A risk assessment procedure for the safety management of airport infrastructures

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Synopsis

Today, the overall yearly number of accidents, incidents and serious incidents in civil aviation is some 50 worldwide, with an average of 13000 victims.

Experience has demonstrates that before an accident occurs various incidents and numerous failures reveal the existence of safety risks.

In this context, risk assessment and risk management are important tools for understanding risks, defining acceptable levels of risks, and reducing risks.

Risk management is the systematic application of management and engineering principles, criteria and tools to optimize all aspects of safety within the constraints of operational effectiveness, time, and cost throughout all mission phases.

Risk assessment is the process which associates "hazards" with "risks". When we know the various impacts a hazard may have on our mission and an estimate of how likely it is to occur we can now call the hazard a risk. Risk is the probability and severity of loss from exposure to the hazard. The assessment step is the application of quantitative or qualitative measures to determine the level of risk associated with a specific hazard. This process defines the probability and severity of hazard based upon the exposure of personnel or assets to that hazard.

The outcome of the risk assessment process is a list of risks developed from the output of the hazard identification process. The first risk is the most serious threat to the mission, the last is the least serious risk of any consequence. Each risk is either labeled with its significance (high, medium, etc.) or the section in which it is place is labeled. This allows us to see both the relative priority of the risks and their individual significance.

In this paper the authors propose an original risk assessment procedure for any airport.

The original points in this methodology are: the causes identified associated with each hazard by analysing other studies and both National and International databases; the hazard probability assessment through to the cumulative probability of the causes identified using the Total probability theorem; the conditional probability assessment was established by analysing the National database for causes belonging environmental and surface conditions categories and by analyzing the International database for causes belonging aircraft performance characteristics category; hazard severity assessment was established by analysing of National database.

A risk assessment procedure for the safety management of airport infrastructures

In the last 10 years the number of accidents in civil aviation has remained almost constant. It is feared that the proposed incline in air traffic will result in an unacceptable increase in the number of accidents in the new future.

Experience has demonstrates that before an accident occurs various incidents and numerous failures reveal the existence of safety risks.

In this context, the risk assessment procedure consent the determination of the probability of the causes that generate accidents, and becomes an operative instrument, particularly efficient in the prevention of hazards.

In this study the authors propose an original risk assessment procedure for any airport. In particular the criteria will be provided for the assessment of the probability that the causes generate hazard. Furthermore a qualitative classification will be proposed to define the level of severity associated with the events.

The elaboration of the procedure of risk management will rely on statistic analysis of data take from National and International databases.

The final objective of this research group is to propose criteria for risk assessment directly pertinent to a specific airport. In this regard the authors wish to draw attention to the fact that some risk assessment procedures are frequently not specific to the airport studied.

RISK MANAGEMENT PROCESS

System safety is a specialty within system engineering that supports program risk management. It is the application of engineering and management principles, criteria and techniques to optimize safety. The goal of System Safety is to optimize safety by the identification of safety related risks, eliminating or controlling them by design and/or procedures, based on acceptable system safety precedence.

The causes of an accident are factors, events, acts, or unsafe conditions which singly, or in combination with other causes, result in the damage or injury that occurred and, if corrected, would have likely prevented or reduced the damage or injury. A hazard is any condition, event, or circumstance, which could induce (cause) an accident. Risk is defined as the probability that an event will occur.

A risk is "the combination of the probability, or frequency, of occurrence of a defined hazard and the severity of the consequences of the occurrence". A risk is thus an attribute of a hazard.

There are many types of risk, but in this study, risk is categorized into three types: *Initial Risk, Current Risk, and Residual Risk*.

Initial Risk is the severity and likelihood of a hazard when it is first identified and assessed. It is used in the beginning or very preliminary stages of a decision, program or analysis. Initial Risk is determined by considering both verified requirements and assumptions made about system state. Once the initial risk is established it not changed. Typically, Initial Risk is an assessment formed and kept within the purview of system safety.

Current Risk is the predicted severity and likelihood of a hazard as it exists currently, using both validated requirements and verified requirements. Current Risk may change over time based on actions taken by the decision maker that relate to the validation and/or verification of the requirements or controls associated with the hazard.

Residual Risk is the risk that remains after all requirements have been implemented or exhausted and all requirements have been verified. Only verified requirements or controls can be used to assess Residual Risk. When conducting an analysis, *Predicted Residual Risk* is the term used prior to formal verification of requirements or controls based on the assumption that validated and recommended safety requirements will be verified.

Risk assessment and risk management are important tools for understanding risks, defining acceptable levels of risks, and reducing risks.

Risk management (RM) is based on the philosophy that it is irresponsible and wasteful to wait for an accident to happen, then figuring out how to prevent it from happening again. We manage risk whenever we modify the way we do something to make our chances of success as great as possible, while making our chances of failure, injury or loss as small as possible. It's a commonsense approach to balancing the risks against the benefits to be gained in a situation and then choosing the most effective course of action.

Risk management is the systematic application of management and engineering principles, criteria and tools to optimize all aspects of safety within the constraints of operational effectiveness, time, and cost throughout

all mission phases. To apply the systematic risk management process, the composite of hardware, procedures, and people that accomplish the mission or produce mishaps, must be viewed as a system.

Risk management must be a fully integrated part of planning and executing any operation, routinely applied by management, not a way of reacting when some unforeseen problem occurs.

Careful determination of risks, along with analysis and control of the hazards they create results in a plan of action that anticipates difficulties that might arise under varying conditions, and predetermines ways of dealing with these difficulties. Managers are responsible for the routine use of risk management at every level of activity, starting with the planning of that activity and continuing through its completion.

The goals of risk management are:

- To derive the values of likelihood and severity of consequence for each hazard. These will, in general, not be precise values, but rather an informed judgement as to "order of magnitude".
- 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 last two points are usually extended to the specification of, and selection from, a number of mitigating strategies, possibly as part of a wider cost benefit analysis.

To stand any chance of achieving these goals we first 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 management, 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 the outside world, air traffic control has radio and telephones; there are navigational aids that communicate with aircraft, such as the distance measuring beacons and instrument landing systems; there are road links; there may be rail links; etc. We will consider an airside interface, the runway. It is "A defined rectangular area on a land aerodrome prepared for the landing and take-off of aircraft" (ICAO 1995). It is the interface between the air navigation system and the ground handling area.

The Risk Management (RM) process consisting in six steps (Figure 1).

Step 1: Hazards identification

A hazard can be defined as any real or potential condition that can cause mission degradation, injury, illness, death to personnel or damage to or loss of equipment or property. Experience, common sense, and specific risk management tools help identify real or potential hazards. Hazard identification is the foundation of the entire RM process. Obviously if a hazard is not identified it can not be controlled.

Identify hazards associated with these three categories:

➢ Mission Degradation.
➢ Personal Injury or Death.
➢ Property Damage.

Action 1: Mission/Task Analysis. The 5-M's are examined. The 5-M model, provides a basic framework for analyzing systems and determining the relationships between composite elements that work together to perform the mission.

The 5-M's are Man, Machine, Media, Management, and Mission. Man, Machine, and Media interact to produce a successful Mission or, sometimes, an unsuccessful one. The amount of overlap or interaction between the individual components is a characteristic of each system and evolves as the system develops. Management provides the procedures and rules governing the interactions between the various elements.

Successful missions, or mishaps, do not just happen, they are indicators of how well a system is functioning. The basic cause factors for mishaps fall into the same categories as the contributors to successful missions—Man, Media, Machine, and Management.

