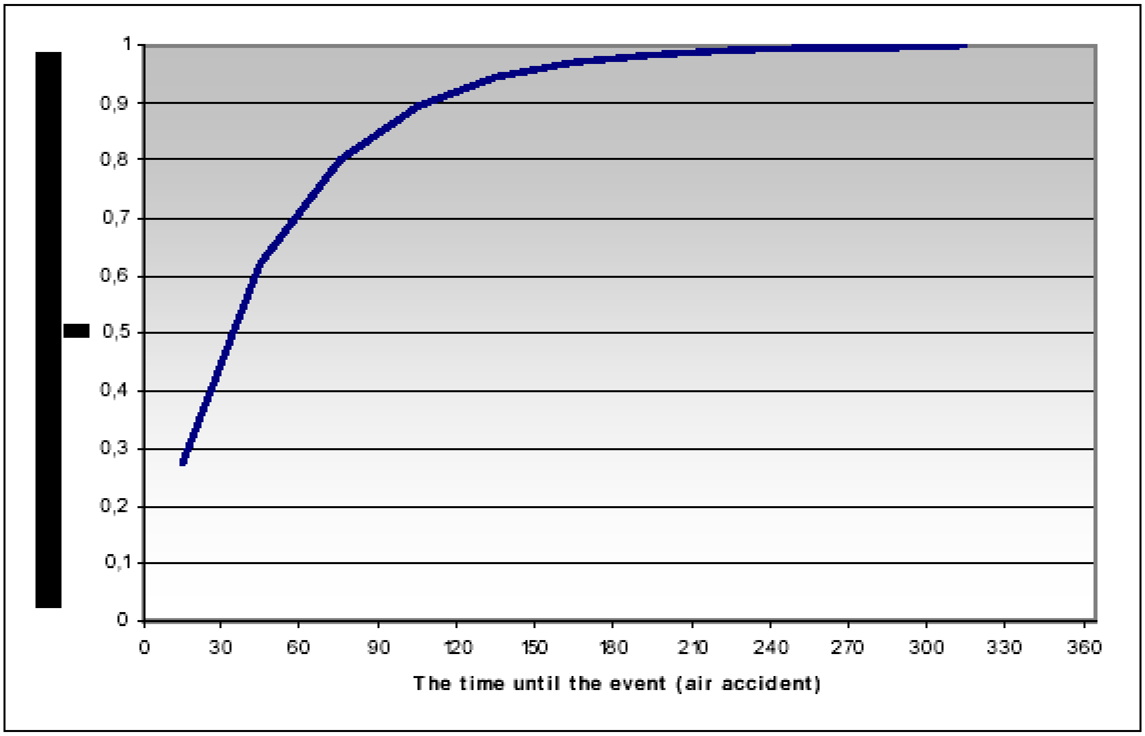

Figure 3.3.: Dependence of the probability of the occurrence of at last one air accident within time period t.

3.1.2. Model formulation $Pr^i\{A\}$ to landing phase

Divided the point sample of touchdown in two subsets corresponding to the two classes of aircrafts (C and D). For each of these a fixed number of touchdown distance intervals has been defined. To avoid to have empty intervals (condition that corresponds to a lower part number of intervals) or information loss around the form of the function distribution (condition that corresponds to an elevated interval numbers) the number of these and the respective ampleness have been defined through the relationships:

$$k = 1 + 3.3 \cdot log_{10}\, n_i \qquad (3.4.)$$

$$\Delta x = \frac{x_{max} - x_{min}}{k} \qquad (3.5.)$$

with n_i total number of landings related to the above weight class aircraft of the-exempts.
Bringing for the whole sample and for the single weight classes the distribution of the touchdown points and interpolating the obtained results, may been possible to verify, through the test of the hypotheses ρ^2, of which will be said subsequently, that these are distributed according to a Normal function of average and standard deviation varying according to the weight class aircraft:

$$f(x) = \frac{1}{\sigma\sqrt{2\pi}}\, e^{-\frac{1}{2}\left(\frac{x-\mu}{\sigma}\right)^2}, \text{ with } -\infty < \mu < +\infty \ and\ \sigma > 0 \qquad (3.6.)$$

particularly:

$\mu = 2.02\ and\ \sigma = 1.79$ 79 for the C class aircrafts;

$\mu = 1.58\ and\ \sigma = 1.16$ for the D class aircrafts.

