DOTTORATO DI RICERCA IN INFRASTRUTTURE E TRASPORTI

SCHEDA PER L'AMMISSIONE AL III ANNO DI CORSO

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Curriculum 11042 Infrastrutture e Transporti **Tutore** Prof.ssa Paola Di Mascio

Argomento della ricerca:

Definition of a revised risk assessment model around Airports

SEZIONE A
Ricerca di Dottorato
(massimo 5 pagine)

1 – Aggiornamento del programma logico e cronologico delle attività *(Precisazione del tema prescelto per la Tesi finale; inquadram, ento delle attività già svolte e da compiere nell'ultimo anno, con aggiornamento delle previsioni su obiettivi e metodologia; cronoprogramma).*

The thesis covers the definition of a revised third-party risk assessment model around Airports, to help the identification or validation of the Public Safety Zones (PSZ) / Runway Protection Zones (RPZ), specifically at the runway ends.

The activities carried-out include the review of recent scientific literature in the field, such as the work performed in Italy by a team of researchers from Sapienza - University of Rome [1], [2], [3], England by National Air Traffic Service (NATS) [4] and Loughborough University [5], Ireland by Environment Resources Management (ERM) [6], the Netherlands, by National Aerospace Laboratory NRL[7], [8] or several research projects developed in the United States, under the Airport Cooperative Research Program (ACRP) [9], [10], [11]. The risk model developed by Sapienza with Italian Civil Aviation Authority (ENAC) collaboration [1] is derived from above mentioned Irish, English and Dutch models.

The activity performed also includes comparative evaluation of the results of the Sapienza and ARCP - RPZ risk assessment models. Then, an update of the aircrafts accidents database has been realized, to define a new accident distribution (location) and accident probability sub-models. Preliminary curves of probability density distribution curves have been developed. In the next period these curves will be validated and optimized and the accident probability and accident consequence sub-models will be revised.

2 – Attività di ricerca realizzata nei primi due anni *(identificazione e documentazione delle attività di: raccolta dati, sviluppo modelli, calibrazione, validazione delle procedure, eventuali criteri di autoverifica, etc.).*

Data collection:

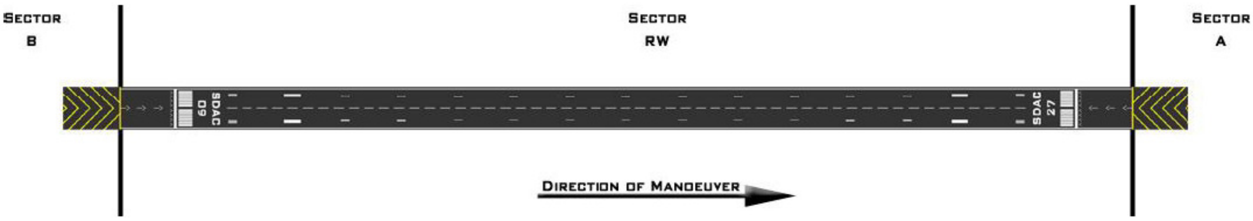
The data collection for the thesis is mainly based on historic aircraft accidents around airports and serves to define the accident location model. This collection includes three main elements.

First, as previously indicated, Sapienza existing risk assessment model (Sapienza Airport Risk Analysis Software - SARA) [1] considers a database of 813 events over 15 years (from 1996 to September 2011). This initial database is also used in *Spatial Distribution of Aircraft Crashes*

SDAC [12] and includes accidents from North America and Western Europe only, with most of the aircrafts (92%) having a MTOW[1] of 5 700 kg or more; the remaining 8 % of the events cover aircrafts with MTOW of 2 900 kg to less than 5 700 kg.

Then, ENAC with Sapienza collaboration, has extended the accident database up to 2016 (414 more events), and has also included accidents of light aircrafts (less than 2 900 kg MTOW) over the entire period (1996 - September 2016). This database has a total of **1719** events (includes accidents from all countries) and has been used for 2016 version of SDAC Software [13]. Events with aircrafts having a MTOW of 5 700 kg or more count for approximatively **63%** of the total.

The type of accident data collected is detailed in [12] and includes, among other information related to the flight, four phases of flight: Approach (A), Landing (L), Take-off (TO) and Initial Climbing (ICL) and the coordinates X & Y of the accident in relation with the runway (three locations or sectors): Before the runway threshold (B), on the runway (RW) and after the runway end threshold (A), as identified in the following figure (extracted from [12]) :



Finally, data collection has been updated during the last year from different sources (ANSV – Italy [14], TSB – Canada [15], NTSB – USA [16], BEA – France [17] , aviation accident web sites, etc.) by detailed research of recent events from 2017 to September 2020.

The research of accidents has been focused on occurrences in the same phases of flight (A, L, TO and ICL), including the veer-off events (only when the aircraft final location has been outside of the RSA or the Airport limits) when the position of the accident (or wreckage) is identified in official accident reports or extracted from the treatment of available sources (reports, photos and satellite images). The aircrafts involved in **73%** of these new events have a MTWA of 5 700 kg or more.

As such, the **updated database** to be use for the thesis includes **1825** events, from 1996 to September 2020, with the following specifics:

- 64 % of the events with aircrafts with MTWA of 5 700 kg or more; 14% of the events with aircrafts with MTWA of 3 000 kg and more, but less than 5 700 kg; 5 % of the events with aircrafts with MTWA of 2 000 kg or more, but less than 5 700 kg and the remaining 17% of the events with aircrafts having a MTWA of less than 2 000 kg.

- 58 % of the events have occurred in countries having "Western Standards", such as EU, North America, Australia, etc.