1. Man. Area of greatest variability and thus the majority of risks.
   - *Selection*: Right person psychologically/physically, trained in event proficiency, procedural guidance, habit pattern.
   - *Performance:* Awareness, perceptions, task saturation, distraction, channelised attention, stress, peer pressure, confidence, insight, adaptive skills, pressure/workload, fatigue (physical, motivational, sleep deprivation, circadian rhythm).
   - *Personal Factors*: Expectancies, job satisfaction, values, families/friends, command/control, discipline (internal and external), perceived pressure (over tasking) and communication skills.

2. Media. External, largely environmental forces.
   - Climatic: Ceiling, visibility, temperature, humidity, wind, precipitation.
   - Operational: Terrain, wildlife, vegetation, man made obstructions, daylight, darkness.
   - Hygienic: Ventilation/air quality, noise/vibration, dust, contaminants.
   - Vehicular/Pedestrian: Pavement, gravel, dirt, ice, mud, dust, snow, sand, hills, curves.
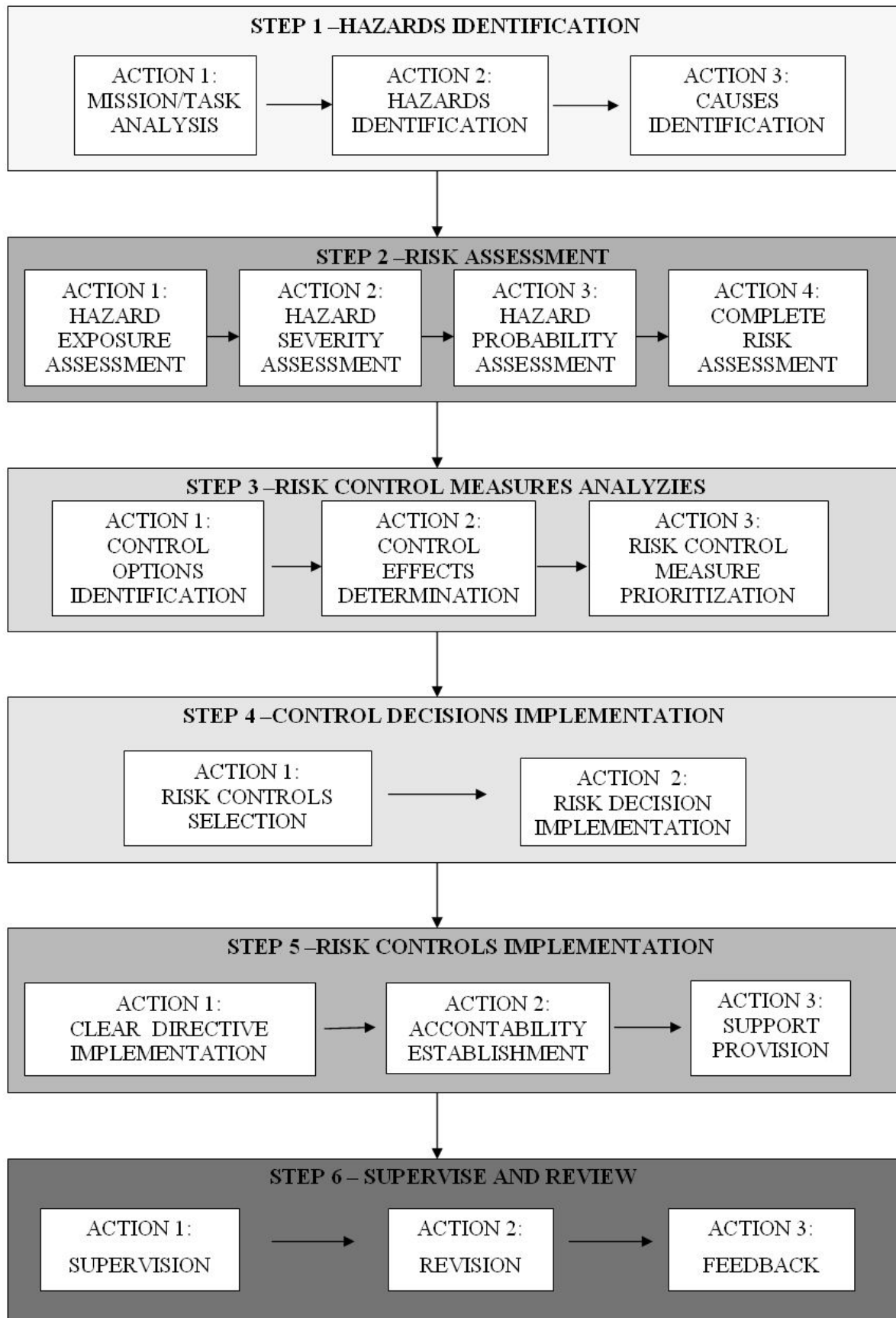
RISK MANAGEMENT PROCESS

STEP 1 – HAZARDS IDENTIFICATION

ACTION 1: MISSION/TASK ANALYSIS	→	ACTION 2: HAZARDS IDENTIFICATION	→	ACTION 3: CAUSES IDENTIFICATION

STEP 2 – RISK ASSESSMENT

ACTION 1: HAZARD EXPOSURE ASSESSMENT	→	ACTION 2: HAZARD SEVERITY ASSESSMENT	→	ACTION 3: HAZARD PROBABILITY ASSESSMENT	→	ACTION 4: COMPLETE RISK ASSESSMENT

STEP 3 – RISK CONTROL MEASURES ANALYZIES

ACTION 1: CONTROL OPTIONS IDENTIFICATION	→	ACTION 2: CONTROL EFFECTS DETERMINATION	→	ACTION 3: RISK CONTROL MEASURE PRIORITIZATION

STEP 4 – CONTROL DECISIONS IMPLEMENTATION

ACTION 1: RISK CONTROLS SELECTION	→	ACTION 2: RISK DECISION IMPLEMENTATION

STEP 5 – RISK CONTROLS IMPLEMENTATION

ACTION 1: CLEAR DIRECTIVE IMPLEMENTATION	→	ACTION 2: ACCONTABILITY ESTABLISHMENT	→	ACTION 3: SUPPORT PROVISION

STEP 6 – SUPERVISE AND REVIEW

ACTION 1: SUPERVISION	→	ACTION 2: REVISION	→	ACTION 3: FEEDBACK

Figure 1: Risk Management (RM) process

3. Machine. Used as intended, limitations, interface with man.
- Design: Engineering reliability and performance, ergonomics.
- Maintenance: Availability of time, tools, and parts, ease of access.
- Logistics: Supply, upkeep, repair.
- Tech data: Clear, accurate, useable, available.

4. Management. Directs the process by defining Standards, Procedures, and Controls. Be aware that while management provides procedures and rules to govern interactions, it cannot completely control the system elements.
- Standards: Doctrine statements, various criteria, policy, and AF Policy Directives.
- Procedures: Checklists, work cards, multi-command manuals.
- Controls: Crew rest, altitude/airspeed/speed limits, restrictions, training rules/limitations, rules of engagement (ROE), lawful orders.

5. Mission. The desired outcome.
- Objectives: Complexity understood, well defined, obtainable.
- The results of the interactions of the 4-M's (Man, Media, Machine, and Management).

