UDC 656.7.052(045)

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# INTEGRATED RISK PICTURE METHODOLOGY FOR AIR TRAFFIC MANAGEMENT IN EUROPE

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**Abstract.** *The article deals with the analysis of the researches conducted in field of the Integrated risk picture methodology. Benefits of the concept, operational documentation and potential users of Integrated risk picture methodology have been reviewed. Principles of implementation and impact on Air Traffic Management have been analysed and general recommendations applicable for Ukrainian aeronautical system have been proposed.*

**Keywords:** Air Traffic Management, aviation risks modelling techniques, European Air Traffic Management programme, Integrated risk picture methodology, risk assessment, risk models, safety of flights.

## 1. Introduction

The EUROCONTROL strategy for safety in Air Traffic Management (ATM) requires a detailed understanding of the potential contribution of ATM to aviation accidents, in order to optimise safety improvement efforts. At present, the safety of new ATM tools and concepts is ensured through a detailed safety assessment process, but until now there has been no system for evaluating their combined effects on safety (2004 Baseline…2004).

It is possible that unrecognised interdependencies between ATM systems may prevent their planned safety benefits from being realised. EUROCONTROL therefore decided to construct an *integrated risk picture* (IRP) (2004 Baseline…2004; Air Traffic…2006), showing the overall ATM contribution to aviation accident risks, and highlighting possible interdependencies, so that the priorities for safety improvements can be identified in a systematic way.

The ATM 2000+ Strategy (Air Traffic…2006) sets the objective of ensuring that the numbers of ATM induced accidents do not increase and, where possible, decrease. Since demand for air travel is expected to double by 2015, this implies that the rate of accidents per flight hour must be halved.

Following recent serious aviation accidents (Accident…2005), the *EUROCONTROL High Level European Action Group for ATM Safety* identified priority actions to improve safety in European airspace, including research to develop an integrated risk picture for ATM in Europe.

The overall objective of the article is to review an integrated risk picture for ATM in Europe, showing the relative safety priorities in the gate-to-gate ATM cycle, and the safety impacts of future ATM developments.

The present article represents the methodology that underlies the risk picture (IRP 2005 and 2012). It provides details of the approach, the model structure, the quantification, the validation and the predictions of future ATM performance (Main Report…2006).

## 2. Risk modelling challenges

The key challenge for the risk model is to construct a quantitative link between accident risks and underlying causes, distinguishing ATM from other contributors, so that areas for risk reduction can be identified. The following factors make this difficult (2004 Baseline…2004; Main Report…2006):

– *System complexity.* The complex system of safeguards intended to prevent aviation accidents means that most accidents are complex, involving a combination of failures. These are sometimes independent, and can appear extraordinary and unpredictable. In other cases the failures are interlinked, with subtle connections to the underlying safety culture;

– *Data limitations.* Behind the immediate technical and operational causes of accidents, there are often common problems of safety management and regulation. However, these are rarely made explicit in accident investigations, and hence are difficult to substantiate. Similarly the contribution of airspace management to failures in air traffic control is rarely identified;

– *Diffuse influences.* While technical systems can be modelled, with some simplification, as either working or not working, and human operators can be modelled as occasionally committing distinct errors, the underlying problems of safety management and regulation cannot be represented as simple success or failure. They do not directly cause accidents and, although they have a strong influence on the accident risks, this influence is diffuse and difficult to define;

– *Interdependencies.* An "integrated" risk picture is not a simple matter of adding up independently estimated parts of the risk picture, because of interdependencies between them. These interdependencies are rarely apparent in individual accidents, but become important when apparently independent influences are added together in a model, as they may lead to over-estimation of their combined benefits;

– *Uncertain ATM developments.* The nature of the ATM system in 2012 is still under development, and many of the details are difficult to define at this stage. Some aspects may change quite radically, and hence it is difficult to estimate what their effects on safety might be (Operational…2004).

## 3. Description of the Integrated risk picture methodology

EUROCONTROL is developing an integrated risk picture for air traffic management in Europe, showing the relative safety priorities in the gate-to-gate ATM cycle (Operational…2004; ATM…2005).

