Aircraft Accident Database Project – A Focus on Contextual Analysis

Dr. phil. Carl Oliva, Oliva & Co., 8050 Zurich
Cornelia Hüttenmoser Oliva, Oliva & Co., 8050 Zurich

Conference paper STRC 2004
Session 2: Safety

STRC | 4th Swiss Transport Research Conference

Monte Verità / Ascona, March 25-26, 2004

Aircraft Accident Database Project – A Focus on Contextual Analysis

Carl OLIVA / Cornelia HÜTTENMOSER OLIVA
Sociological Basic Research and Development Planning
Oliva & Co.
CH-8050 Zurich

Phone: +41 1 312 75 19
Fax: +41 1 312 75 19
e-Mail1: carloliva@aol.com
e-Mail2: connyhuemo@aol.com

Abstract

Our starting point is the quest for a scientific quality control instead of the actual quest for quality and safety management in international civil aviation. We propose that the scientific quality control has to go beyond the analysis of a single aircraft accident investigation. Aircraft accidents are contextual driven and therefore contextual dependent. In consequence, this investigation firstly discusses the actual change of the safety-related contextual dimension, namely the change in the communication and navigation infrastructure of international civil aviation. Secondly this investigation discusses the quality and focus of databases being the evidence for the probability of aircraft accident in the sense of prevention. Thirdly this investigation demonstrates, as an example, how to proceed to determine a context-dependent aircraft accident rate for a certain airport concentrating on third party risk questions.

Keywords

Aircraft Accident – Third Party Risk – Methodology – Aircraft Accident Rate – Charlotte/Douglas International Airport – 3rd Swiss Transport Research Conference – STRC 2003 – Monte Verità

1. Introduction

1.1 Actual Situation

The murder of an air traffic controller on the 24th of February 2004 engaged at the Swiss Air Navigation Services stipulates the common hypothesis that the explanation of an aircraft accident can be understood as a so called ‘chain-reaction’, but it only reflects a part of the problem or what should be called the common sense of the happening of an aircraft accident [1, 2]. The investigators – social scientists – would firstly not be satisfied with this kind of explanation. Secondly it is more a question of the code of ethics, which builds the basis for every scientific research done. Hence, it is more than a social scientist’s duty to find out how an aircraft accident in future can be prevented.

1.2 Quest for a Scientific Quality Control

“One lesson has already been learned from the accident: air traffic control requires real quality and safety management.” [3] This statement–written one and half years ago of the aircraft collision over southern Germany–shows the need for an in deep scientific approach of safety analysis in order to build up the here demanded and recommended structures for a safe international civil aviation. Whether the quality and safety management must be supplied by corporate structure in order to prevent an aircraft accident in the future at all, mustn’t be answered in the first place, moreover the piece of advice must be set on a scientific **quality control** of the notional quality and safety management. Therefore, and again from a scientific point of view, the following three questions play a major role in the frame of investigations of the prevention of aircraft accidents.

- The quality and safety management remains speculative as long as no standardization is implied in the sense of a scientific quality control. The quality control starts with the question of which are the **terms** defined and used so that an aircraft accident can be prevented in future?

- Hence, the demand of defining the terms is a question of the policy applied in international civil aviation: Which level of technical standard shall be intended in the future to conform with a global international civil aviation so that the applied **tools** re-assuring adequately the here proposed scientific quality control?

- Therefore, the inset of quality control tools must be compatible with a global international standard in civil aviation: Which is the range and the scope of a sole, national civil aviation **policy** which, in fact, is basically understood as inter-reliant on the international dimension?

1.3 Primary Problems

These questions are drawing the arrangement upon which the scientific quality control of a safety management in international civil aviation must be understood, thus focussing on a description of the problems surrounding the **context** of aircraft accidents. In consequence, this investigation firstly discusses the problem of the ability to share safety-related and technical data of international civil aviation in the form of reports and **databases** contemplating analysis of aircraft accidents. Secondly this investigation discusses the quality of such databases being the evidence for the probability of aircraft accident in the sense of prevention.

1. One of the problems is the lack of taxonomies and definitions of the very subject matter of the databases, such as classification of aircraft, phase of flight, communication and navigation infrastructure (defining certain procedures), and occurrence categories.

2. Another problem is the near land at the ends of runways where development is not only restricted, but to minimize the number of people on ground at risk of death or injury as a reason of an aircraft crash during landing and take-off.

3. A third problem is to distinguish the phase of flight definitions along flight procedures such as landing, take-off, and en-route to aid the analyst determining at what point of the flight the course of action began constituting the accident.

The remedy to meet a scientific quality control sends on ahead a contextual analysis provided by a database project, under the point of view of the scientific risk research in a more specific sense of every safety analysis done. The scientific quality control concept describes an integrated view of the technical system, such as international civil aviation, for the prevention of future aircraft accidents. The target is a model build upon a clear defined database allowing the implementation of results due a safety analysis in order to support the performance of the technical system.

2. Framework for Safety Analysis

2.1 Definitions

2.1.1 Safety and Security of a Technical System

To catch the contexts of aircraft accidents, one is advised to trace the aspects of safety in civil aviation. In a complex technical system like the system of international civil aviation, we have to give an answer to the question: What database does reflect the basic idea of safety? The term safety is typically differentiated from security. Security can be generally understood to protect a technical system against external risks (e.g. sabotage). The term safety can be generally understood to protect the technical system of inherent risks (e.g. safety management system).

2.1.2 Minimum Risk Level and Interactions Processes

This general understanding of security as well as safety is shared by the three main stakeholders of the technical system, the international civil aviation. These are aircraft operators, airport providers, and providers of civil aviation services. Upon this shared perspective of security and safety, several programmes have been launched to achieve a *minimum risk level* for required processes in this technical system [4, 5, 6].

If the risk of the technical system–international civil aviation–would be defined as the degree of exposure to danger in the sense of the potential impact of a functional hazard, then the technical system would be looked at solely and producing an isolated point of view. This isolated view would at best only reflect one stakeholder's standpoint. Now, following this isolated inspection, this kind of technical system, which involves persons, processes, and technical equipment, assigned to fulfil its specific type of activity would *firstly* then be completely safe, if it has freed itself from any unacceptable risk. *Secondly*, still following the isolated view, this kind of technical system would therefore not regard the interaction processes within the given environment of international civil aviation. Therefore, the international civil aviation is here defined as a technical system operating under the condition of interaction process with at least on of the main three stakeholders at a time. The interaction process is defined by various procedures and regulations.