This action is accomplished by reviewing current and planned operations describing the mission. The commander defines requirements and conditions to accomplish the tasks. Construct a list or chart depicting the major phases of the operation or steps in the job process, normally in time sequence. Break the operation down into 'bite size' chunks.

Action 2: Hazards identification. Hazards, and factors that could generate hazards, are identified based on the deficiency to be corrected and the definition of the mission and system requirements. The output of the identification phase is a listing of inherent hazards or adverse conditions and the mishaps which could result. The analysis must also search for factors that can lead to hazards such as alertness, ambiguity, or escape route. In addition to a hazard list for the elements above, interfaces between or among these elements should be investigated for hazards. Make a list of the hazards associated with each phase of the operation or step in the job process. Stay focused on the specific steps in the operation being analyzed.

Action 3: Causes identification. Make a list of the causes associated with each hazard identified in the hazard list. A hazard may have multiple causes related to each of the 5-M's. In each case, try to identify the root cause (the first link in the chain of events leading to mission degradation, personnel injury, death, or property damage). Risk controls can be effectively applied to root causes.

Step 2: Risk assessment

Risk assessment is the process which associates "hazards" with "risks". When we know the various impacts a hazard may have on our mission and an estimate of how likely it is to occur we can now call the hazard a risk.

Risk is the probability and severity of loss from exposure to the hazard. The assessment step is the application of quantitative or qualitative measures to determine the level of risk associated with a specific hazard. This process defines the probability and severity of a mishap that could result from the hazard based upon the exposure of personnel or assets to that hazard.

There are three key aspects of risk. Probability is the estimate of the likelihood that a hazard will cause a loss. Some hazards produce losses frequently, others almost never do.

Severity is the estimate of the extent of loss that is likely. The third key aspect is exposure, which is the number of personnel or resources affected by a given event or, over time, by repeated events.

Action 1: Hazard exposure assessment. Surveys, inspections, observations, and mapping tool can help determine the level of exposure to the hazard and record it. This can be expressed in terms of time, proximity, volume, or repetition. Repeated exposure to a hazard increases the probability of a mishap occurring. Understanding the exposure level can aid in determining the severity or the probability of the event. Additionally, it may serve as a guide for devising control measures to limit exposure.

Action 2: Hazard severity assessment. 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.

The following severity categories provide guidance to a wide variety of missions and systems (Table 1).

Action 3: Probability assessment. Determine the probability that the hazard will cause a negative event of the severity assessed in Action 2 above. Probability is proportional to the cumulative probability of the identified causes for the hazard. Probability may be determined through estimates or actual numbers, if they are available. Assigning a quantitative mishap probability to a new mission or system may not be possible early in the planning process. A qualitative probability may be derived from research, analysis, and evaluation of historical safety data from similar missions and systems. The following are generally accepted definitions for probability (Table 2).

Table 1: Severity of the hazard

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: (1) Large reduction in safety margin or functional capability (2) Crew physical distress/excessive workload such that operators cannot be relied upon to perform required tasks accurately or completely (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: (1) Significant reduction in safety margin or functional capability (2) Significant increase in operator workload (3) Conditions impairing operator efficiency or creating significant discomfort (4) Physical distress to occupants of aircraft (except operator) including injuries 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. Includine: (1) Slight reduction in safety margin or functional capabilities (2) Slight increase in workload such as routine flight plan changes (3) Some physical discomfort to occupants or aircraft (except operators) Minor occupational illness and/or minor environmental damage, and/or minor property damage
No Safety Effect	Has no effect on safety

Table 2: Probability of the hazard

Frequent	*Qualitative*: Anticipated to occur about once every three months during the entire system/operational life of an item. *Quantitative*: Probability of occurrence per operational hour is equal to or greater than 1.10^{-3}.
Probable	*Qualitative*: Anticipated to occur one or more times during the entire system/operational life of an item. *Quantitative*: Probability of occurrence per operational hour is less than 1.10^{-3}, but greater than 1.10^{-5}.
Remote	*Qualitative*: Unlikely to occur to each item during its total life. May occur several time in the life of an entire system or fleet. *Quantitative*: Probability of occurrence per operational hour is less than 1.10^{-5}, but greater than 1.10^{-7}.
Extremely Remote	*Qualitative*: Not anticipated to occur to each item during its total life. May occur a few times in the life of an entire system or fleet. *Quantitative*: Probability of occurrence per operational hour is less than 1.10^{-7} but greater than 1.10^{-9}.
Extremely Improbable	*Qualitative*: So unlikely that it is not anticipated to occur during the entire operational life of an entire system or fleet. *Quantitative*: Probability of occurrence per operational hour is less than 1.10^{-9}.

Action 4: Risk Assessment. Combine severity and probability estimates to form a risk assessment for each hazard. By combining the probability of occurrence with severity, a matrix is created where intersecting rows and columns define a Risk Assessment Matrix. The Risk Assessment Matrix forms the basis for judging both the acceptability of a risk and the management level at which the decision on acceptability will be made. Figure 2 is an example of a matrix.

This matrix classifies risk into three levels: High, Medium, and Low. These levels will conduct risk resolution for each identified hazard in accordance with Figure 3.

The outcome of the risk assessment process is a list of risks developed from the output of the hazard identification process. The first risk is the most serious threat to the mission, the last is the least serious risk of any consequence. Each risk is either labeled with its significance (high, medium, etc.) or the section in which it is place is labeled. This allows us to see both the relative priority of the risks and their individual significance.

	No safety effect 5	Minor 4	Major 3	Hazardous 2	Catastrophic 1
Frequent A					
Probable B					
Remote C					
Extremely remote D					
Extremely improbable E					

Figure 2: Risk Assessment Matrix

Low Risk

Low Risk – Acceptable without review.

Medium Risk

Medium Risk – Acceptable with review by the appropriate management level. A risk resolution system is required.

High Risk

High Risk –A risk resolution system is required until the risk is reduced or accepted at the appropriate management level.

Figure 3: Risk Acceptance Criteria

Step 3: Control measures analysis
This step involves the targeting of priority risk issues for control.
Investigate specific strategies and tools that reduce, mitigate, or eliminate the risk. Effective control measures reduce or eliminate one of the three components (probability, severity, or exposure) of risk.
Action 1: Control options identification. Starting with the highest-risk hazards as assessed in Step 2, identify as many risk control options as possible for all hazards. Refer to the list of possible causes from Step 1 for control ideas. Risk control options include: rejection, avoidance, delay, transference, spreading, compensation, and reduction.
Action 2: Control effects determination. Determine the effect of each control on the risk associated with the hazard. The estimated value(s) for severity and/or probability after implementation of control measures and the change in overall risk assessed from the Risk Assessment Matrix should be recorded.
Scenario building and next mishap assessment provide the greatest ability to determine control effects.
Action 3: Risk controls prioritization. For each hazard, prioritize those risk controls that will reduce the risk to an acceptable level. Priorities should be recorded in some standardized format for future reference. Opportunity assessment, cost versus benefit analysis and computer modelling provide excellent aids to prioritize risk controls. If the control is already implemented in an established instruction, document, or procedure, that too should be documented.