The IRP is the output of a "risk model", representing the risks of aviation accidents, with particular emphasis on ATM contributions. In order to ensure that the risk model reflects ATM as it develops in the future, the risk model is founded on an "ATM model", describing the ATM system whose risks are modelled.

The overall structure of the risk model is shown in Fig. 1. Five accident categories are identified where ATM may make a significant contribution either in causing or preventing accidents. A separate fault tree model is used to represent specific causal factors for each accident category, including failures of the various barriers against accidents, and accident precursors that may be quantified and monitored through incident experience.

A separate influence model (IRP…2005) is used to represent more diffuse factors such as the nature of the operating environment and the quality of safety management, human performance and safety equipment.

This influence model (IRP…2005) is the same for all accident categories, and hence represents common causes underlying the barrier failures, as well as factors too diffuse to model in a fault tree.

The model is quantified using accident and incident data, with corrections for recent trends, so as to obtain a risk picture that is fully consistent with accident experience.

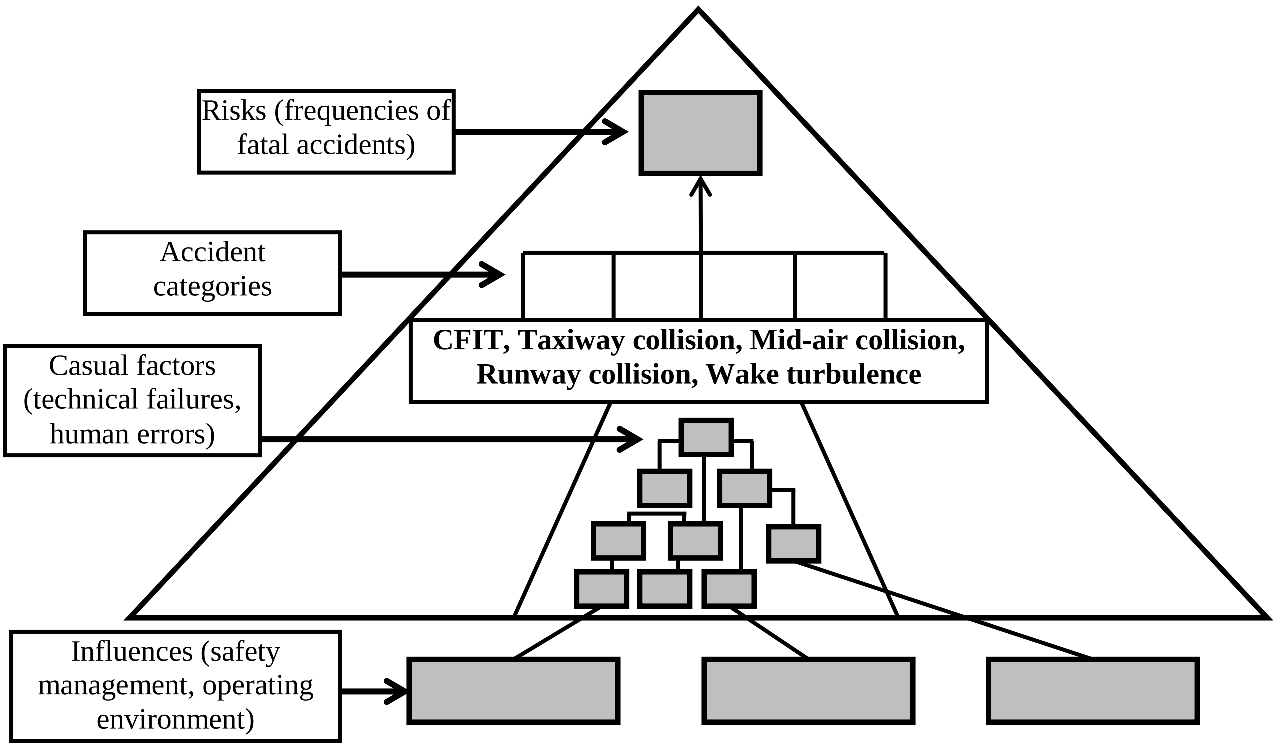


**Fig. 1.** Overall ATM risk model structure

In order to obtain the risk picture for 2012, a set of ATM changes is defined, which are expected to be in place by 2012. Each ATM change is represented through judgemental adjustments to the base events and influences in the risk model.