2.1.3 The View of the Intrinsic Risk Enhances the Safety Focus

The task of this technical system is the specification and regulation of a global air traffic management (ATM) in a risk free manner by providing expeditious services[1] [7]. Air Traffic Management is defined as a main component providing primarily safety for all the attached air traffic services (ATS), which must pay attention to an airspace capacity management in order to provide profiles with a minimum constraint [8]. Hence, safety is more than a freedom from an unacceptable minimum risk level [9]. Risk is now defined as the probability that a chance of a system benefit occurs[2] divided by the probability of damage experienced[3] within a specific technical system [10]. The operation of this technical system can be expressed by the ratio (the probability of benefit divided by the probability of damage experienced), which must be as **low** as possible. Saying this, one has to consider simultaneously that this ratio never equals zero. This is the definition of the intrinsic risk. Considering the intrinsic risk means to enhance the safety focus of every technical system wanting to become completely safe. Being free of any unacceptable risk is therefore the aim of an international and globally connected civil aviation. The intrinsic risk of international civil aviation must not only be recognized, but analyzed accordingly.

Analyzing the intrinsic risk of this technical system starts with measuring its performances. The hypothesis is that observed deviations of the technical system can be taken as indicators to seize parts of the intrinsic risk. An approach to classify the potentials of risks is determined by the incidents investigations [11]. So, one would be tempted to set-up a risk scale imaging different risk levels with the description of being acceptable, tolerable, and unacceptable. A scientific quality control would instantly question the quality of the used raw data, because the measurement of risk with the aid of a scale can be as good as the quality of the raw data are. Before introducing risk levels in any manner, first of all, a corresponding, and qualitative high standardized **database** ought to be established. Therefore, the need for the database project is

---

[1] The concept of GASP has been forwarded to the ICAO Council in 1997.

[2] Provisions of an expeditious service in the sense of trade-offs are less delays and more cost effectiveness.

[3] Here, a serious incident or an accident is meant.

shown in order to minimize the intrinsic risk of the technical system itself. It further shows, the need for an individualized database, since all of the here involved stakeholders have different challenges, but one analogous aim: The prevention of incidents and accident in air traffic.

2.2 Range of the Investigation

2.2.1 Changes in Aeronautical Issues

The present communications, navigations and surveillance/air traffic management (CNS/ATM) infrastructure has evolved quickly and mostly without globally-agreed criteria for safety, capacity and performance. Especially, an increasing level of automation and new technologies, for example the satellite based navigation, does change the mode and therefore the role of users, respectively operators, in the technical system. One is urged to pose the question about the means and instruments enhancing safety and capacity for the technical system to meet a minimum performance level in the future [11a].

Facing a growing autonomy by the ATM services providers, the international civil aviation organisation (ICAO) launched the global aviation safety plan (GASP)[4]. One objective of the GASP is to reduce the number of accidents and fatalities irrespective of the volume of air traffic. Another objective is to achieve a decrease in the worldwide accident rates[5]. Besides the here two stated objectives, there are further fundamentals to be achieved. One of them is the reviewing of the causal factors of aircraft accidents worldwide. In particular the **variation** in accident rates must be explained and safety issues must be published. Not only shall the existing database system be reviewed [13]. Solutions for the identification of safety issues shall be further developed for example:

---

[4] The GASP concept was endorsed at the 32nd ICAO Assembly in Montreal from the 22. 09. - 2.10. 1998.

[5] Overall, the number of catastrophic accidents in commercial transport operations declined by 8 per cent over the 1988-97 period. This is true whether the accident record is analysed in terms of the number of fatal accidents or hull losses. More encouraging still, the number of aircraft destroyed in 1996 and 1997 were below the accident trend line. The number of fatal accidents, too, fell below the trend line in 1997, the first time this has happened since 1994 [12].

- airport and airspace capacity enhancement developments in a safe manner;
- development of a enhanced of air-ground communication procedures (incl. minimum skill-level requirements in the common usage of the English language in ATC communications);
- new technology equipment regarding terrain portrayal on approach charts and electronic terrain data for cockpit displays;
- guidance material for flight data analysis programmes required for the operators of large commercial aircraft.

Publishing safety standards issues needs further solutions for its identification.

2.2.2 Satellite based Communication and Navigation

Another fundamental is to maintain the activities identifying the safety issues on a global perspective. Indications for a successful implementation of the global navigation system (GNSS), which is steered by the global air navigation plan for CNS/ATM, should provide a seamless implementation of the global navigation for all flight phases[6]. For many air traffic service providers, or states, it is offering the opportunity to dismantle some or all of the ground-based navigation aids. One ICAO strategy is the introduction and application of non-visual aids for the approach and landing phase on the promotion of the global navigation satellite system GNSS. Consequently, the GNSS should supply an additional standard ‘procedure’ (landing aid) vis-à-vis to the proven and well experienced instrument landing system (ILS) and microwave landing system (MLS).

During the development process of air navigation systems, a competition of the systems becoming an applied standard has always been observed [14]. With the introduction of GNSS similar concerns occurred, whether GNSS now becomes the ‘sole-means’ of air navigation systems [15]. Especially, the U.S. global positioning system (GPS), the Russian Global navigation satellite System (GLONASS), and the deployment of the European Galileo System; though, the modernization and development has progressed more slowly than expected by the global air navigation plan. The satellite based augmentation system (SBAS) shall be imple-

[6] In preparation are also amendments for relevant ICAO documents including Doc 9750 and Annex 10.

mented with the European geostationary navigation overlay service (EGNOS) and it shall be commissioned in 2004-2005. The advances of an SBAS based on approach procedures with vertical guidance (APV) versus a non-precision and a precision approach for category I (CAT I) can be summarized as follows:

1. Approach procedure with vertical guidance compared with non-precision approach:

- The vertical guidance corresponds to a stabilized descent and integrity, and therefore
- is no need given for a guidance system at an airport.

2. Approach procedure with vertical guidance compared with Cat I precision approach:

- The lateral approach design is identical, and the vertical design is slightly more restrictive,
- the lowest decision altitude is 75m (250 ft), and
- less ground infrastructure is required (e.g. lighting).

The ground based augmentation system (GBAS) is a core satellite constellation functioning on a multi-mode receiver (MMR) with a very high frequency (VHF) data link. The GBAS is planned for precision approach procedure CAT I in 2006; further precisions are studied.

An advantage of SBAS, GBAS and the aircraft based augmentation system (ABAS) is seen in the whole integration of board systems (e.g. inertial), the air traffic control procedures, and pilots by the core constellation of GPS and GLONASS [16]. Moreover, the satellite based navigation system can not only be combined with the distance measuring equipment (DME) supporting the radio navigation (RNAV), but also the approach and landing with the ILS. Terrestrial ground based navigation aids shall only be needed, if necessary. The next generation of satellite navigations constellations will be GPS III, GLONASS-K, and Galileo bringing a better resistance to known interferences and a reduction in complexity.