Step 4: Control Decisions implementation
Decision makers at the appropriate level choose the best control or combination of controls based on the analysis of overall costs and benefits.
Make Control Decisions, involves two major dimensions. The first is the selection of the risk controls to actually use from among those developed in the Develop Risk Controls step (step 3). The second is the decision whether or not to accept the residual risk present in a mission or project after applying all practical risk controls. The decision maker selects the control options after being briefed on all the possible controls. It is not an ad hoc decision, but rather is a logical, sequenced part of the risk management process. Decisions are made with awareness of hazards and how important hazard control is to mission success or failure (cost versus benefit).
Action 1: Risk controls selection. For each identified hazard, select those risk controls that will reduce the risk to an acceptable level. The best controls will be consistent with mission objectives and optimum use of available resources (manpower, material, equipment, money, and time). Implementation decisions should be recorded in some standardized format for future reference.

Action 2: Risk decision implementation. Analyze the level of risk for the operation with the proposed controls in place. Determine if the benefits of the operation now exceed the level of risk the operation presents. Be sure to consider the cumulative risk of all the identified hazards and the long term consequences of the decision. When a decision is made to assume risk, the factors (cost versus benefit information) involved in this decision should be recorded.

Step 5: Risk Controls implementation

Once control strategies have been selected, an implementation strategy needs to be developed and then applied by management and the work force. Implementation requires commitment of time and resources.

Part of implementing control measures is informing the personnel in the system of the risk management process results and subsequent decisions. If there is a disagreement, then the decision makers should provide a rational explanation.

Action 1: Clear directive implementation. To make the implementation directive clear, consider using examples, providing pictures or charts, including job aids, etc. Provide a roadmap for implementation, a vision of the end state, and describe successful implementation.

Action 2: Accountability establishment. The accountable person is the one who makes the decision (approves the control measures), and hence, the right person (appropriate level) must make the decision. Also, be clear on who is responsible at the unit level for implementation of the risk control.

Action 3: Support provision. To be successful, command must be behind the control measures put in place. Prior to implementing a control measure, get approval at the appropriate command level. Then, explore appropriate ways to demonstrate command commitment. Provide the personnel and resources necessary to implement the control measures.

Step 6: Supervise And Review

Risk management is a process that continues throughout the life cycle of the system, mission, or activity. Leaders at every level must fulfil their respective roles in assuring controls are sustained over time. Once controls are in place, the process must be periodically revaluated to ensure their effectiveness.

The sixth step of RM, Supervise and Review, involves the determination of the effectiveness of risk controls throughout the operation. This step involves three aspects. The first is monitoring the effectiveness of risk controls. The second is determining the need for further assessment of either all or a portion of the operation due to an unanticipated change as an example. The last is the need to capture lessons-learned, both positive and negative, so that they may be a part of future activities of the same or similar type.

Action 1: Supervision. Monitor the operation to ensure:
1. The controls are effective and remain in place.
2. Changes which require further risk management are identified.
3. Action is taken when necessary to correct ineffective risk controls and reinitiate the risk management steps in response to new hazards.
4. Anytime the personnel, equipment, or mission tasking change or new operations are anticipated in an environment not covered in the initial risk management analysis, the risks and control measures should be reevaluated.

Action 2: Revision. The process review must be systematic. After assets are expended to control risks, then a cost benefit review must be accomplished to see if risk and cost are in balance. Any changes in the system are recognized and appropriate risk management controls are applied.

Action 3: Feedback. A review by itself is not enough, a mission feedback system must be established to ensure that the corrective or preventative action taken was effective and that any newly discovered hazards identified during the mission are analyzed and corrective action taken. Feedback informs all involved as to how the implementation process is working, and whether or not the controls were effective.

Whenever a control process is changed without providing the reasons, co-ownership at the lower levels is lost. The overall effectiveness of these implemented controls must also be shared with other organizations that might have similar risks to ensure the greatest possible number of people benefit.

PROPOSAL OF A RISK ASSESSMENT PROCEDURE

In the preceding section we dealt with the Risk Management process.
In this section we propose a Risk Assessment procedure (steps 1 and 2 of the RM process) for a specific airport.
In order to develop this procedure we use data about accidents/incidents from National and International databases and specific data about the airport studied.
Applying statistic analysis to these data we obtain the quantitative value of the hazard probability and the qualitative judgement of the hazard severity.
Combining the probability with the severity through the Risk Assessment Matrix we obtain the single hazard Risk level for the airport studied.

Data requirement for risk assessment

The current methodology requires some data to be available about airport movements and aircraft types followed, and for each accident/incident, about ground path (runway, taxiway, apron), phase of flight and aircraft type.

Data about accidents/incidents occurred in Italian airports are collected by ANSV (Agenzia Nazionale per la Sicurezza del Volo), the Italian agency for flight safety, and stored in their database.
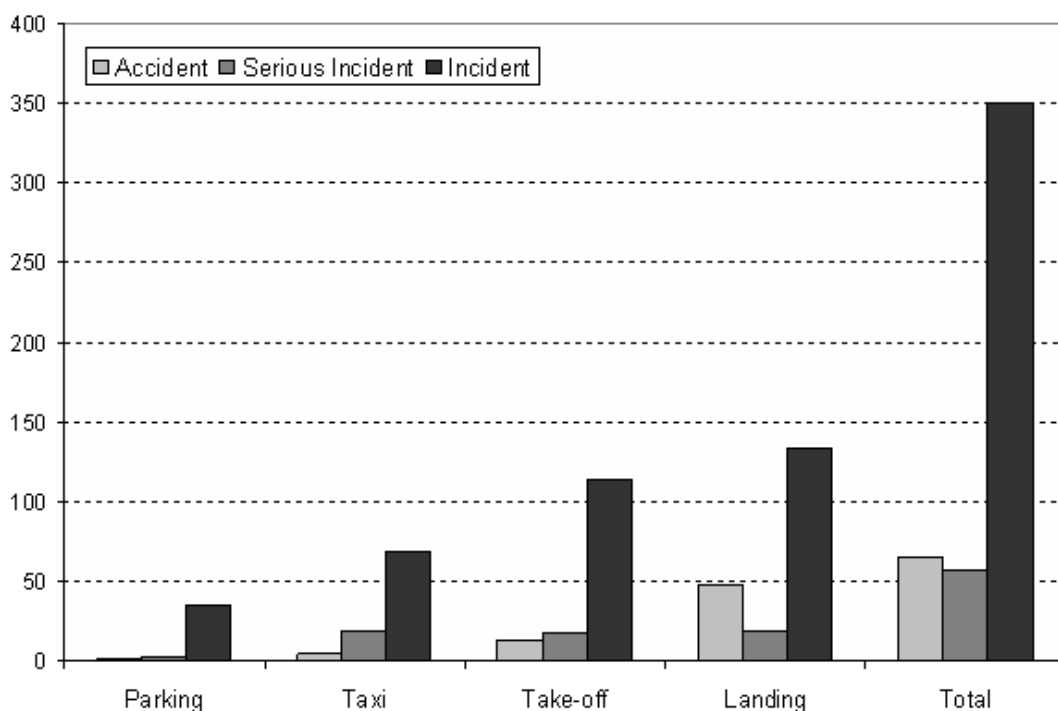
All accidents, serious incidents and incidents in this database are selected according to the following criteria:

- only events occurring during the period 2001-2004 in Italian airports during take-off, taxi, landing and parking operations to aircraft with any take-off weight are considered;
- events occurring to helicopters and military aircraft, or due to sabotage, terrorism and military actions are excluded.