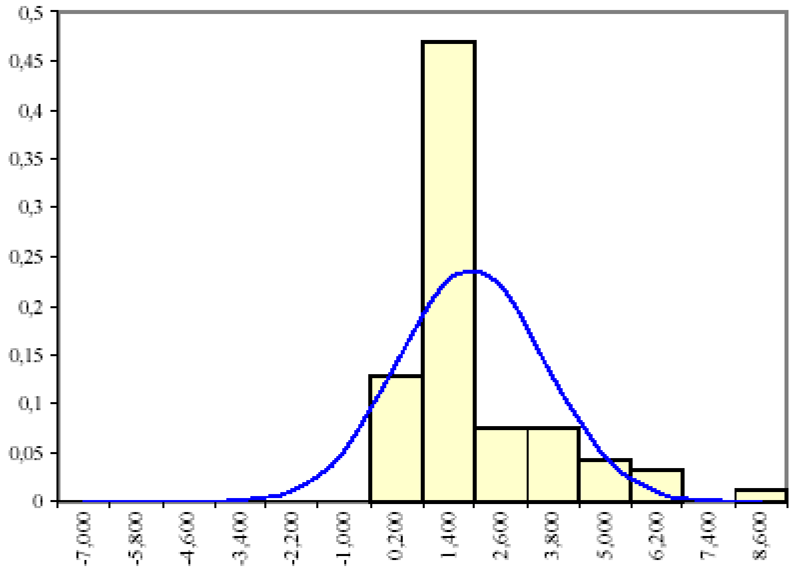

Figure 3.4.: Touchdown point distribution related to the whole the weight classes of aircraft

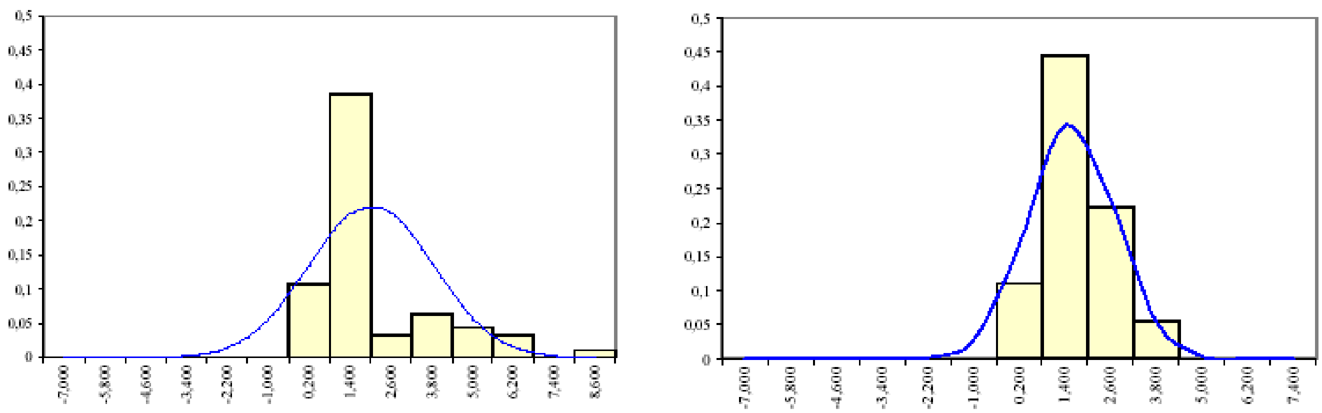

Figure 3.5.: Touchdown point distribution related, respectively, to the C and D weight classes of aircraft

Therefore the probability that an aircraft touches the runway in the point A is obtained by the following integral:

$$Pr^{i}(A) = Pr\left\{x_A - \frac{\Delta x}{2} \le x \le x_A + \frac{\Delta x}{2}\right\} = \int_{x_A - \frac{\Delta x}{2}}^{x_A + \frac{\Delta x}{2}} \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{x-\mu}{\sigma}\right)^2} dx \qquad (3.7.)$$

or, equivalently, from the following figures as difference of the ordinates corresponding to the points $x_A - \frac{\Delta x}{2}$ e $x_A + \frac{\Delta x}{2}$