As radio frequency interferences (RFI) are known as a problem, the question of safety must be put forward [17]. At Zurich Airport a reference station (RIMS) has been installed, because Switzerland is participating at the EGNOS. Tests in the environment show that–despite significant terrain–masking corrections can be achieved. Operations seem to be feasible in locations, which are restricted to visual flight rules (VFR) due to limited possibility of installing an ILS and therefore relying on RNAV procedures during the approach and landing phases. Although being a small state, Switzerland sees in the implementation of GNSS a significant challenge, but the GNSS development is not possible due to resource constraints.

Summarized, the investment in future communication and navigation technology are time consuming and benefits accrue after years. At the same time, these investments point at the future potential of the intrinsic risk minimization. Hence, the improvements of air navigation had necessarily to be described. Not only because of the recently observed changes in the field of the new satellite based communication and navigation generation, but also to become aware of the future performances in international civil aviation. Today, these technical developments are the preparations for the year 2025 and onwards.

These developments are the challenges to be reflected and integrated in a safety analysis done currently. As shown here, both, the communication and the navigation technology are not only undergoing profound global technical changes, but also are developing in a competitive surrounding of regulations programmes on the international and national level. This situation will be focused on the serious incident and accident reporting system in the next chapter.

2.2.3 Serious Incident and Accident Reporting System

An incident is defined as an occurrence, other than an accident, associated with the operation of an aircraft affecting or could affect the safety of operation; a serious incident involves circumstances indicating that an accident nearly occurred; an accident is defined as an occurrence associated with the operation of an aircraft which takes place between the time any person boards the aircraft with the intention of flight until such time as all such persons have disembarked (…) [18]. The accident definition includes further steps and reflects the persons fatally or serious injured, the structural failure or sustained damage of the aircraft, and a missing aircraft[7]. The purpose of an accident investigation is to prevent future occurrences upon the analysis of data and information. With other words, one aspect of safety is also understood as a learning process. As stated by the ICAO, the sole objective of an accident or incident inves-

[7] The standards and recommended practices of the ICAO differentiates **contextual** and factual data in further Annexes 6 and 10, and Documents 9713, 4444, and 9306 to the Convention on International Civil Aviation.

tigation is again the prevention of accidents and incidents and it is not the purpose to apportion blame of liability[8].

The Eurocontrol pursues the safety regulatory requirements (ESARRs) for ATM across the European Civil Aviation Conference (ECAC) region [6]. In its institutional strategy for ATM in Europe, it is foreseen to establish a formal mechanism in Europe, separately from service provisions, for a multilateral development and harmonisation of the ATM safety regulatory regime [19]. The harmonized European incident definitions initiative (HEIDI) is one of the main projects within ESARR2. The frame is build upon the institution of the safety regulation commission (SRC). The SRC is understood as a formal mechanism to enhance this development and harmonisation process supporting a total aviation safety system approach. Although, most definitions coincide with the terms of the ICAO, one gets the impression of a proactive and standard approach to safety measurement.

Both, the Annex 13 to the Convention of international civil aviation as well as the ESARR2, require the regulator to implement a non-punitive reporting system [20]. Switzerland is a contracting state of the ICAO and a member of ECAC and therefore of Eurocontrol, made provisions for the full integration of the international law. Now it seems that some problems occur with the reporting system described in ESARR2. Although, the ESARR2 is not yet a compliant reporting system, every safety infringement (e.g. loss of separation) must be reported to Swiss aircraft accident investigation bureau (AAIB), and the question is put forward, if there a choice has to be made between the application of criminal law and the increase in aviation safety [21].

The international regulations clearly states that the reporting system is non-punitive, but as shown in this example it varies in different national regulations. This contradiction points at core of the here discussed database project: internationally a non-punitive reporting systems is promoted vis-à-vis a national reporting system facing at least partially criminal prosecution whilst reporting certain information. Consequently, an **inherent** bias must be supposed in data. Investigators must have an answer for the question, how safety analysis scientifically is quality controlled, if it seems that only limited and paucity data is available.

[8] Annex 13: Aircraft Accident and Incident Investigation. 2001. Chap. 3, § 3.1.

2.3 The Database Project

2.3.1 Brief Overview on Air Safety Data Sources

Like Harro Rantner states, air safety data-sources are key elements in the process of preventing accidents [23]. He proposes as a hypothesis: The amount of publicly available safety information and the ease, of which it is accessible, depends on the severity of the occurrence. The most severe occurrence is the aircraft accident. As a consequence of this hypothesis, however, we expect a rather good accessibility to accident data. But this does not mean that we will meet also a high quality of data. The quality of accessible data varies from organization to organization within the business of data collection.

According to Annex 13 to convention of international civil aviation, an aircraft accident should be conducted by the state of occurrence, though this state may delegate the investigation to state of registry or state of operator. Further it is recommended that serious incidents should also being investigated. And once more, the sole objective of the investigation of an accident or incident shall be the prevention of accidents and incidents. Information regarding the results of the investigation is usually made available by the responsible aircraft accident investigation authority of a country or any other party in charge of the investigation in the form of a preliminary and/or final report. One of the problems associated with access to accident/incident investigation reports is the fact that there is no easily accessible central report repository.

The database from the National Traffic Safety Board (NTSB) is the best publicly available one. Their reports of accident investigations include: the history of flight, injury information, damage to aircraft, pertinent personnel information, aircraft information, meteorological information, aids to navigation, communication, airport information, flight information, wreckage or impact information, medical or pathological information, fire, survival or forensic aspects, tests and research, organizational and management information, effective investigative techniques.

The ICAO accident reporting system (ADREP) is another accident/incident database with an almost worldwide coverage. A common problem for both, NTSB and ADREP, databases is the fact that there is a large difference in the quality of the reports. Identical occurrences can be classified in entirely different ways and misspellings of, for instance, aircraft model designators are not uncommon. The ADREP database cannot be considered as complete because some member states rarely or never submit reports [20].

An independent database is the "World Directory of Airliner Accidents", but one of the best sources on paper is perhaps the UK Civil Aviation Authority (CAA) World Airline Accident Summary (WAAS), which is now being maintained by air claims. The Netherlands Aviation Safety Network (ASN) has established a report standardization that offers a well accessible database. This database too is not complete because of biased reporting.

2.3.2 Shortcomings in Data

In applied risk research several distinctive methods sharing uniform raw data are presenting different outcomes for the probability of an aircraft crash [26]. This fact is mainly explained as a cause of the application of historical data. If there are missing aircraft crashes, then an *under*estimation of the aircraft accident rate results. If there are missing aircraft movements, then an *over*estimation of the resulting aircraft accident rate can be observed. Therefore, one matter for further examination is the call for a reliable and complete data, yet another matter is an answer of the validity of the appropriate database. The investigation aims to close the gap of the methodological appropriateness by stressing on important features of the comparative quantitative research for example the space of experience, the unit of analysis, observation, and data selection.