- 44% of the events have occurred inside the airport perimeter; 56 % outside of the airport perimeter;

- 30% of the events are of runway veer-off type; 62% of the events have occurred at a distance of less than 5 km from the airport (runway threshold) or 67 % at less than 10 km.

In order to facilitate the usage and also for comparison purpose, the updated database (2020) preserves the same data fields as the 2011 and 2016 SDAC databases.

Refer to Annex 1 for some examples of accident occurrences.

[1] MTOW – Maximum Take-Off Weight of an aircraft

Data collection validation

When building the database for this thesis, a comparison has been made with recent literature. As such, the accident database used by ACRP Report 168 Runway Protection Zones (RPZs) Risk Assessment Tool [11] count 1069 events (from 1980 to 2014), mainly from North America, including light aircrafts ,while ACRP Report 50 Improved model for Risk Assessment of RSA [10] considers 1414 events (accidents and incidents). Other studies (NRL [7], [8], NATS [4], ERM [6]) consider fewer occurrences or shorter time interval, but with specific selection criteria (large airports and/or aircrafts, "Western" countries only, etc.). Another recent sensitivity analyses study (Ketadbari et al. [18]) considered a database sample of 1329 events.

Consequently, while the data collection will be continued until the end of 2020, this updated database (1996 –2020) is considered adequate in this stage; filter selection can also be operated to sample the date to respect specific criteria, if needed.

Review of existing risk assessment models outputs (SARA and ARCP – RPZ Tool)

All risk assessment models consider three sub-models: accident probability (frequency), accident location and accident consequences. As such, SARA's probability model is based on airport movements and historical aircraft accident rates (as per aircraft generation, similar with NRL [8], even if the later have used revised rates in 2013) while ACRP's model is a logistic equation which considers several variables associated to causal and contributing factors of an event (identified as Normal Operations Data or NOD [10] and based on US data and information). While using NOD approach is considered (Trucco et al. [19]) an improvement from previous models (which rely only on historical accident data), the availability of such data (specifically outside US/North America) in a standard format might be challenging for other locations, as highlighted by a recent study for Iranian airports [20]. The location model of SARA uses Weibull probability density distribution curves (related to Gaussian and Gamma distribution) as two distributions (y as variable / trajectory of the aircraft respectively x as variable / runway centerline lateral occurrence) considering four type of events (take-off overrun/overshoot (crash), landing undershoot/overrun), while ACRP location model uses five complementary cumulative probability distribution curves (take-off overrun/veer-off, landing undershoot/overrun/veer-off) multiplied by the accident frequency to obtain a complementary cumulative probability frequency distribution (longitudinal and transversal distribution with non-linear exponential functions); both of models use historical accident databases. The consequence model of SARA considers the severities of the accident (destroyed area on ground) based on aircraft weight and wingspan and calculates the individual risk by considering accident probability and probability distribution (location). ACRP consequence model considers the likelihood of the occurrence and the level of severity (of the aircraft and airport facility, as defined by FAA) and the population density of the RPZ.

Considering these two models, a comparative risk assessment has been performed for a single runway airport in Italy. Same traffic input data has been considered, such as yearly movements per aircraft type and runway number. The results – iso-risk /crush likelihood contours - are presented in Annex 2.1 and, while the order or magnitude of the calculated risks is comparable, the shape of the risk contours present some notable differences.

It is worth to note that SARA calculates and identifies the risk contours as per Italian regulation (10^{-4}, 10^{-5}, 10^{-6} iso-risk), while the ACRP calculates the risk inside the required RPZs, as defined by FAA standards (however the dimensions of the RPZ can be set-up to different / non-standard values). Then, SARA calculates the risk from the runway end, whereas ACRP calculates the risks from the beginning of the RPZ (at 200 feet from runway end). The different output can also be explained by the fact that ACRP considers the runway required distance vs. aircraft performance (through the NOD data) and the runway's declared distances (such as ASDA[2] and LDA[3]).

Then, a similar comparative risk assessment calculation has been realized during Sapienza' s Master Degree Program for another Italian airport, including an exhaustive description of both methods and their output (in Italian) [21]; the results (in superposed format) are presented in Annex 2.2, similar differences in shape of the contours can be observed.

Definition of the revised model

The revised model should consider the accident location model and the accident probability (frequency) model. The consequence model will therefore be update.

Revision of the location probability model

The revision of this model is based on the updated database with new historical accident data. In this stage, the probability density distribution curves have been revised with new coefficients, as presented in Annex 3.

Revision of the event probability model

A probability model based on aircraft accident rates should consider updated values, specifically for third and fourth generation aircrafts. Industry data is considered [22] to revise these rates.

3 – Esame delle problematiche emerse e degli aspetti critici *(breve discussione degli elementi caratterizzanti il lavoro compiuto, con particolare attenzione agli aspetti più critici ed alle difficoltà emerse, con indicazione delle soluzioni individuate o delle alternative praticabili per la prosecuzione delle attività).*

The databases from 2016 and 2020 include accidents with light aircrafts. Preliminary sensibility analysis of the probability distribution curves indicates that the model requires further modification (different curves) for an airport operating only light aircrafts (MTOW of less than 5 700 kg). Then, the use on a probability model which includes NOD approach for other locations than US (or North America) remains to be validated.

4 – Potenzialità di conseguire un "impatto" scientifico significativo *(giudizio critico sulla efficacia ed originalità che la ricerca, al termine del Dottorato, potrà dispiegare, in relazione al quadro scientifico di riferimento e all'evoluzione delle conoscenze in corso in ambito nazionale ed internazionale).*

The definition or changes of the configuration of the Public Safety Zones (PSZ) and/or Runway Protection Zones (RPZ) and the risk assessment for these zones are at the interest of all stakeholders, or even regulated by some Authorities (such as ENAC). A revised risk assessment model should provide an updated tool to define the Third Party Individual Risk (IR) by calculating iso-risks of 10^{-4}, 10^{-5} and 10^{-6} contour curves of airport runways.