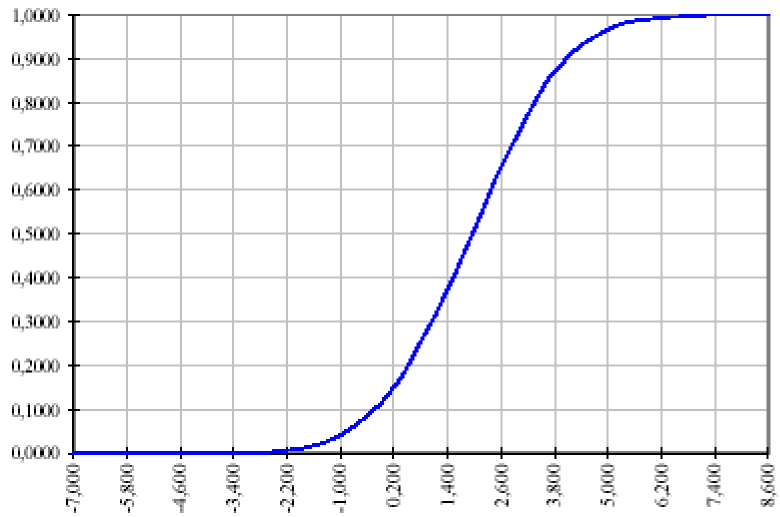

Figure 3.6.: Probability cumulative distribution to the touchdown point (A) for the C class

For example if we would determine the probability of touchdown for class C aircraft in the distance measuring interval 1.400 – 2.600 ft, uniforms such distances (dividing for 1.000), from the preceding figure are drawn that: $Pr\{1.4 \leq x \leq 2.6\} = Pr\{x \leq 2.6\} - Pr\{x \geq 1.4\} = 0.68 - 0.37 = 0.31$.

3.1.3. Model formulation $Pr^i\left\{B/_A\right\}$ to landing phase.

Also in this case to define a statistic model that allows to determine the probability that an airplane of *i* class stops in the point B, of coordinates (x_B; y_B), after having touched in the point A of the runway, for every class of aircraft and for the different touchdown zones, the stop distances were been divided along the aces x and y in homogeneous intervals of ampleness equal to:

$$\Delta x = \frac{x_{max} - x_{min}}{k} \text{ and } \Delta y = \frac{y_{max} - y_{min}}{k} \quad (3.8.)$$

with $k = 1.3.3 \cdot log_{10}\, n_{ij}$, where n_{ij} is the sample numerousness related to the weight class the and to the touchdown interval *j*.

Bringing the distribution of the stop points along the axle x, relatively to the sample, to the single classes of aircraft and the touchdown single distance intervals defined above, the results have been obtained may be showed in the following figures:

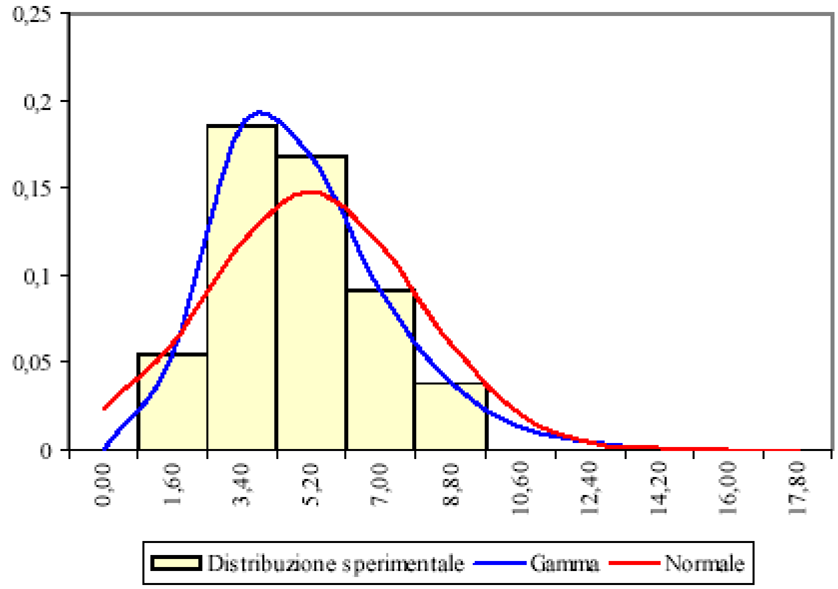

Figure 3.7.: Example of stop points distribution related to the distances of touched by the runway threshold lesser or equal than the 800 ft and class C of aircraft