The promotion of our database project lays in the solution for specific problems and specific contexts. Aims of harmonization within projects–like HEIDI–are showing shortcomings, as Eurocontrol realized itself, raw data do vary. We met the following assumptions and dimensions of our database.

2.3.3 The Focus on our Database Project

As a consequence of this status quo of available data, we decided to develop a database that is process-oriented on the one side, and context-oriented on the other side. Our database is considering the main purposes of the NTSB database, namely:

- determination of event severity,
- providing a basis for prevention and mitigation strategies, and
- setting a basis for priorities and resource allocation.

Our data-matrix has three main dimensions:

- The phase of event: pre-crash, crash, post-crash;
- The risk factors: human, vehicle, physical environment, socioeconomic environment;
- The contexts: type of aircraft operations, flight-rules, aircraft type and generation, communication and navigation infrastructure, type of airport, internal vs. external risk, etc.

2.3.4 The Contexts and Dimensions

For this investigation statistical and narrative accident data, and airport movement data were collected, which are globally available. So, the approach and landing accident factors were identified. The taxonomy had to be developed in order to carry out the analysis of the gathered information. The navigation guidance facilities of an airport and aircraft equipment had to be considered as well. These data build up the context as for one of the main investigation questions.

The term "context dimension" is here defined as infrastructural circumstances with highly internal connected technological, navigational, and communicational relations, in which air traffic happens. In this case the contextual dimension is related to the so called terminal area (TMA) [24]. The definition and therefore the structure of this airspace dimension will vary from location to location dependent upon local requirements. The contextual dimension is the product of four input principles, based upon ICAO direction:

1. The **procedure design** defines departure, arrival, and holding procedures for the airport in question. Controlled terminal airspace structures are provided for the protection of aircrafts carrying out IFR during the arrival and departure phase.
2. The **airspace structure** is the product of the establishment of a controlled airspace so that it corresponds to the flight profile requirements of an IFR procedure, which are supported by the air traffic control services. The construction of this structure has the following core elements: a) airways within the flight information region (FIR), b) control area (CTA) and TMA, and c) control zone (CTR).
3. The specific **functional differentiation** of the airspace that is the division of air traffic services for example the responsibility between the services of the approach control (APP) and the area control center (ACC). This interface can have a significant effect

on the capacity of an ATM system with respect to the requirements for coordination and the workload imposed on both ground and air.

4. The **terminal airspace classifications** supports the aim to ensure that a demanded mix of flight operations, whether these are designed for IFR or visual flight rules (VFR) procedures, at and around the airports do not impair the safety.

Along this contextual dimensions–inputs–will enhance a certain measurement of the contextual performances as an output. These inputs will result in a specific amount of traffic-features of an airport that are:

- **classifiable** and therefore usable to construct indicators,
- **comparable** along with certain other indicators,
- therefore **reliable** (repeated observation of the same events by the same observer shall yield the same data),
- though **inter-subjectively acceptable** (repeated observation of the same events by different observers shall yield the same data), and
- in the whole **valid** (data shall be obtained of such a kind and in such a way that legitimate inferences can be made from the manifest level to the latent-contextual level).

2.3.5 Inclusion Criteria for the Accident Database

All reported aircraft accidents were provided by the mentioned sources (chap. 2.3.1). The in depth search, necessary for each aircraft accident, is very challenging, but in many cases the full study of the accident report was compulsory. The following criteria were applied for the recording of an event.

1. Commercial aircraft operators carrying out scheduled and non-scheduled flights; passenger, freight, and positioning flights; domestic and international; (excluded are training, experimental, and test flights like aerial application and survey etc.).

2. Aircraft with turbojet and turboprop engines and with fixed-wing (excluded are piston engine and helicopters).

3. Aircrafts with a maximum take-off weight equal or greater than 5.67 t (excluded are aircrafts involved by sabotage, terrorism and military).

4. All aircraft accidents have occurred between 1970 and 2002.

5. All aircraft accidents did occurred in the initial and final approach phase for an instrument guided landing using instrument flight rules; for visual flight rules the well known downwind pattern becomes applicable. If the aircraft did reach the approach stage after an immediate departure or due a missed approach procedures the case was considered in the database (excluded are flare and rollout after touchdown, overrun and therefore contribution to third party risk on the aerodrome itself). This decision bases on the scarce data availability.

6. Aircraft accidents resulting in the loss of the aircraft hull (most accident in the approach and landing phase show fatalities and are leading to hull loss).

7. Only comparable traffic mixture of airports for the investigated airport (excluded were all those airports which differ form the traffic mixture pattern significantly).

As already set out in Chapter 2.2.3, and also according to the National Transportation Safety Board (NTSB) we define an **aircraft accident** as an occurrence with the operation of an aircraft, which [22]:

- takes place between the time any person boards the aircraft with the intention of flight until all such persons have disembarked, AND
- any person suffers death or serious injury, OR
- the aircraft receives substantial damage (Part 49 of Code of Federal Regulation 830).

The **substantial damage** adversely affects the structural strength, performance, or flight characteristics of the aircraft and would normally require major repair or replacement of the affected component. The **fatal injury** results in death within 30 days of an accident. An **incident** is an occurrence other than an accident associated with the operation of an aircraft, which affects–or could affect–the safety of operation.

2.3.6 One Stakeholder – the Airport Operator

The safety analysis needs specific knowledge about the ratio between the accident occurrences and the air traffic exposure in order to calculate the accident rate (AR) of the airport investigated. A worldwide accident rate is therefore not a good judgment, for it does represent an artificial fact on the different contextual dimensions, facing the problem that nobody may neither understand nor interpret this result. The worldwide accident rate can, statistically spoken, be interpreted as the grand mean with a high amount of fragmented specific contextual dependencies. Though, we only can compare occurrences or events with comparable events, we have to design a typology of airports with contextually similar features. Constructing the AR in similar contexts can be determined within the frame of contextually comparable airports, especially counting the number of accident occurrences and measuring the air traffic exposure within this group of airports.

How to measure similar contexts between comparable airports? There are some antecedents that should be fulfilled, namely

- to compare as many as possible airports worldwide,
- to describe these airports with indicators that do not change their meaning between large and small airports, and
- to utilize the indicators that reflect the mentioned structural inputs in the most appropriate way.

Relying on these antecedents, we propose to apply the following indicators.