Their modelled effects, and the effects of changes in traffic levels, are then summed to estimate the total risks and causal breakdown for 2012. The effects of positive and negative interactions between improvements are also modelled as far as possible.

The IRP is the output of a “risk model”, representing the risks of aviation accidents, with particular emphasis on ATM contributions. In order to ensure that the risk model reflects ATM as it develops in the future, the risk model is founded on an “ATM model”, describing the ATM system whose risks are to be modelled (Fig. 2).

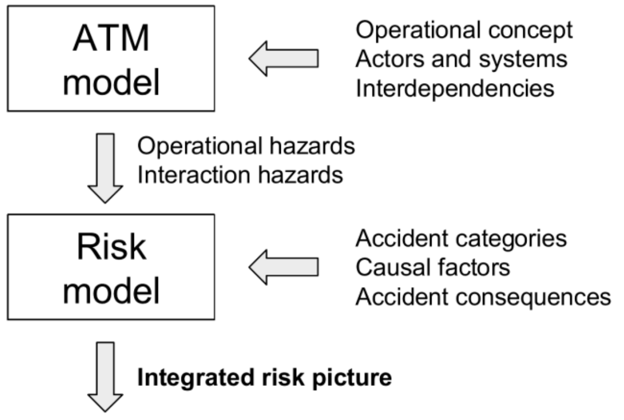


**Fig. 2.** Modelling approach

The key features of the two models are as follows:

– The *ATM model* represents the operational concept for commercial aviation, i.e. the way in which different actors and systems (particularly within ATM) work together. This is a very simplified description, representing the interdependent nature of modern aviation in a form that is optimised for development of the risk model. It covers the generic types of operations in the main European states, rather than the details of all current national variations;

– The risk model represents the way in which different causal factors (human, procedural and equipment failures, including failures of safety nets) combine to result in aviation accidents. Its output is the required risk picture.

The links between the ATM and risk models are “hazards”, i.e. potential errors or failures that might form or contribute to accidents.

## 4. ATM model

The ATM model represents the ATM system in diagrammatic form, in order to support the risk model. Its objectives are (Main Report…2006):

– To define the major ATM elements (tasks, actors and systems), which are represented in the risk model;

– To represent the concept of operations, i.e. the way in which different actors and systems work together within ATM;

– To identify potential interdependencies due to the use of common information sources, which should be represented in the risk model.

The model uses the Structured Analysis and Design Technique (SADT) notation. For each task (or functional element) of the ATM system, the model shows the necessary inputs and outputs, while also highlighting the required resources (actors and systems) and applicable constraints (Fig. 3). This is sufficient to define the main actors and systems involved in ATM, and to identify information flows between them, so that interdependencies can be identified and so that it is clear whether or not they are represented in the risk model.

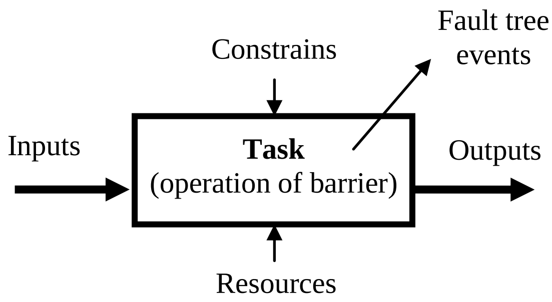


**Fig. 3.** Generic ATM model

The main components of ATM are:

– *Airspace Organisation and Management* (AO&M). This involves the structuring of airspace to accommodate different types of air activity and volumes of traffic;

– *Air Traffic Flow and Capacity Management* (ATFCM). This involves making optimum use of ATC capacity and restricting traffic flow to match the available capacity;

– *Air Traffic Control* (ATC). This involves maintaining a safe, orderly and efficient flow of traffic. It includes the infrastructure for communications, navigations and surveillance;

– *Airport operations*. This involves traffic management and safety processes on or in the vicinity of airports;

– *Aircraft operations*. This involves the activities within the aircraft, whether in response to ATC or on the flight crew's own authority;

– *Information management*. This covers flight plans, and the provision of meteorological and aeronautical information.