From an analysis of the obtained results it is deduced that the probabilistic distribution function of the stop points along the axle x is a Gamma function:

$$f(x;a) = \frac{e^{-x}x^{a-1}}{\Gamma(a)} \tag{3.9.}$$

with parameter:

$a = 6$ for the class C of aircrafts and for all the distances of touchdown point A on the runway;

$a = 8$ for the class D of aircrafts and distances from A point lesser or equal to the 2.000 ft;

For the stop point far to touchdown more than 2.000 ft it is possible to approximate, for class D of aircrafts, the empirical data with a Normal function of average $\mu = 8.05$ and standard deviation $\sigma = 1.46$

$$f(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{x-\mu}{\sigma}\right)^2} \tag{3.10}$$

Therefore the probability that an aircraft stopped in the point with coordinates (x_B; 0) once touched in A is given from:

$$Pr^i\left\{x_B/A\right\} = \int_{x_B-\frac{\Delta x}{2}}^{x_B+\frac{\Delta x}{2}} \frac{e^{-x}x^{a-1}}{\Gamma(a)}dx \tag{3.11}$$

for the class C of aircrafts of independently from the touchdown point, and for the aircrafts of class D and distances of touched by the threshold runway lesser or equal to the 2.000 ft. While for the class D aircrafts and distances of touched by the runway threshold more than 2.000 ft, this is given from:

$$Pr^i\left(x_B/A\right) = \int_{xB-\frac{\Delta x}{2}}^{x_B+\frac{\Delta x}{2}} \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{x-\mu}{\sigma}\right)^2} dx \tag{3.12}$$

In equivalent way, the probabilities can be calculated through the following figures as difference of the ordinates corresponding to the points:

$$x_B - \frac{\Delta x}{2} \text{ and } x_B + \frac{\Delta x}{2} \tag{3.13}$$

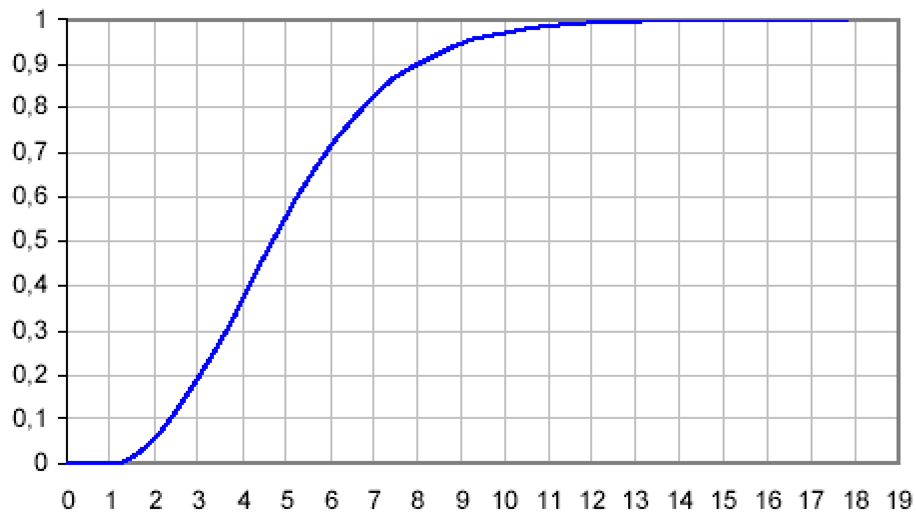

Figure 3.8.: Cdf $Pr^i\left\{x_B / A\right\} = \int \frac{e^{-x} x^{a-1}}{\Gamma(a)} dx$ **related to the C aircrafts and to all the touchdown points (type A)**

Likewise in y direction we have determined the stop points distribution, expressed by a normal function:

$$f_y(y) = \int \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{y-\mu}{\sigma}\right)^2} dy \tag{3.14}$$

with:

- $\mu = 0.846; \sigma = 1.439$ for the class C airplanes and touchdown distances lesser or equal to the 800ft;
- $\mu = 0.380; \sigma = 1.434$ for the class C airplanes and distances of touchdown among to the 800 and the 2.000 ft;
- $\mu = -0.309; \sigma = 2.408$ for the class C airplanes and touchdown distances more than 2.000ft;
- $\mu = -0.248; \sigma = 2.321$ for the class D airplanes and touchdown distances lesser or equal to 2.000 ft;
- $\mu = -0.44; \sigma = 0.943$ for the class D airplanes and touchdown distances more than 2.000ft;

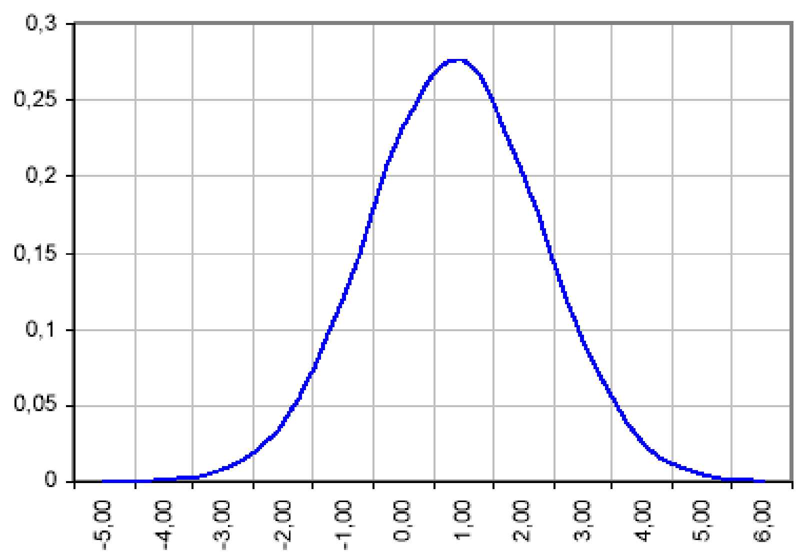

Figure 3.9.: A Cdf of the stop point in y direction related to the touchdown zone (800 ft)

Therefore the probability that the aircraft stops in the point (0; y_B) once touched in A is given from:

$$Pr^i\left\{y_B/_A\right\} = \int_{y_B-\frac{\Delta y}{2}}^{y_B+\frac{\Delta y}{2}} \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{y-\mu}{\sigma}\right)^2} dy \qquad (3.15.)$$

Finally the probability that the C class aircraft stopped in the B point, after touching in A point is given from:

$$Pr^i\left\{B/_A\right\} = \int_{x_B-\frac{\Delta x}{2}}^{x_B+\frac{\Delta x}{2}} \frac{e^{-x}x^{a-1}}{\Gamma(a)} \cdot \int_{y_B-\frac{\Delta y}{2}}^{y_B+\frac{\Delta y}{2}} \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{y-\mu}{\sigma}\right)^2} dy \qquad (3.16.)$$

instead, for the D class of aircraft the above probability is changed in:

$$Pr^i\left\{B/_A\right\} = \int_{x_B-\frac{\Delta x}{2}}^{x_B+\frac{\Delta x}{2}} \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{x-\mu}{\sigma}\right)^2} dx \cdot \int_{y_B-\frac{\Delta y}{2}}^{y_B+\frac{\Delta y}{2}} \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{y-\mu}{\sigma}\right)^2} dy \qquad (3.17.)$$

3.1.3.1. Model formulations $Pr^i\{A\}$ and $Pr^i\left\{B/_A\right\}$ for take – off phase

Following an analogous procedure to the landing case, it has been possible to verify that the distances in which the take-off was aborted are distributed according to a normal function:

$$f(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{x-\mu}{\sigma}\right)^2} \text{ with } -\infty < \mu < +\infty \textit{ and } \sigma > 0 \qquad (3.18.)$$

with

$a = 5.09$ *and* $\sigma = 2.72$ for the C weight class of airplane;

$a = 5.16$ *and* $\sigma = 3.17$ for the D weight class of airplane.