This database includes 65 accidents, 56 serious incidents and 350 incidents (Table 3, Figure 4)

Table 3: Events in Italian airports during take-off, taxi, landing and parking operations

	Parking			Taxi			Take-off			Landing			Total		
Year	A	SI	I	A	SI	I	A	SI	I	A	SI	I	A	SI	I
2001	0	0	12	1	3	14	3	1	25	18	9	40	22	13	91
2002	0	0	7	0	7	19	3	5	29	10	5	32	13	17	87
2003	0	1	11	2	4	22	4	3	36	12	2	36	18	10	105
2004	1	1	5	1	5	13	3	8	24	7	2	25	12	16	67
Total	1	2	35	4	19	68	13	17	114	47	18	133	65	56	350
	38			91			144			198			471		

Figure 4: Accidents, serious incidents and incidents in Italian airports (years: 2001-2004)

Hazards identification (Step 1)

The phase of hazard identification is carried out according to other study, basing on historical accidents/incidents data obtained from ASN (Aviation Safety Network) database and by courtesy of ANSV.

In order to characterize the airside risk level, we take into account the hazards that follow, aggregated by flight phase:

Take-off:
  ➢ overrun
  ➢ veer-off
  ➢ collision with obstacle
  ➢ collision with another aircraft

Landing:

- ➢ overrun
- ➢ veer-off
- ➢ collision with obstacle
- ➢ collision with another aircraft
- ➢ landing short

We identify the causes which may produce the hazards listed above, and grouped them in four categories:

1. aircraft performance characteristics
2. surface conditions
3. environmental conditions
4. human factors

The causes identified for each hazard are shown in the fishbone diagrams (Figures 5, 6, 7, 8, 9, 10, 11).
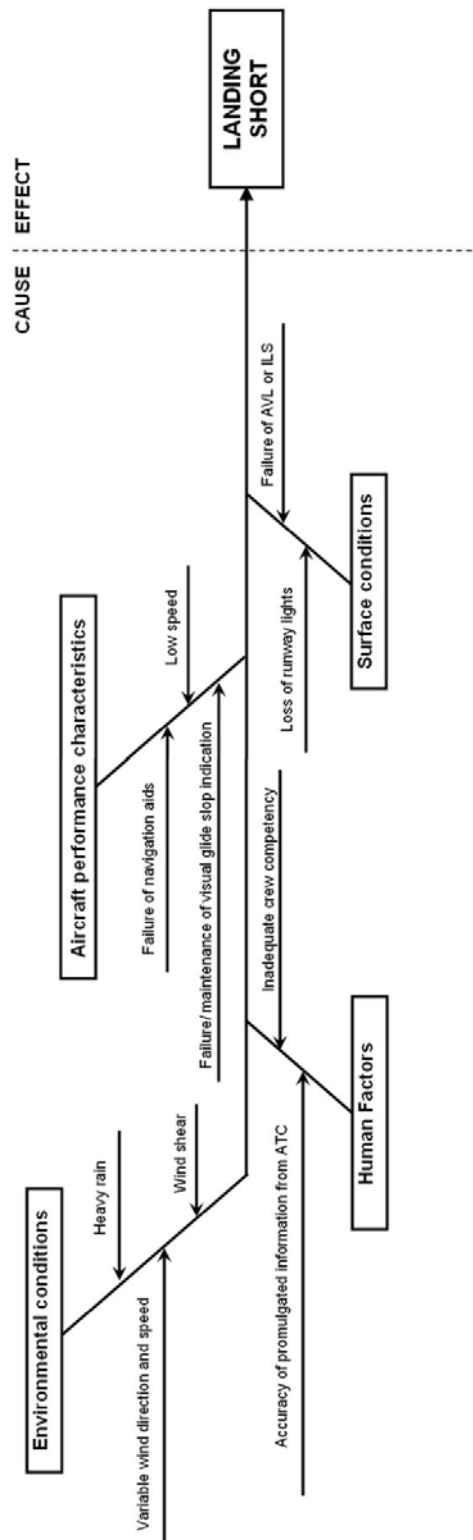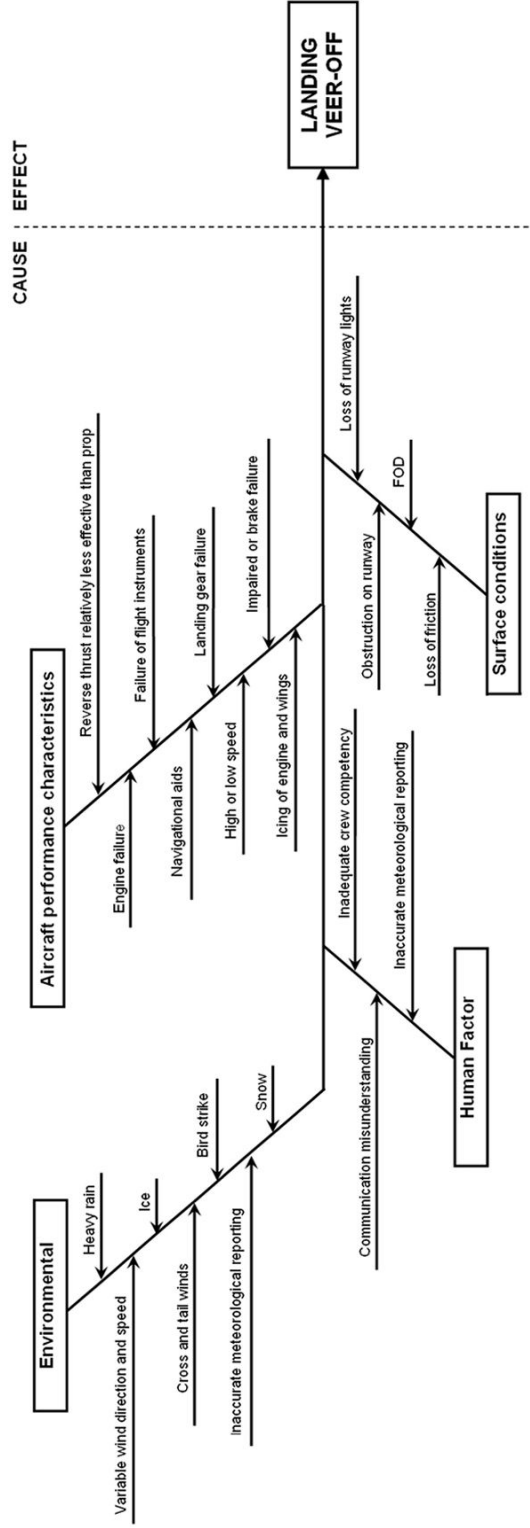
Figure 5: Landing short fishbone diagram
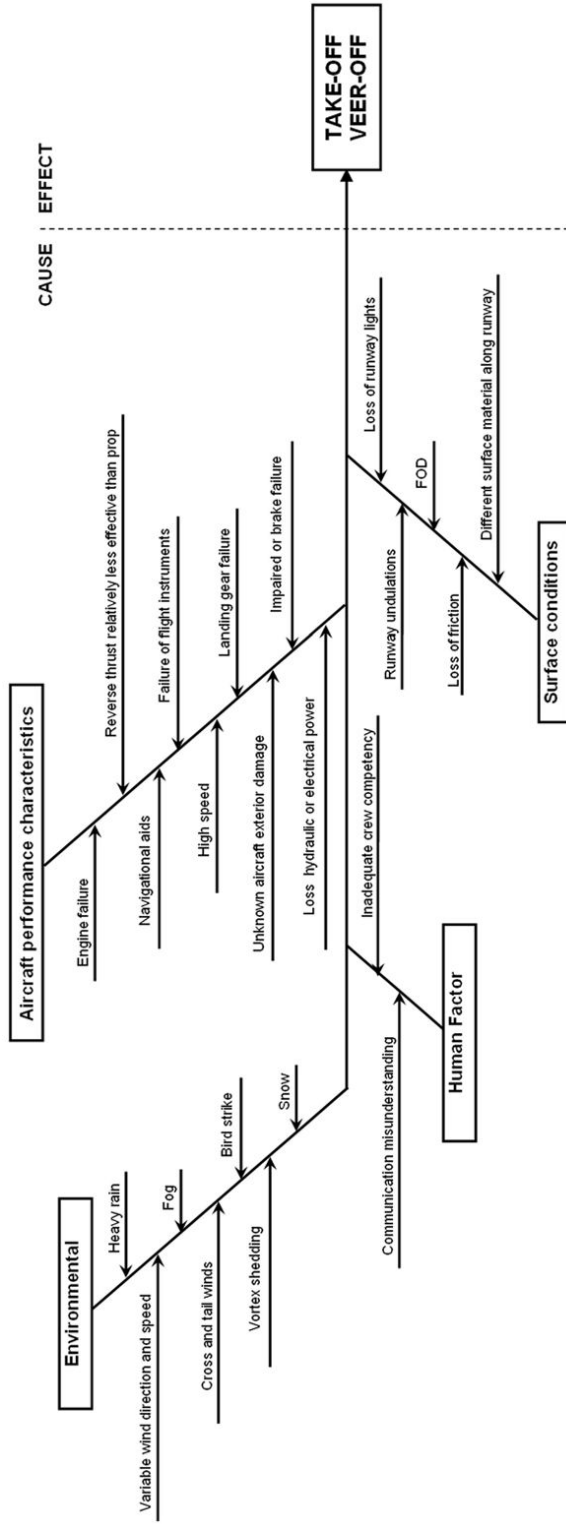
Figure 6: Landing veer-off fishbone diagram
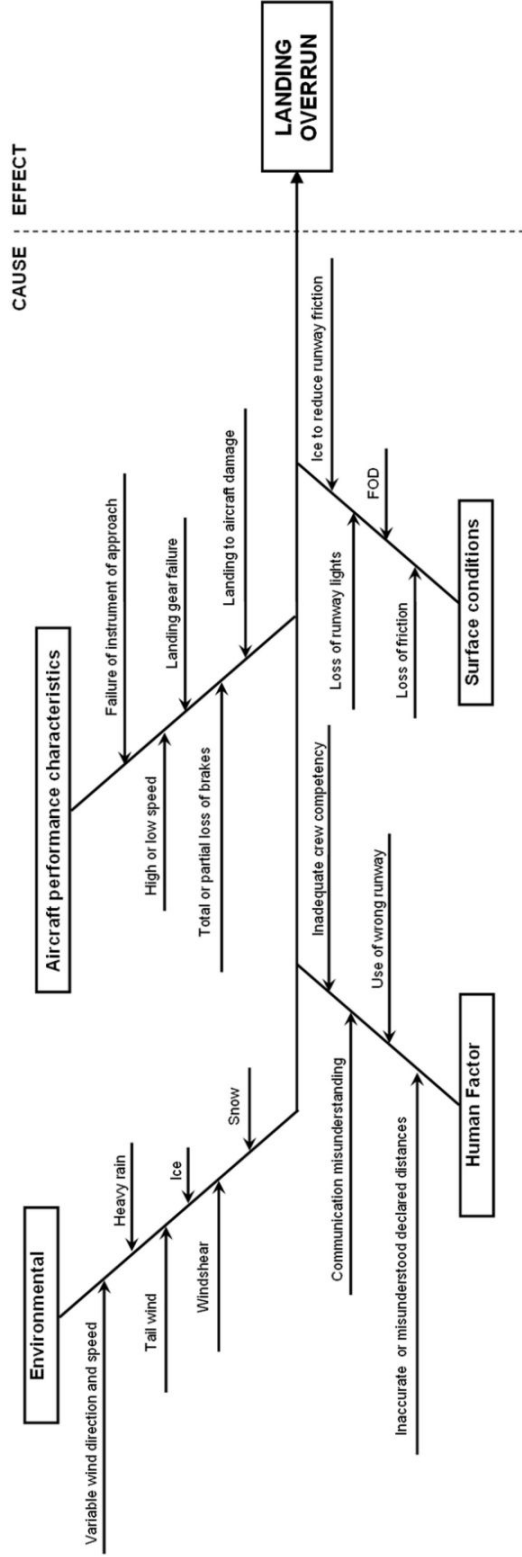