1. The aircraft movements per year are reflecting the capacity of the ATM system at the location investigated.
2. The number of passenger per year shows at least partially the economic efficiency provided by an airport’s infrastructure.
3. The volume of freight per ton in a year proofs another part of economic efficiency.

One of the goals of air traffic services, and therefore also for an airport control tower, is to achieve a safe, orderly, and expeditious air traffic flow. Besides the stipulation for time series data, no further indicators are required. The Airport Council International (ACI) collects and provides data for airports according to the worldwide commercial air traffic. Consequently, no data are supplied for the general aviation. This investigation uses some of these data in its database.

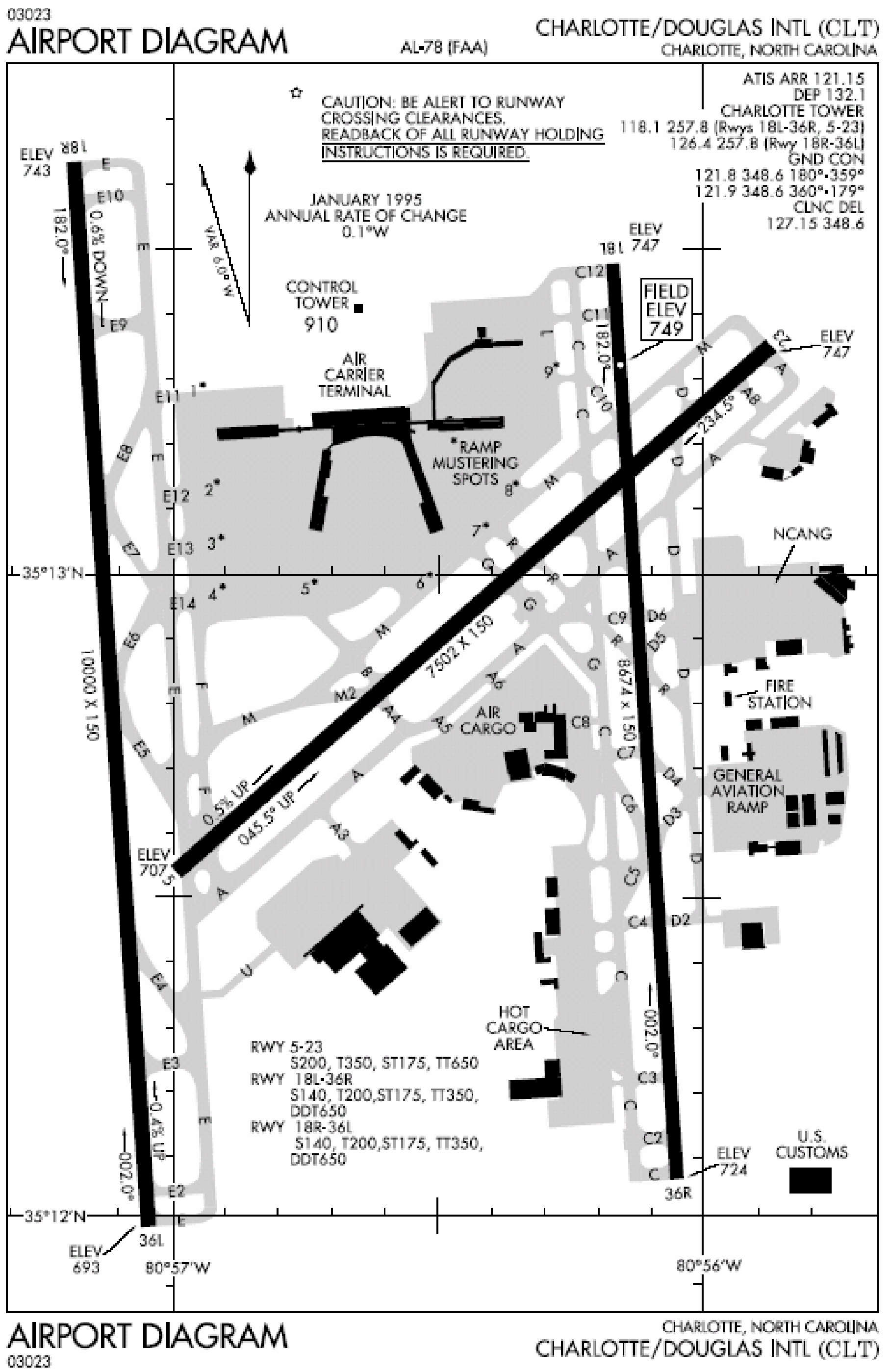
As an example, we will show the context determination of Charlotte-Douglas International Airport, situated in North Carolina in the United States (Fig. 1). In 1938 Eastern Airlines started at Charlotte-Douglas International Airport its first regularly scheduled passenger service; in 1950 United Airlines followed, in 1956 Delta Airlines, and in 1962 Eastern Airlines begins the region's first regularly scheduled jet service. As a consequence of the airline's industry deregulation, the Flying Tigers begins in 1978 its first scheduled international cargo flight to Zurich in Switzerland. In 1979 Piedmont Airlines chooses Charlotte as a hub for its rapidly expanding airline. In the same year, the airport adds its third runway. In 1990 Lufthansa German Airlines starts services under the deregulated "Open-Sky" agreement. In 1990 construction work begins for the runway 36R extension and NC160 road relocation. In 1994 British Airways begins service to London via a "global alliance" with USAir. In the same year Northwest begins service. In 1996 Continental Airlines and ValuJet begins service. In 1997 USAir becomes US Airways, Air Canada begins service, and Cargo buildings are constructed for Emery Worldwide & United Worldwide Cargo. 1998 US Airways establishes Airbus crew training base and begins construction on new training facility. In 2000 US Airways begins daily non-stop service to Paris and Frankfurt; Canadian Regional and Southeast begin service.

As shown in Figure 1, Charlotte-Douglas International Airport has three runways, RWY 05/23 (2286 m), RWY 18L/36R (2644 m), and 18R/36L (3048 m).

Charlotte-Douglas International Airport ranks in 2002 on the 14th position for operations, on the 19th position for the passenger, and on the 33rd position for cargo nationwide. Today, the main airlines are: American Airlines, Air Canada, ATA, Continental Airlines, Delta Airlines, Lufthansa (serves Munich Airport in March 2004), Northwest Airlines, and US Airways. The regional carriers are: American Eagle, Delta Connection, United Express, Northwest Jetlink, Continental Express, and US Airways Express. Among the international destinations, we will find European places like: Frankfurt, and London. The airport counts today 16'500 employees. A 4th runway is planed. A night curfew does not exist.

In the year 2003 Charlotte-Douglas International Airport did count altogether 443'394 aircraft operations. Among these are 207'347 operations by air carrier, 196'708 operations by air taxi, 37'339 operations by general aviation, and 1'973 by military operations.