The probability function is:

$$Pr^i(x) = \int_{x_A-\frac{\Delta x}{2}}^{x_A+\frac{\Delta x}{2}} \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{x-\mu}{\sigma}\right)^2} dx \qquad (3.19.)$$

For the probability function that determine the aircraft or debris stop point distribution we have determined that they changes in accord with Gamma function:

$$f_x(x) = \frac{e^{-x}x^{a-1}}{\Gamma(a)} \qquad (3.20.)$$

with

$a = 5$ for the C weight class of airplane;

$a = 4$ for the D weight class of airplane.

The probability function is:

$$Pr^i\left\{x_B/_A\right\} = \int_{x_B-\frac{\Delta x}{2}}^{x_B+\frac{\Delta x}{2}} \frac{e^{-x}x^{a-1}}{\Gamma(a)} \qquad (3.21.)$$

In y direction we have relived a normal distribution to determine the stop point in the (y_B,0) coordinates related to the aborted take – off in B points:

$$f_y(y) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{y-\mu}{\sigma}\right)^2} \text{ with } -\infty < \mu < +\infty \textit{ and } \sigma > 0 \qquad (3.22.)$$

with

$\mu = 0.05$ *and* $\sigma = 1.464$ for the C weight class of airplane and stop distances lesser or equal to 4.500 ft;
$\mu = -0.428$ *and* $\sigma = 0.920$ for the C weight class of airplane and stop distances more than 4.500 ft;
$\mu = 1.563$ *and* $\sigma = 3.898$ for the D weight class of airplane and stop distances lesser or equal to 4.500 ft;
$\mu = 0.167$ *and* $\sigma = 0.518$ the D weight class of airplane and stop distances more than 4.500 ft and the probability function is:

$$Pr^i\left\{ y_B / A \right\} = \int_{y_B - \frac{\Delta y}{2}}^{y_B + \frac{\Delta y}{2}} \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{y-\mu}{\sigma}\right)^2} dy \qquad (3.23.)$$

The probability that the aircraft stopped in the B point, after aborted the take – off manoeuvre in A point is given from:

$$Pr^i\left\{ B / A \right\} = \int_{x_B - \frac{\Delta x}{2}}^{x_B + \frac{\Delta x}{2}} \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{x-\mu}{\sigma}\right)^2} dx \cdot \int_{y_B - \frac{\Delta y}{2}}^{y_B + \frac{\Delta y}{2}} \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{y-\mu}{\sigma}\right)^2} dy \qquad (3.24.)$$

3.2. Results

The product of the model components defined in the above paragraphs, in every point of the grid schematized, gives the isoprobabilistic points in which we may be determine aircraft or debris relate to the accident. If we join such last points we determine the crash location areas around the airport, as show in the following figure.
Those contours are obtained hypothesizing a specific value of mix index traffic: C and D weight classes. Particularly in this research we have considered Naples International Airport with mix index traffic like this shared:

- 68% aircrafts belonging to C weight class;
- 32% aircrafts belonging to D weight class.

If the above repartition change the contours may be change. In fact in the probability determined with the model implemented in the previous paragraph it is hypothesized a relation between the probability of the accident location $(P(B))$ and the mix index traffic $\left(\frac{n_i}{\sum_{i=1}^{n} n_i} \right)$:

$$Pr_I^i\{B\} = \frac{n_i}{\sum n_i} Pr^i\{I\} \cdot Pr^i\{A\} \cdot Pr^i\left\{ B / A \right\} \qquad (3.25)$$