Figure 7: Take-off veer-off fishbone diagram

LANDING OVERRUN

Environmental

Variable wind direction and speed
Tall wind
Heavy rain
Ice
Windshear
Snow

Aircraft performance characteristics

Failure of instrument of approach
Landing gear failure
High or low speed
Total or partial loss of brakes
Landing to aircraft damage

Surface conditions

Loss of runway lights
FOD
Loss of friction
Ice to reduce runway friction

Human Factor

Inadequate crew competency
Use of wrong runway
Communication misunderstanding
Inaccurate or misunderstood declared distances

Figure 8: Landing overrun fishbone diagram

TAKE-OFF OVERRUN

Aircraft performance characteristics

Engine failure
Reverse thrust relatively less effective than prop
Too fast
Failure of flight controls
Unknown aircraft exterior damage
Landing gear failure
Loss of hydraulic power
Impaired or brake failure
Loss of electrical power

Surface conditions

Runway undulations
Loss of runway lights
FOD
Loss of friction

Environmental conditions

Heavy rain
Bird strike
Bright sunlight
Snow

Human Factors

Request from ATC to take-off before aircraft ready
Inadequate crew competency
Use of wrong runway
Communication misunderstanding
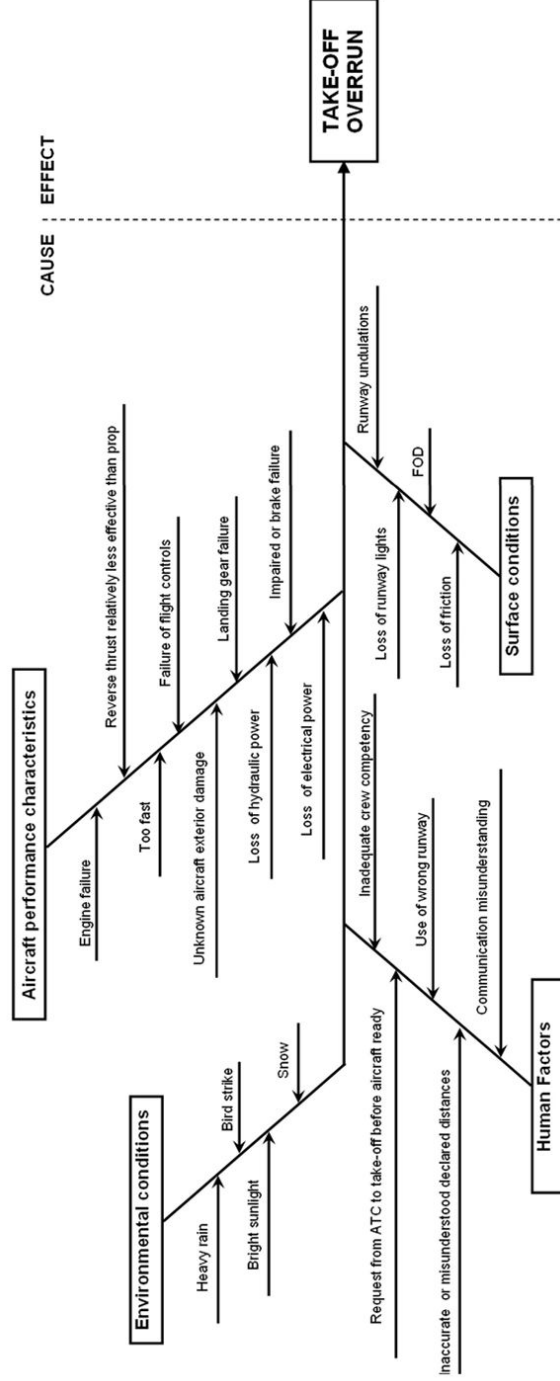Inaccurate or misunderstood declared distances