5 – Schema di impostazione della Tesi finale di Dottorato e programmazione delle attività di completamento.

[2] Acceleration Stop Distance Available
[3] Landing Distance Available

The following activities include the finalisation of the data collection (end of 2020), the optimisation of the revised probability distribution curves and the revision of the event probability (frequency) model. Then, the revised models will be implemented into software platform such as VBA ® and/or Excel ® spreadsheet.

6 – Cronoprogramma *(seguire lo schema seguente)*

n.	Attività	II Anno (consuntivo)				III Anno			
		I	II	III	IV	I	II	III	IV
1	Scientific Literature Research in the field of interest								
2	Update of the accident database								
	REVISED PERIOD								
3	Review of existing models (SARA, ACRP)								
	REVISED PERIOD								
4	Comparison of models' output								
	REVISED PERIOD								
5	Analysis of new probability distribution (location) curves and accident probability curves ~~including veer-off risks~~								
	REVISED PERIOD								
6	Revised accident probability model, accident distribution (location) model and accident consequence model								
	REVISED PERIOD								
7	Sensitivity analysis of the model								
	REVISED PERIOD								
8	Final report								
	REVISED PERIOD								

SEZIONE B

Attività di collaborazione e supporto; formazione ed acquisizione di capacità evolute

(massimo 2 pagine)

1 – Partecipazione alle attività di didattica presso la struttura di afferenza *(attività seminariale, supporto alla didattica frontale, preparazione di materiale didattico, collaborazione per ricevimento studenti, collaborazione allo svolgimento di tesi di laurea e stages).*

Correlatore per la tesi de laurea

LE AREE DI SICUREZZA NEI TERRITORI LIMITROFI AGLI AEROPORTI: Confronto fra i metodi di valutazione del rischio E.N.A.C. e F.A.A. [21]

Studente: Daniela Pinto Moreno, gennaio 2020

2 – Attività di formazione *(soggiorni presso strutture di didattica e ricerca in Italia e all'estero, corsi curriculari o speciali frequentati, partecipazione a seminari, convegni, workshop, etc.).*

- 20 April 2020 - Antonio Cappuccitti - Infrastructures, planning and mitigation of territorial and urban vulnerabilities;
- 08 May 2020 – Claudio Durastanti -- Statistical elements;
- 15 May 2020 – Claudio Durastanti -- Statistical elements;
- 21 May 2020 – Claudio Durastanti -- Statistical elements;
- 22 May 2020 – Claudio Durastanti -- Statistical elements;
- 28 May 2020 – Claudio Durastanti -- Statistical elements;
- 28 May 2020 – Claudio Durastanti -- Statistical elements;
- 27 May 2020 - Paolo Delle Site - Multi - Attribute Value Theory and Analytic Hierarchy Process;
- 29 May 2020 - Gianluca Dell'Acqua, Salvatore Biancardo - Building Information Model;
- 8 June 2020 - Mattia Crespi, Roberta Ravanelli - Geo Big Data analysis with Google Earth Engine
- 15 June 2020 - Mattia Crespi, Augusto Mazzoni - PVT estimation from Android Raw GNSS Measurements;
- 23 June 2020 – Seminario Carla Nardinocchi "Tecniche della geomatica per la elaborazione di nuvole di punti; seminario Valerio Baiocchi "La Geomatica ed i suoi più recenti sviluppi";
- 23 September 2020 - Luca Persia, Antonio D'Andrea- Sustainable Mobililty;
- 25 September 2020 - Maria Vittoria Corazza - Preparation of international projects;
- 14 October 2020 - Giuseppe Loprencipe - Bibliographic databases;
- 23 October 2020 (scheduled) - Carla Nardinocchi - GIS Application.
- 30 October 2020 (scheduled) - Mara Lombardi -Risk Analisys;

3 – Collaborazione a studi, ricerche, programmi strutturati *(contributi in PRIN, ricerche di Facoltà e di Ateneo, convenzioni, etc., con inquadramento del programma e specificazione dell'attività prestata).*

As a member of the World Road Association (PIARC) in Technical Committee C2: Design and Operation of Safer Road Infrastructure (cycle 2016-2019) and Technical Committee 2.1 Mobility in Urban Areas (cycle 2020-2023), I have collaborated to the following PIARC publications:

- Setting Credible Speed Limits – Case Study Report (2019R26EN): contributor, final reviewer and quality control of the English version. ISBN 978-2-84060-560-7
- Road Safety - Catalogue Of Case Studies : Road safety improvements relevant to Vulnerable Roads Users, Human Factors an Low and Middle Income Countries (2019R47EN): contributor and report editor. ISBN 978-2-84060-604-8
- Review of Global Road Safety Audit Guidelines – With Specific Consideration for Low- and Middle-Income Countries (2019R41EN): contributor and final reviewer. ISBN : 978-2-84060-589-8 ISBN; and quality control of the French version (2019R41FR), ISBN : 978-2-84060-596-6

SEZIONE C

Informazioni

(Tale sezione contiene le informazioni richieste alla fine ogni anno dall'Ufficio Dottorati)

1) Titolare di borsa erogata dalla Sapienza - Università di Roma…………….SI☐ NOX

2) Nazionalità …………………………………………………………………………..

3) Dottorato in cotutela ……………………………………….………………SI X NO ☐

Relatore: Ing. Costandino PANDOLFI (ENAC)

4) Dottorato con doppio titolo …….…………………………….……………SI☐ NOX

5) Borsa con finanziamento esterno …………………………….……………SI☐ NOX

6) Università di provenienza ………………………………………………………………….