Figure 1 Airport Diagram of Charlotte/Douglas International Airport



3. Findings

3.1.1 Description of a Single Occurrence as a Starting Point

In this part we describe by the use of a single accident occurrence, how an accident may proceed in order to determine some principal components of such an event. This example stresses our database dimension defined as the "Phase of Event". Our main questions in this part are:

- What? "Occurrences"
- When? "Phase of Flight"
- Why? "Sequence of Event"

In the terminology of our database, the type of occurrence is defined "Loss of Control – in Flight", and this event occurs between the "Final Approach Fix (or Outer Marker) and the Runway Threshold". A first insight is given by a short description supplied by the NTSB documentation with the identification "DCA94MA027":

> "On Friday, January 7, 1994, at 2321 eastern standard time, a Jetstream J4101, N304UE, operated by Atlantic Coast Airlines of Sterling, Virginia, and doing business as United Express 6291, a scheduled commuter flight from Dulles International Airport to Columbus Ohio, crashed 1.2 nautical miles east of runway 28L at Port Columbus International Airport, Columbus, Ohio. The aircraft had been cleared for an ILS approach to runway 28L and had been in contact with the tower when it crashed into a concrete block manufacturing structure about 1.2 miles from the airport. The pilot, co-pilot, flight attendant and two passengers were fatally injured. Two of the other three passengers received minor injuries while the third was not injured. The airplane was destroyed. Instrument meteorological conditions prevailed at the time and the airplane was on an instrument flight rules (IFR) flight plan."

The NTSB determines the probable cause(s) of this accident as follows [25]:

1. An aerodynamic stall that occurred when the flight crew allowed the airspeed to decay to stall speed following **a very poorly planned and executed approach characterized by an absence of procedural discipline**;

2. Improper pilot response to the stall warning, including failure to advance the power levers to maximum, and inappropriately raising the flaps;
3. Flight crew inexperience in 'glass cockpit' automatic aircraft, aircraft type, and in seat position, a situation exacerbated by a side letter of agreement between the company and its pilots;
4. The company's failure to provide adequate crew resource management training, and the FAA's failure to require such training;
5. The company's failure to provide adequate stabilized approach criteria, and the FAA's failure to require such criteria; and
6. The unavailability of suitable training simulators that precluded fully effective flight crew training.

➢ Note: Items 1, 2, and 3 were approved by a Board vote of 4-0. Item 5 was adopted 3-1, with the dissenting Member believing the item was a contributory cause. The Board was divided 2-2 on items 4 and 6, two Members believing them causal and two Members, contributory.

What does it mean, when the NTSB report does focus on “a very poorly planned and executed approach characterized by an absence of procedural discipline”? First of all, the report is convinced that there was no indication of any preexisting discrepancy or pre-impact mechanical failure of the structure, systems, or flight controls of the airplane, which contributed to the accident. However, the weather was no contributing factor to the accident.

The accident did evolve as follows: The captain associated the illumination of the left engine ignition light with en engine failure. But the left engine ignition light illuminated as a result of a momentary negative torque condition when the propeller speed levers were advanced to 100 percent and the power levers were at flight idle. Contrary to the assumption of the captain, there was no evidence of an engine failure. The cockpit voice recorder (CVR) sound spectrum analysis revealed that both propellers operated at approximately 100 percent RMP until impact and examination of both engines revealed that they were operating under power at the impact. As a consequence, the captain’s improper assumption that an engine had failed and the captain’s subsequent failure to follow approved procedures for engine failure is the most probable causes of this accident. The captain failed to follow established procedures for engine failure identification, singe engine approach, single engine go-around, and stall recovery. The flight-crew failed to manage resources adequately. Specifically, the captain did not designate a pilot to ensure aircraft control, did not invite discussion of the situation, and did not brief his intended actions. Additionally, the first officer did not assert himself in a timely and effective manner and did not correct the captain’s erroneous statement about engine failure.

The analysis of this accident did lead, among others, to the following recommendations:

- Publish advisory material that encourages air carriers to train flight crews in the identification and proper response to engine failures that occur in reduced power conditions and in other situations that are similar;
- Require all airlines operating under 14 CFR Parts 121 and 135 and independent facilities that train pilots for the airlines to maintain pertinent standardized information on the quality of pilot performance in activities that assess skills, abilities, knowledge, and judgment during training, check flights, initial operating experience (…).

The concentration of the investigation on a single accident, and the comparison of these accidents give very important contextual insights. The most important consequence is therefore an ongoing learning process driven by the formulation and implementation of recommendations.

From our point of view, there is more information included than we may detect by concentrating only on the single event. If we start on comparing all these accident reports in a systematically manner, quasi on a higher system level, then we will have the possibility to disclose quite a new dimension behind the occurrences, phase of flights, and sequences of events. This dimension we will define as the **contextual dimension of an event**. By changing to this system level, our analysis of the accident leads us to a further question.

Especially, the previous example demonstrates the effect of the “human factor”, how it contributed to the evolution of this specific process finally leading to an accident. It is a common sense, that there are two main directions to reduce the effect of the “human factor”, namely **automation** of human interactions by technological progress on the one side, and **standardization** of role behavior on the other side. Both, the automation and the standardization contribute to augment the safety level. How the safety level augmentation, the here named **SLA**, does proceed, depends as well on the contextual dimension. Additionally, we propose that the contextual dimension has a high variability. Therefore, our fourth concept can be emphasized with the following question:

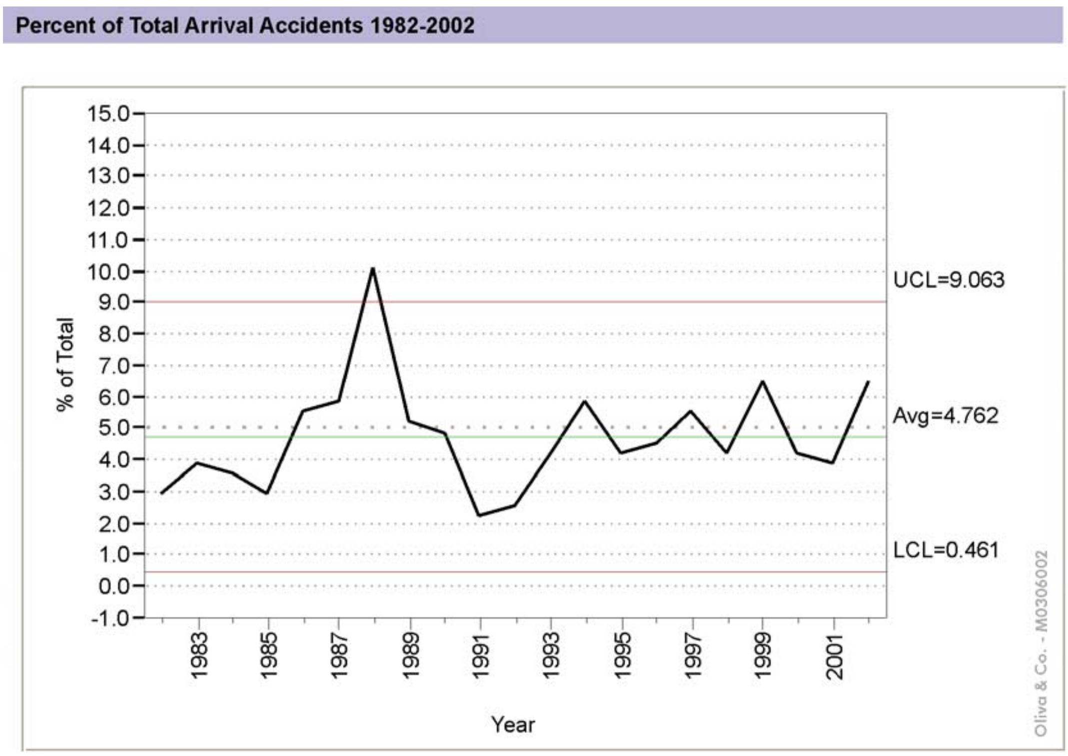
- Where? “Context”

3.1.2 Arrival Accidents from 1982 - 2002

The next step shows the evolution of aircraft accidents occurring in the initial and final approach phase. As already discussed, data are inconsistent and incomplete. Facing this situation we did investigate to collect all worldwide accidents during the arrival flight phase. Applying the previously shown inclusion criteria, 306 occurrences were coded and registered in our database. Figure 2 shows the distribution of these accidents occurred during the arrival flight phase per year from 1982 until 2002.

As shown in the control chart (Fig. 2) the centreline indicates the average expected value is being below 5 % of the total arrival accidents. The upper and lower control limits (UCL respective LCL) show the range of variation to be expected in the summary statistics of arrival accidents when the process is in statistical control. In 1988 the average line (Avg) is outside the upper control limit, which signals the presence of a special cause of variation: 31 arrival accidents were observed in this year.

Figure 2 Development of Arrival Accident during the past 20 years



3.1.3 Accident Rate

Now we will give an answer to the following question: Which airports belong to the same type as the Charlotte-Douglas International Airport? We did raise this question because of our aim to determine the AR for an airport in question.

In a first step we did collect data on as much airports as possible. To get a stable result we did collect them for a five-year period, 1997 to 2001. As a starting point we had more than 800 airports. From this set of data, we did choose all those airports that had a complete status configuration during this period of time with respect to aircraft movements, number of passenger, and cargo. The numbers of airports was reduced to the number of 280.

In a second step we did perform a hierarchical cluster analysis [27] determining the groups of airports, especially to determine the multidimensional distance-structure between all of the 280 involved airports. The next steps are the application of this distance-structure to determine a group of airports with the lowest possible distance with respect to each other starting at the specific airport in question.

In a third step we had to determine the homogenous group of airports surrounding a certain airports, in this case Charlotte-Douglas International Airport. This step was investigated with the use of variance analysis [28] choosing a sequential strategy.

Figure 3 Sequential One Way Analyses with Charlotte-Douglas International Airport as a Starting Point

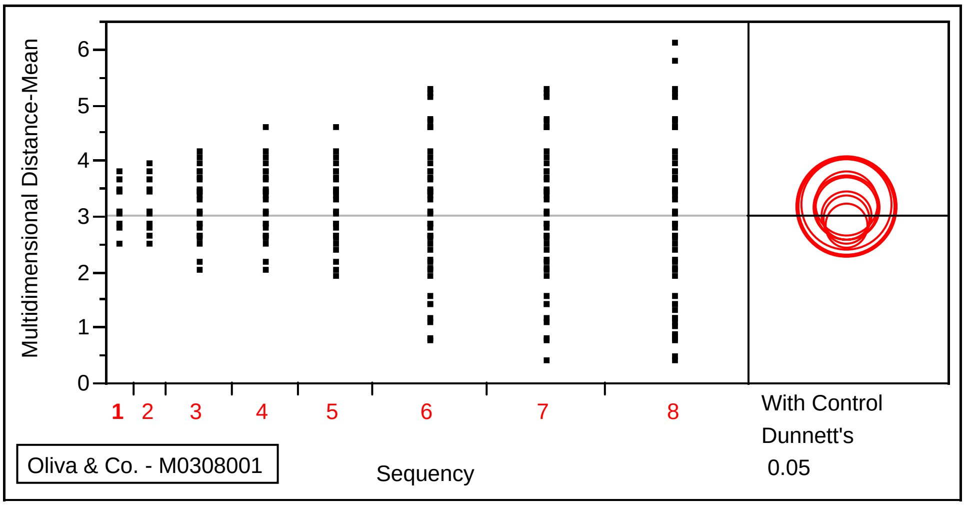


Figure 3 shows that the groups of airports from 1 to 5 as very homogenous. This core-context includes the aerodromes shown in Table 1.

In a fourth step we had to complete the time-series data for each airport in order to determine the AR, meaning to collect and cumulate movement data for the time period from 1991 until 2002 (exposure) on the one side, and to count all aircraft accidents during the same time period on the other side.

The movements, shown in Table 1, are cumulated values for the time-period from 1991 until 2002. The counts of aircraft accidents are related to the question of third party risk in the environment of an airport, that means:

1. Area of 40 km x 40 km,
2. Arrivals and departures,
3. Outside the airfield.

Table 1 Airports with low distance to Charlotte-Douglas International Airport

Aerodrome	IATA-Code	Movements (cumulated)	Accidents (Arrivals)
BANGKOK	BKK	2100118.5	0
BRUSSELS	BRU	3177845	0
CHARLOTTE	CLT	5402340.5	1
COPENHAG	CPH	3116340.5	0
CINCINNATI	CVG	4584044.5	0
ROME	FCO	2808904.5	0
HONOLULU	HNL	4304771	0
WASHINGTON	IAD	4166975	1
INDIANAPOPIS	IND	2925550	0
OSAKA	KIX	1056409.5	0
NEW YORK, LA GUARDIA	LGA	4219109.5	0
LONDON; GATTWICK	LGW	2671896	0
MADRID	MAD	3219303.5	0
ORLANDO	MCO	4015548.5	0
OAKLAND	OAK	5581419.5	0
PARIS, ORLY	ORY	2739930.5	0
BEIJING	PEK	1655165	0
PITTSBURGH	PIT	5280038.5	1
LOUISVILLE	SDF	2015180.5	0
SALT LAKE CITY	SLC	4282534	1
SYDNEY	SYD	3192022	0
TAIPEI	TPE	1173572.5	0
VANCOUVER	YVR	3849611.5	0
ZURICH	ZRH	3249896.5	1

The arrival accident rate ($AR_{Arrivals}$) for this specific case is shown below in formula 1.