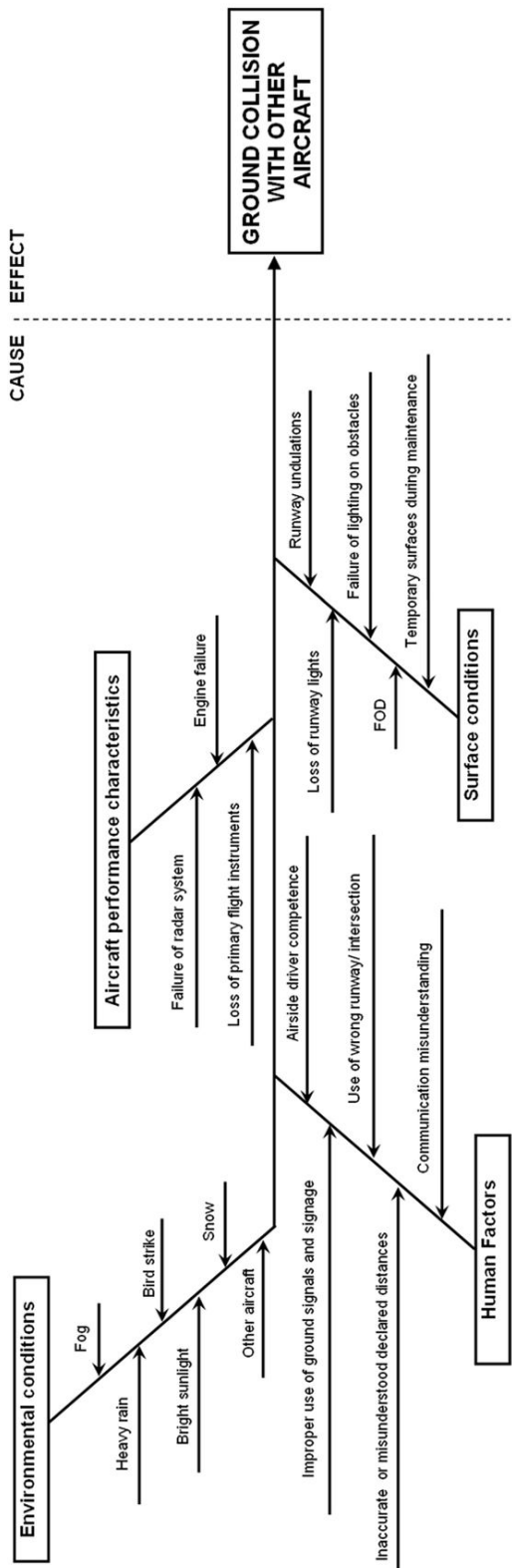**Figure 9: Take-off overrun fishbone diagram**

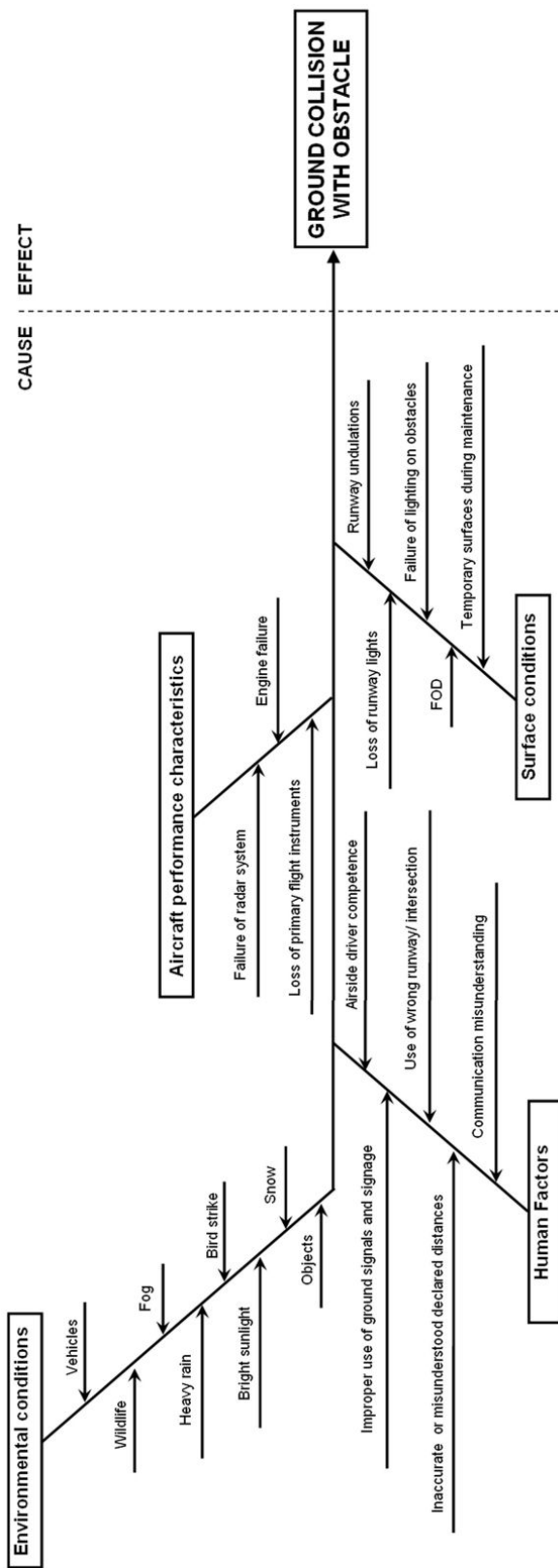**Figure 10: Ground collision with other aircraft fishbone diagram**

Figure 11: Ground collision with obstacle fishbone diagram

Risk Assessment (Step 2)

In the present risk assessment methodology we use quantitative measures to determine the probability, and qualitative measures to determine the severity associated with single hazard.

The risk assessment is based on the following formula:

$$R = P \cdot S \qquad\qquad\qquad [1]$$

Where:

R = the risk of the event (overrun, veer-off, collision or landing short)

P = probability that the hazard will occur

S = severity of the hazard

Probability Assessment

The probability is proportional to the cumulative probability of the causes identified for the hazard, so we used the *Total probability Theorem* in order to calculate the probability:

if the events C_1, C_2, ..., C_n are pairwise mutually exclusive, have positive probabilities and together form the whole space the following holds for every event A.

that is:

Hypothesis n° 1: C_1, C_2,..., $C_n \in A$

where:

C_1, C_2,..., C_n = n causes;

A = space of the total probability.

Hypothesis n° 2: $\quad \Omega = \overset{n}{\underset{i=1}{Y}} C_i$

where:

Ω = subset of A.