7) Numero di mensilità di ricerca spese in una struttura di ricerca estera …………………

8) Finanziamenti all'interno di reti internazionali di formazione alla ricerca ..SI☐ NOX

9) Pubblicazioni e altri prodotti degli ultimi 3 anni

Per le aree bibliometriche. *Articoli pubblicati su riviste peer-reviewed internazionali (ed eventualmente proceedings per le aree che accettano) con impact factor (indicizzate WoS) o indicizzate Scopus.*

Per le aree non bibliometriche. *Prodotti editoriali pubblicati dai dottorandi come Monografie dotate di ISBN e/o pubblicazioni in riviste di fascia A (o prodotti editoriali equivalenti ammessi dalla VQR).*

References

[1] L. Attaccalite, P. Di Mascio, G. Loprencipe, and C. Pandolfi, “Risk Assessment Around Airport,” *Procedia - Soc. Behav. Sci.*, vol. 53, pp. 851–860, 2012, doi: 10.1016/j.sbspro.2012.09.934.

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[4] . AW Evans, PB Foot, SM Mason, IG Parker, K Slater, “Third Party Risk Near Airports and Public Safety Zone Policy,” London, 1997.

[5] E. Tan, N. Warren, D. Gleave, and D. Pitfield, “A Review and Statistical Modelling of Accidental Aircraft Crashes Within Great Britain,” vol. 44, no. MSU/2014/07, pp. 1–158, 2014.

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[8] R. de J. Y.S. Cheung, L. de Haij, “Development of NLR third party risk model and its application in policy and decision-making for the airports in the Netherlands,” Amsterdam, 2013.

[9] Transportation Research Board, Ed., *Analysis of Aircraft Overruns and Undershoots for Runway Safety Areas (ACRP Report 3).* Washington, DC: The National Academies Press., 2008.

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[12] A. Cardi, P. Di Mascio, M. Di Vito, and C. Pandolfi, “Distribution of Air Accidents Around Runways,” *Procedia - Soc. Behav. Sci.*, vol. 53, pp. 861–870, 2012, doi: 10.1016/j.sbspro.2012.09.935.

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S.D.A.C." ENAC, Sapienza Univesità di Roma, Roma, Italy, 2016.

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[15] Transportation Safety Board of Canada, "Air transportation safety investigations and reports." https://www.tsb.gc.ca/eng/rapports-reports/aviation/index.html (accessed Oct. 11, 2020).

[16] National Transportation Safety Board, "Aviation Accident Database & Synopses." https://www.ntsb.gov/_layouts/ntsb.aviation/index.aspx (accessed Oct. 01, 2020).

[17] Bureau d'Enquetes et d'Analyses (France), "Safety investigations." https://www.bea.aero/ (accessed Sep. 01, 2020).

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Annex 1

Typical occurrence in initial climbing phase includes accidents outside the airport limits, as illustrated by the following figure:

(Source: Agenzia Nazionale per la Sicurezza dee volo (ANSV), Relazione d'inchiesta: Incidente aeromobile Siai Marchetti F.260D, aviosuperficie "Caorle" (VE), 3 November 2018):

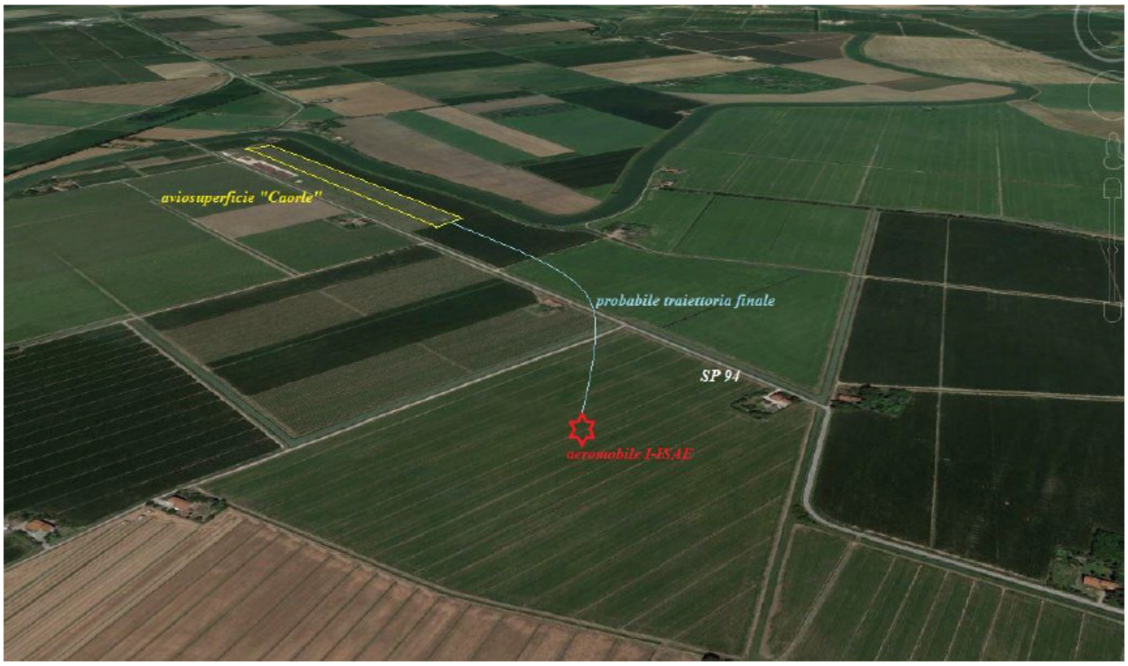
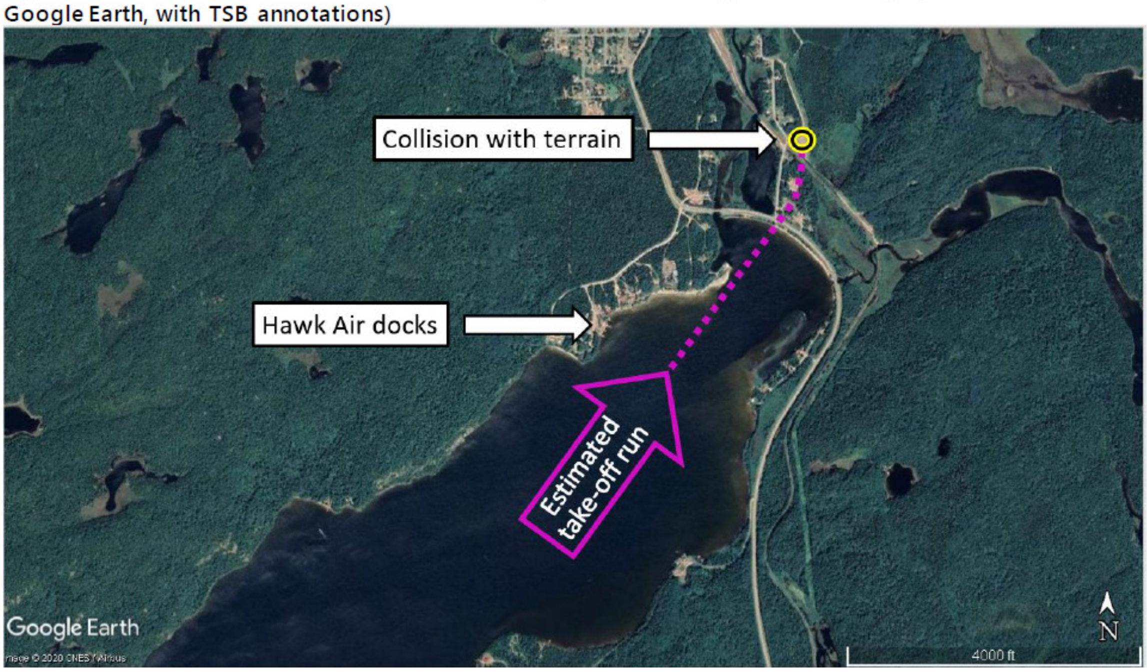