Formula 1 Accident $Rate_{Arrivals}$ for Charlotte-Douglas International Airport

$$AccidentRate(AR_{Arrivals}) = \frac{Events}{Exposure} = \frac{5}{40394263.5} = 1.238E - 07$$

4. Discussion and Conclusion

The presented paper starts with the proposition that quality and safety management remains speculative as long as no standardization is implemented. The paper shows, that investigations shall concentrate on the contextual dimensions as a first conclusion. In this sense, standardization lies on structural features and not on single events. A further aspect of standardization focuses on methodology. Cluster analysis and analysis of variance are appropriate tools. Clustering is a multivariate technique of grouping units together that share similar values. In order to have a test of the homogeneity (or difference) of groups we use analysis of variance techniques. A one-way analysis of variance is the attribution and test that part of the total variability in a criterion is due to the difference in mean among factor groups. These tools can be used to analyze specific questions with respect to the problems of safety level augmentation (SLA).

The gain in implementing such tools is that one shall be capable to analyze airport-related, contextual patterns laying on probability theory. For instance, following ICAO world wide data on arrival-accidents the Accident Rate for 2003 is $AR_{approach}$=6.5E-05. If one compares this number with our context-related Accident Rate for Charlotte-Douglas International Airport $AR_{approach}$=1.238E-07 than one can see the result of a quite different approach of investigation. From the viewpoint of a certain airport, world-level data – without relaying on specific context-information – may lead to an overestimation of the probability of an accident during the arrival phase per aircraft movement. Therefore, from a statistical point of view, Accident Rates estimated on world-level do not only overestimate the accident probability for a vast number of airports, but these estimations may make available artificial and false information, because these statistical means do represent data with very high standard deviation in a rather poor manner. As a consequence, we propose for solving problems in the field of safety level augmentation, however, only to base investigations on context-related database information.

5. References

[1] ‚Fluglotse in Zürich erstochen. Rache für das Bodensee-Unglück?' (2004). Frankfurter Allgemeine Zeitung, 26. Februar, Nr. 48, S. 9.

[2] ‚Rätsel um Tötung des Flugverkehrsleiters. Reduktion der Überflüge wegen schockierter Mitarbeiter.' (2004). Neue Züricher Zeitung, 26. Februar, Nr. 47, S. 45.

[3] Rossier, A.: Editorial. (2003). Skymag, Magazine of Swiss Air Navigation Services, July, No. 5.

[4] Annex 17 to the Convention on International Civil Aviation. (1974). Security, 1st Edition. Montreal: ICAO.

[5] SAFA Report. (2002). The ECAC / JAA Programme for Safety Assessment of Foreign Aircraft. Neuilly-sur-Seine Cedex: ECAC.

[6] EUROCONTROL Safety Regulatory Requirement. (2000). ESARR 2 - Reporting and Assessment of Safety Occurrences in ATM. Edition 2.0. Brussels: Eurocontrol.

[7] The Global Aviation Safety Plan GASP. (1998). 32nd Session of the Assembly of the International Civil Aviation Organisation. Montreal: ICAO.

[8] DOC 4444-RAC/501 Procedures for Air Navigation Services. Rules of the Air and Air Traffic Services, to the Convention on International Civil Aviation. (1996). 13th Edition, Part I. Montreal: ICAO.

[9] ISO/IEC Guide 2 (1996).

[10] Frank, E. (1989). Risikobewertung in der Technik. Risiko in der Industriegesellschaft. Ed: G. Hosemann. Erlangen: UB, S. 43-93

[11] DOC 4444-RAC/501 Procedures for Air Navigation Services. Rules of the Air and Air Traffic Services, to the Convention on International Civil Aviation. (1996).13th Edition, Part II, § 16.2. Montreal: ICAO.

[11a] The PRC's European ATM Performance Measurement System (1999). Edition 1.7. Brussels: Eurocontrol.

[12] Menzel, R. (1998). Analysis Shows that CFIT Continues to Account for the heaviest Loss of Life Worldwide. Montreal: ICAO Journal, Vol. 53, No. 3.

[13] Ferris, R. (2003). Standardization of Aviation Occurrences Statistic should Enhance Safety Focus. Montreal: ICAO Journal, Vol. 58, No. 1.

[14] Freer, D. W. (1986). Maturity brings new challenges – 1957 to 1976. Montreal: ICAO Bulletin, Vol. 41, No. 12, p.25

[15] 11th ANC Air Navigation Conference. (2003). Agenda and Explanatory Notes. Aeronautical Navigation Issues. Montreal: ICAO.

[16] Bowie, R. (2003). A Presentation of GNSS Operations. 11th Air Navigation Conference. Montreal: ICAO.

[17] GNSS Implementation in Switzerland: Status and Priorities (2003). Air Navigation Conference 11-WP/56. Montreal: ICAO

[18] Annex 13 to the Convention on International Civil Aviation (2001). Aircraft Accident and Incident Investigation, 9th Edition. Montreal: ICAO.

[19] Air Traffic Management Strategy for 2000+ (1997). Brussels: Eurocontrol.

[20] A33-17 (2001). Nondisclosure of certain accident and incident records. Montreal: ICAO.

[21] Baumgartner, M. (2003). Speaking out for a 'just reporting culture in ATM'. Skymag, Magazine of Swiss Air Navigation Services, July, No. 5, p. 23-24.

[22] Bruce, D. (2003). Transportation Safety Databases - Accident Records and Exposure Data. Safety Studies and Statistical Analysis Division. Washington: National Transportation Safety Board.

[23] Rantner, H. (2002). Access to Air Safety Information. A paper submitted for the 8th Annual MRO Regulations, Quality & Safety Conference, October 17-18.

[24] Annex 2 (1990); Annex 11; Doc. 4444-RAC / 9426-AN, 8168-OPS, 9368-AN, 9371-AN to the Convention on International Civil Aviation. Montreal: ICAO.

[25] Report AAR-94/07 (1994). Washington: National Traffic Safety Board.

[26] Ferris, R. (2003). Standardization of aviation occurrence statistics should enhance safety focus. Montreal: ICAO Journal, Vol. 58, No. 1

[27] Bailey, K.D. (1975). Cluster Analysis. Sociological Methodology, Vol. 6, p. 59-128.

[28] Scheffé, H. (1959). The Analysis of Variance. New York: John Wiley & Sons, Inc.