Hypothesis n° 3: $\quad C_i \cap C_j = \varnothing \;\; \forall\, i \neq j \;\; e\; i,j = 1,....,n$

Hypothesis n° 4: $\quad P(C_i) > 0 \;\; \forall\, i = 1,....,n$

Thesis: $\quad P(E) = \sum_{i=1}^{n} P(E|C_i) \cdot P(C_i) \qquad\qquad [2]$

where:

$P(E|C_i)$ = probability that, in presence of the cause *i* (e. g. heavy rain), the hazard (e. g. landing overrun) will occur (*Conditional probability*).

$P(C_i)$ = probability that the cause *i* (e.g. heavy rain) will occur.

$P(E|C_i) \cdot P(C_i)$ = probability that the cause *i* will produce the hazard.

The $P(E|C_i)$ assessment is carried out by analyzing of the National database for the causes belonging to environmental and surface conditions (categories 2 and 3) and by analyzing the International database for the causes belonging to the aircraft performance characteristics and human factors (categories 1 and 4).

Using the database it is possible to assess the frequency at which each cause determines a hazard. We assume the frequency as the value of probability.

$$P(E|C_i) = \frac{N_E}{N_{MC}} \qquad\qquad\qquad [3]$$

where:

N_E = number of events occurred during take-off (landing), in a stated period, generated by the cause *i*.

N_{MC} = number of take-offs (landings), in a stated period, occurred in presence of the cause *i*.

Through the formula [3] we calculate an absolute, in fact referring $P(E|C_i)$ to the single airport requires a large amount of data, in order to be statistically significant. Since the available data is quite poor, we refer $P(E|C_i)$ generally to Italian airports.

The probability $P(C_i)$ of the cause *i* is assumed equal to the frequency, at which the cause occurred in the airport studied.

$$P(C_i) = \frac{N_{MC(A)}}{N_{M(A)}} \qquad\qquad\qquad [4]$$

where:

N_{MC} = number of flight take-offs (landings), in a stated period, in the airport studied occurred in presence of the cause *i* (e.g. number of landings occurred in presence of snow).

N_M = total number of take-offs (landings), in a stated period, occurred in the airport studied.

The total number of take-offs and landings occurred in the airport and the number of flight movements occurred in presence of the causes belonging to environmental and surface conditions categories are provided by the airport management company.

The probability of the causes belonging to the aircraft performance characteristics category is not dependent on the airport where they occur, so data about failures, for each type of aircraft, should be provided by airlines companies.

Considering the composition of the traffic flow of an airport which is to be the object in the study, based on data provided by the airlines companies we must realize a valid process of weighting. So, in this case, the formula for $P(C_i)$ assessment belomes the following:

$$P(C_i) = \frac{\sum_{j=1}^{n} N_{Fj} \cdot N_{M(A)j}}{\sum_{j=1}^{n} N_{M(A)j}} \qquad [5]$$

where:

N_{Fj} = number of failures associated with the cause i suffered by the aircrafts of the type j, in a stated period, to refer to total number of take-offs (landings), which an aircraft makes in the same period (e.g. if aircraft of type j had one engine failure in 800.000 take-offs then N_{Fj}= 1/800.000=1,25·10^{-6}).

N_{Mj} = total number of take-offs (landings), which an aircraft of type j makes, in a stated period, in the airport studied.

The probable cause of more than 70% of commercial aircraft hull-loss accidents has been cited as "human error". Today, more accident/incident investigations have been focusing on the human factors in each operations during flight. This includes flight crew operations, air traffic control, ground operations, and maintenance operations.

Human factors shall be systematically integrated into the planning and execution of the functions of world aviation authorities and activities associated with system acquisitions and system operations.

Objectives of the human factors approach should be to: a) conduct the planning, reviewing, prioritization, coordination, generation, and updating of valid and timely human factors information to support agency needs; b) develop and institutionalize formal procedures that systematically incorporate human factors considerations into agency activities; and, c) establish and maintain the organizational infrastructure that provides the necessary human factors expertise to agency programs.

The probability assessment of the causes belonging to the human factors category (e. g. communication misunderstanding, inadequate crew competence, airside driver competence, …), is very difficult. The absence of human factors data could provide useful information for the risk assessment process.

This study does not, therefore discuss the element of human factors.

Severity Assessment

In order to determine the severity of each hazard identified in step 1 we used a qualitative measure based on data about fatalities, injuries and damages of the aircraft for each event in to ANSV database.

For each category of hazard we consider all accidents, serious incidents and incidents belonging to the category and by analyzing their consequence (fatalities, injuries, damage) we attributed the severity to the category of hazard.

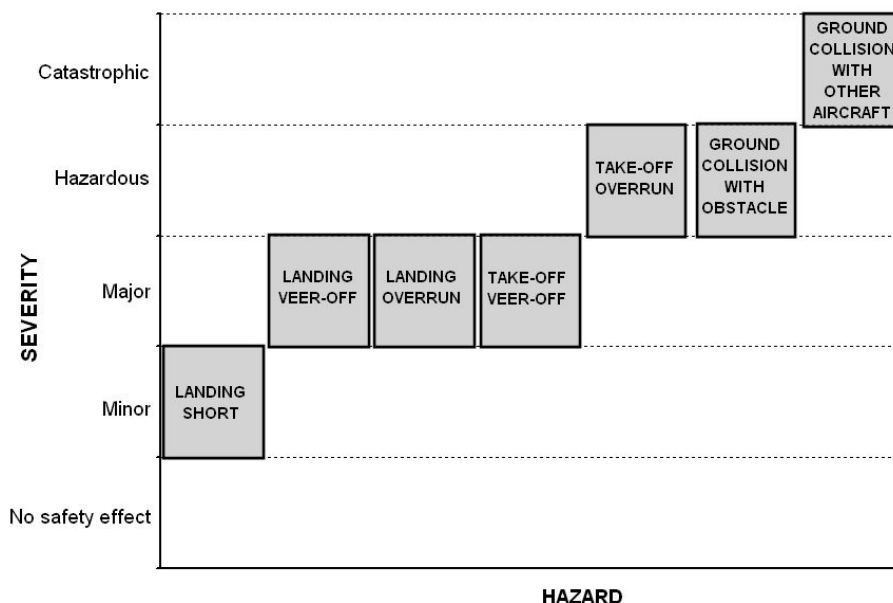The output of the severity assessment is shown in figure 12.

Figure 12: Hazard severity

The consequence shown horizontally indicate an increasing scale of severity, the vertical scale is the range of severity possible for each consequence.

It is interesting to note that "landing short" is considered a hazard of minor consequence, however, "ground collision other aircraft" is a hazard with catastrophic consequence.

CONCLUSION

In the first section of this paper we dealt with risk management process, we analysed the its six steps, however, in the second section we propose a risk assessment methodology for a specific airport.

The methodology consisting of the following steps:

1. data collecting
2. hazard identification
3. causes identification for each hazard
4. probability quantitative assessment
5. severity qualitative assessment
6. risk level assessment

The original points in this methodology are:

➢ the causes identified associated with each hazard by analyzing other studies and both National and International databases

➢ the hazard probability assessment through to the cumulative probability of the causes identified using the *Total probability theorem*

➢ the conditional probability assessment $P(E|C_i)$ was established by analyzing the National database for causes belonging environmental and surface conditions categories and by analyzing the International database for causes belonging aircraft performance characteristics category

➢ Hazard severity assessment was established by analysing of National database.

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