Figura 1: luogo dell'incidente (su supporto Google Earth).

In addition, some events related to water aerodromes operations have also been considered, when the location of the accident has been on land, as illustrated in the following figure

(Source: Transportation Safety Board of Canada, *Air Transportation Investigation Report* A19O0089; released 08 October 2020):

Figure 1. View of occurrence site, with dashed magenta line showing estimated flight path (Source: Google Earth, with TSB annotations)



Also, by considering the main purpose of the thesis, some specific events – near accidents – have also been included in the database.

In this occurrence, the approach descent has been performed below the published approach procedure for the intended runway, and even below the Obstacle Limitation Surface (Lowest flight altitude on approach 39 feet, Ruway Threshold altitude 12 feet).

The following figure presents the details of this occurence:

(Source: Transportation Safety Board of Canada: Aviation Investigation Report A17F0052, released 04 June 2018):

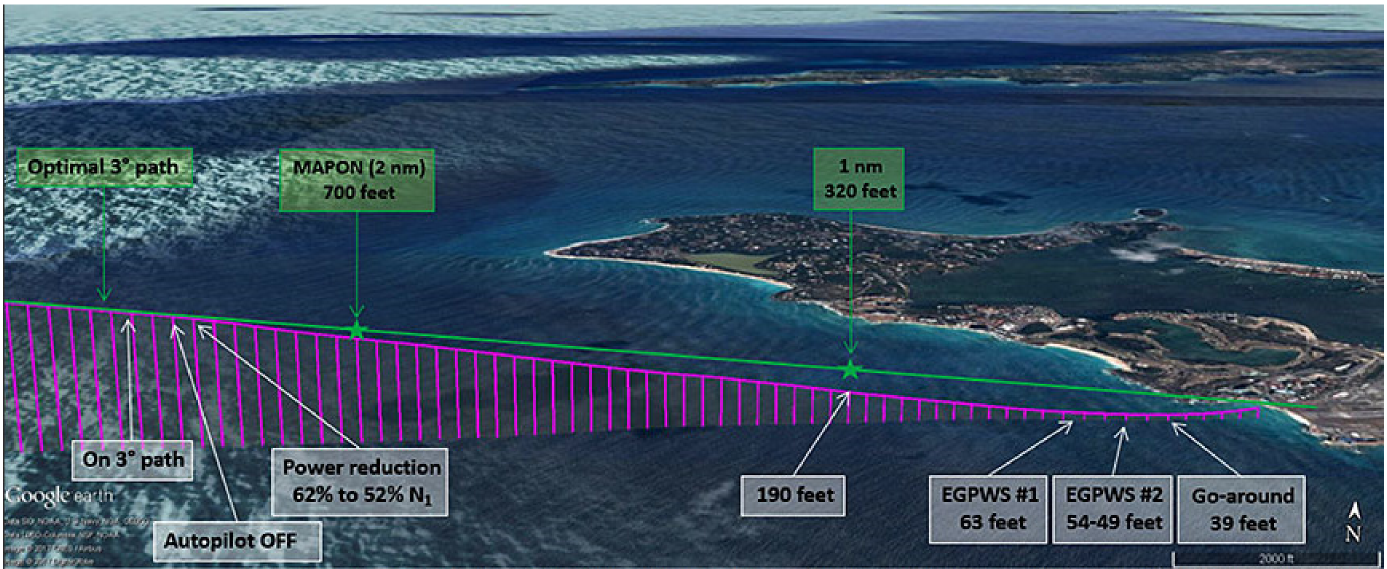


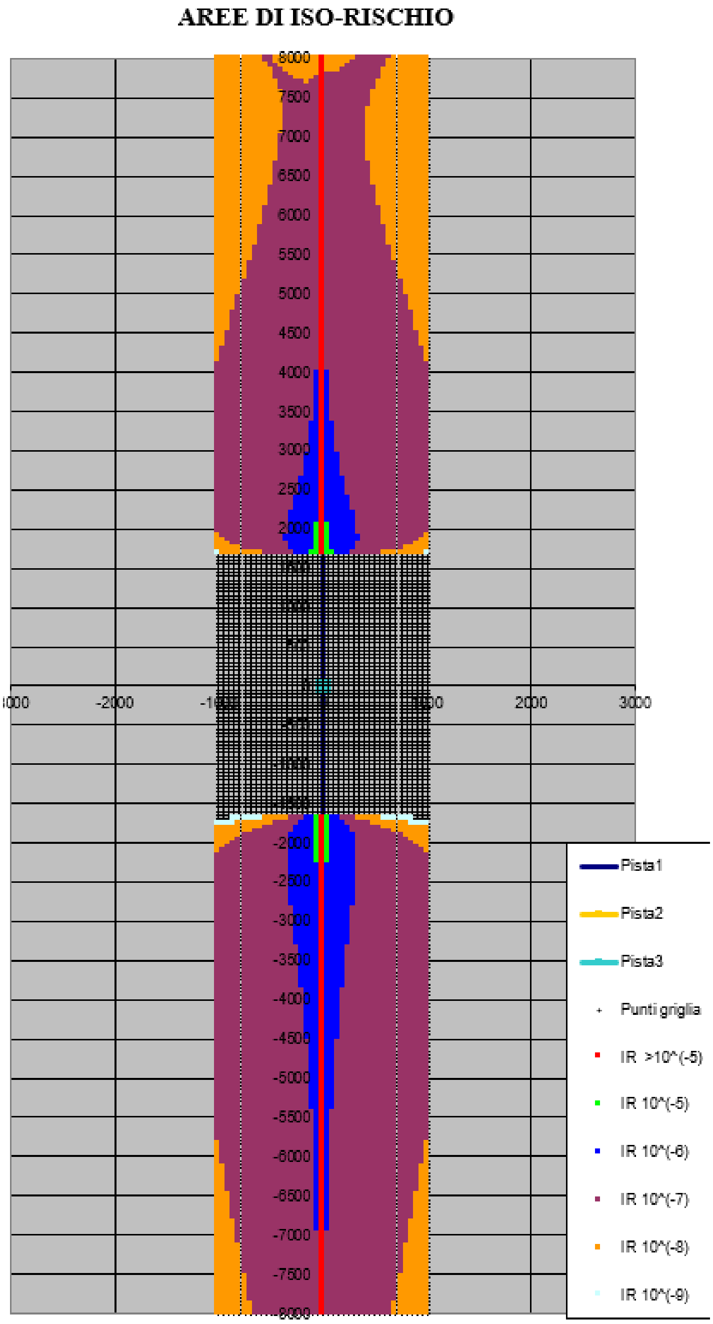
Figure 2. Standard 3° angle of descent versus the aircraft vertical approach path

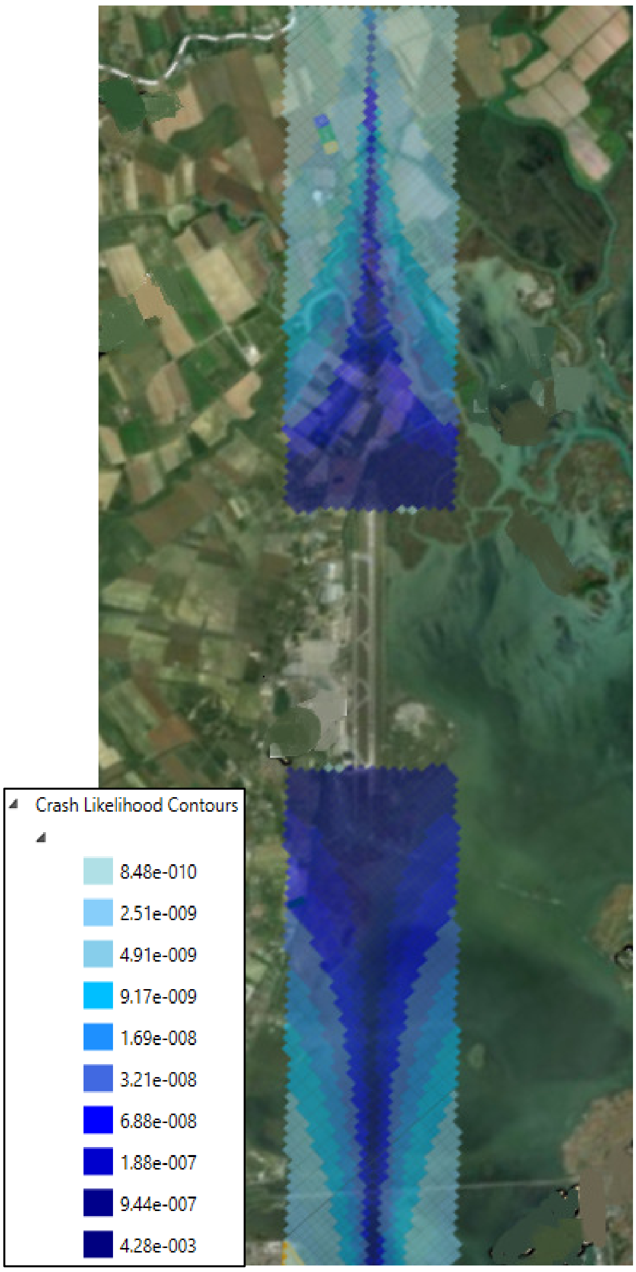
Annex 2.1 - Airport 1

Comparison analysis of output from SARA and ACRP risk assessment models (2019):