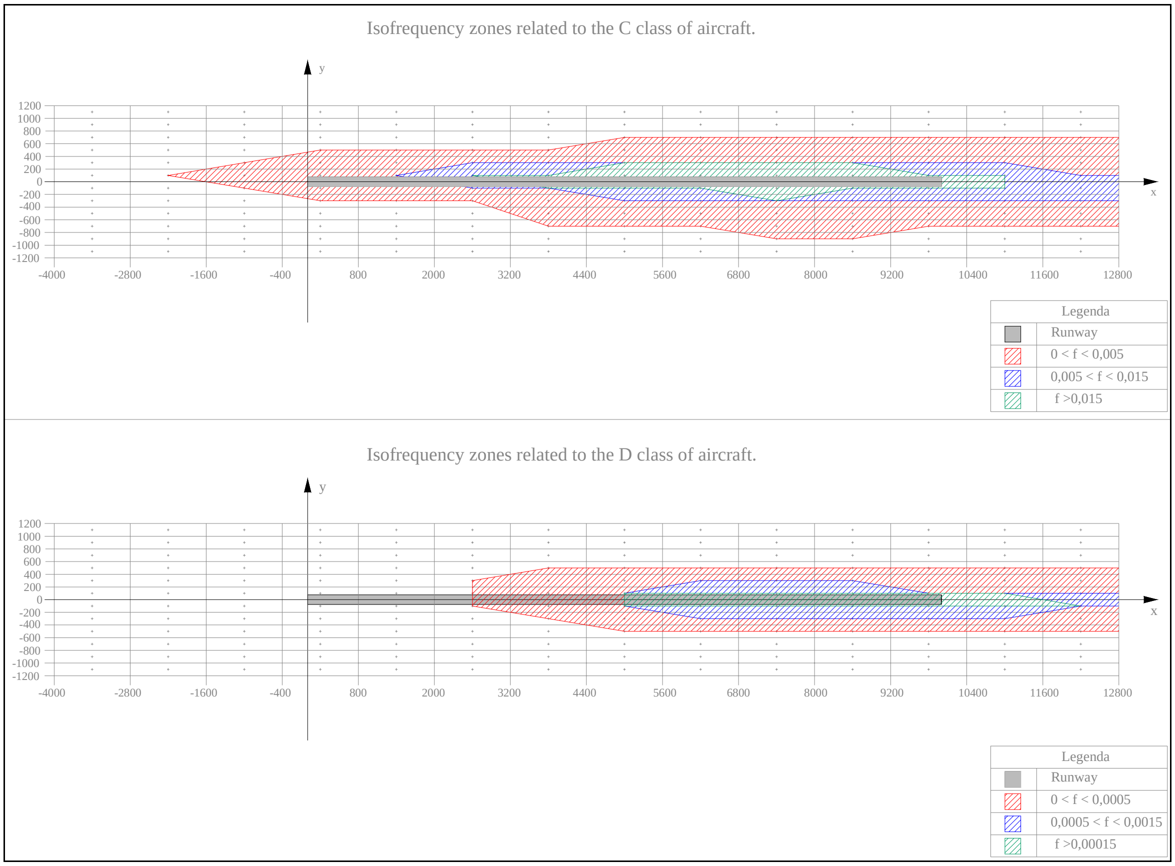

Figure 3.10.: Isofrequency lines around the airport applying the model formulation above mentioned

3.3. Evaluation of the accident consequences.

To assess the consequences of an accident is, for different reasons, rather difficult. In first place it must have determined for an anticipated event in the future, necessarily affection from uncertainties. Close to this difficulty, another exists of it related to the problem to weigh the different consequences (injuries, dead, things damages, etc.) to define homogeneous scale of magnitude.

In the present study we have proposed as magnitude scale that founded on the number of people in the object study area, in relationship to their permanence time. Particularly we have determined the number of people inside every accident location, above schematized, through the product of the housing density, (ISTAT data sources) for the extended area. Such value with *permanence coefficient* we have multiplied. This coefficient will be given by the relationship of the permanence time, in hour, for the fixed people category, inside the interested area, and the total hours in the day, multiplied for 1000; therefore in the resident case this will be equal to 1000, for the students it will be equal to 660; for the employees 330 (in fact we have hypothesized that they remains for the job time alone), for the people on the board in the aircraft we have hypothesized a value equal to 1.

Multiplying dictates values for the respective accident probability, discussed in the previous paragraphs, the risk is obtained.

CONCLUSION

This paper has considered risk assessment applied to airport runways. Some novel – computer based tools have been described that support the assessment by helping in the specification and evaluation of mitigating features.

With this model we determine the region around airport that will be interested by the incident. In other words we determine the area affected by different probability occurrence of incident (*frequency of occurrence of a defined hazard*). To determine the risk we will be multiplied by the magnitude function that will be determine with reference to an accident and the operation of aircraft types.

The final product of this research will be a quantitative tool that can be utilized both in airport project and in the operation management, assessing in the first case an useful tool to the infrastructure realization of determinate capacity in the other case a “limit” to the airport capacity.

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