SARA iso-risk contours

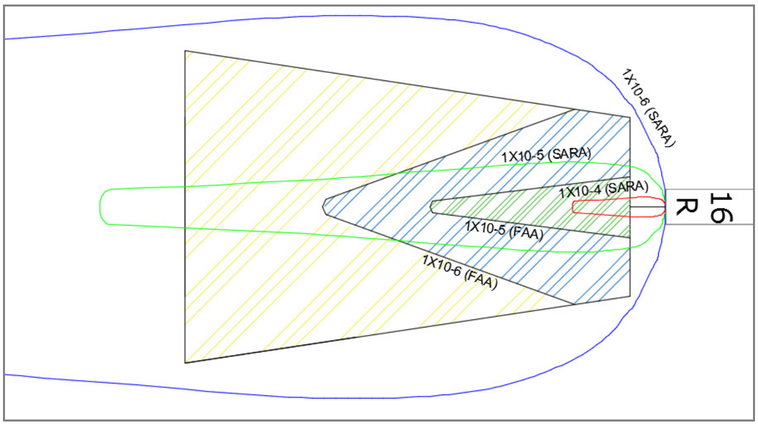
ACRP RPZ crash likelihood contours

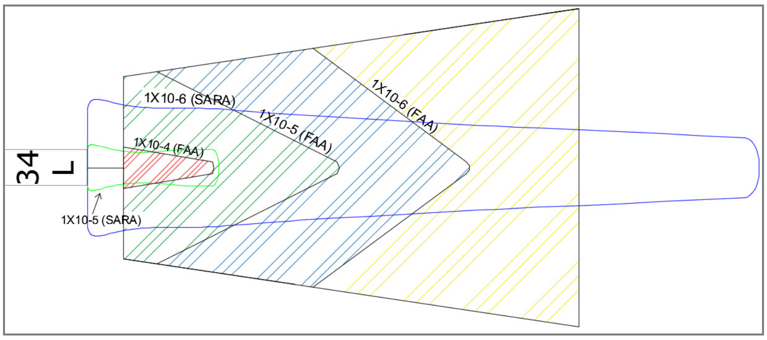


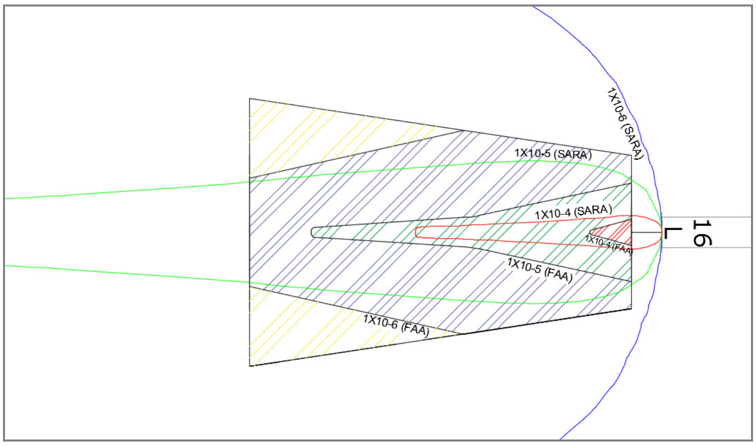


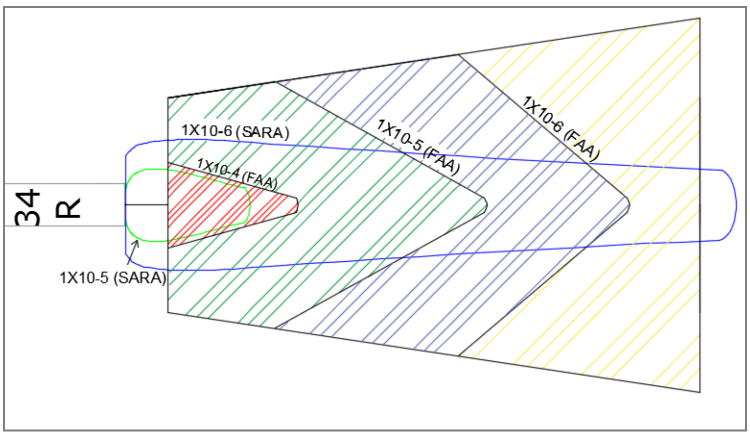
Annex 2.2 - Airport 2

(source: D. Pinto Moreno, LE AREE DI SICUREZZA NEI TERRITORI LIMITROFI AGLI AEROPORTI: Confronto fra i metodi di valutazione del rischio E.N.A.C. e F.A.A. (in Italian) Tesi de laurea, Sapienza – Università di Roma 2020)





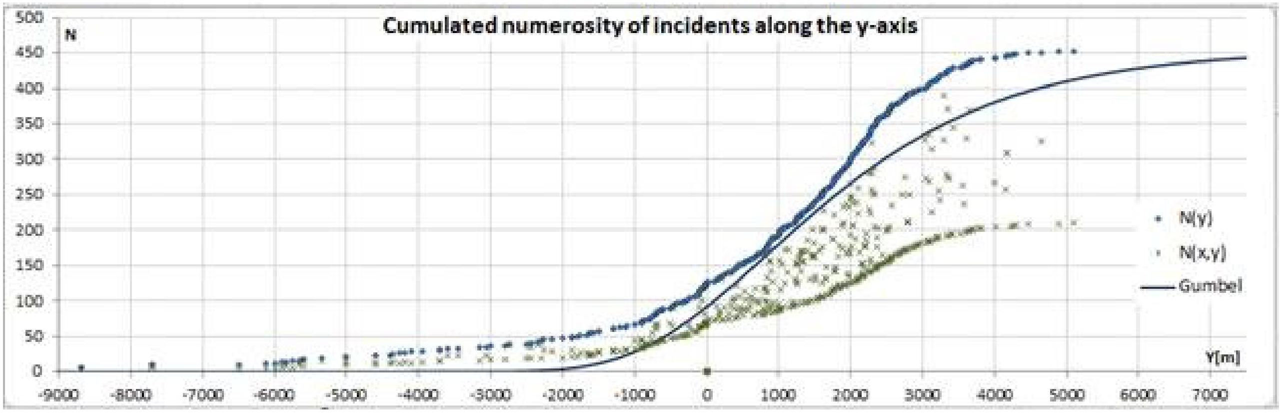




Annex 3

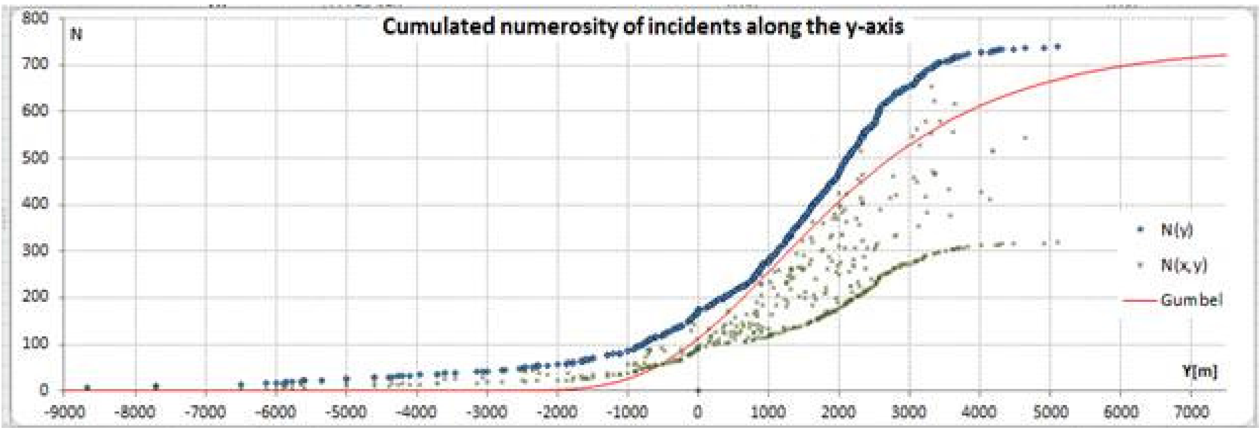
Approach and Landing accident location model

Existing SARA's curves has been developed based on SDAC 2011 database for Commercial Aviation with MTOW of 5700kg or more, N = 455 events considered, with R^2 = 0,9613 (source : Excel files from [1], [12])

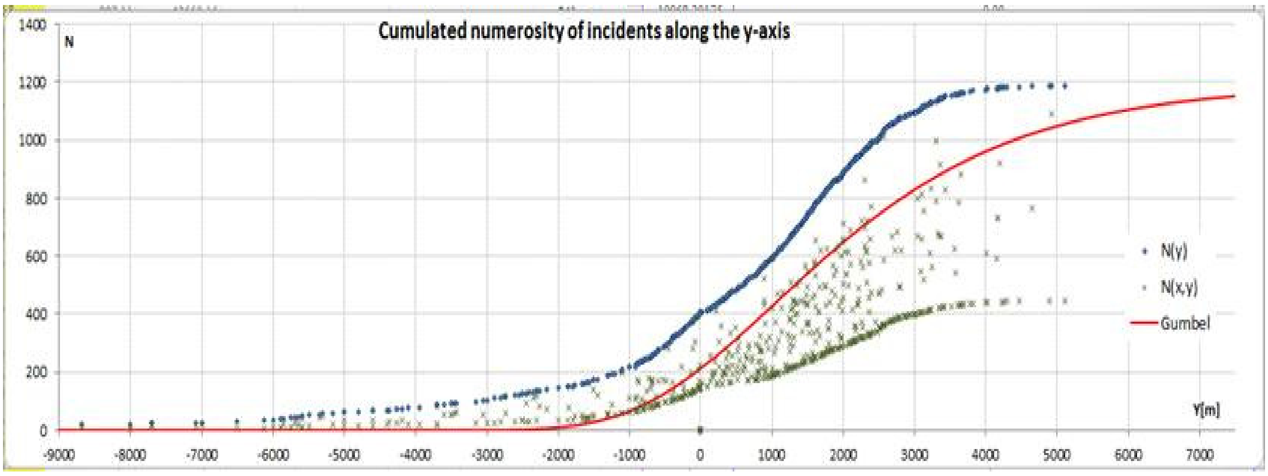


Then, by considering the data from the updated database (1996-2020), it was possible to adapt revised curves (with revised coefficients), as follows:

Type of accidents: Commercial Aviation, with MTOW of 5700kg or more, N=741 events considered with R^2 = 0,9607:



Type of accidents: Commercial, Military and General Aviation, with MTOW of 1000kg or more, N=1193 events considered, R^2 = 0,9500



However, when a curve needs to be obtained for Commercial and General Aviation but with MTOW of less than 5 700 kg, new type of curves need to be found, as the same type of curve is less representative, as follows: N=332 events R^2 = 0,7683