## 5. Fault tree model

The fault tree model represents causal factors, i.e. events or circumstances that could combine to cause the top event. Fault trees are suitable for causal factors that are (Main Report…2006):

– Distinct, i.e. can be clearly distinguished from other causal factors;

– Binary, i.e. only exhibit two distinct states – e.g. failed/working, correct/erroneous, adequate/ inadequate etc.;

– Independent, i.e. can change without changing other causal factors (except those directly above or below them in the tree, or linked through common cause failures);

– Either necessary (for factors combined through AND gates) or sufficient (for factors combined through OR gates) to cause the event above them in the tree.

In principle, a fault tree should only represent causal factors that satisfy all the above criteria.

In practice, the definitions of causal factors for the fault trees can be chosen to meet these criteria as far as possible. The underlying influences of human, technical system and management performance, which are more diffuse and interdependent, are represented through the influence model.

The top event in the fault tree is a fatal accident. At the first level of decomposition, this is split into fatal accidents in each of 5 accident categories (Fig. 1). There is a separate fault tree for each accident category.

The remaining structure of the fault tree is determined by sequences of accident precursors and barrier failures, as illustrated in Fig. 4.

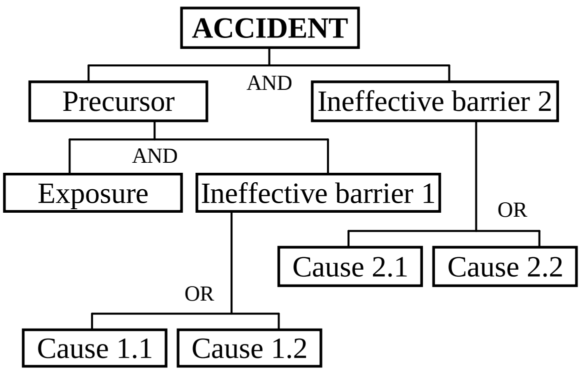


**Fig. 4.** Schematic fault tree structure

Accidents may arise from several different scenarios, which are specific sequences of precursors and barrier failures.

The base events are the most detailed causal factors that are appropriate for modelling through the fault tree technique, according to the criteria above. In most cases, base events are the causes of barrier failures.

The fault tree makes use of two main types of logic gates:

– OR gates represent the alternative causes of failure of any one barrier;

– AND gates represent the combination of failures of different barriers, necessary to produce the top event.

In general, events are conditional on the occurrence of all prior failures in the barrier failure sequence. As far as possible, the fault tree is arranged so that any sequences of prior events proceed from left to right, with the earliest precursors on the extreme left and the last barrier failures on the extreme right.

## 6. Form of results

The following types of results are available from the model (Main Report…2006):

– *Frequencies of fatal accidents*. The fatal accident frequency is the top event of the fault tree, and the best measure of overall risk available from the IRP. The fatal accident frequency for individual modelled accident categories may be more appropriate in some cases;

– *Frequencies of ICAO-defined accidents*. The ICAO definition of accidents includes not only fatal accidents but also accidents causing serious injury or damage to the aircraft requiring major repair. In each modelled accident category, a precursor event is defined that is equivalent to an ICAO-defined accident, so that the frequency of ICAO-defined accidents can be obtained;

– *Frequencies of accident precursors*. In each modelled accident category, a sequence of precursor events is defined, whose frequencies may be used as a benchmark for monitoring safety performance in specific situations (airports, sectors, airlines etc);

– *Probabilities of barrier failures*. In each modelled accident category, the reliability of various barriers is defined, which (once the IRP is calibrated to a target-compliant future case) may be used as safety objectives for safety cases of the corresponding systems;

– *Causal contributions*, i.e. the relative importance of the causal factors (base events and influences) to the overall risk. This is the main type of result available from the IRP, indicating how much the fatal accident frequency may changes in response to changes in the causal factors.

## 7. Conclusions

The IRP delivers results in the form of overall risks and causal breakdowns. The main risk metric is the frequency of fatal accidents in each modelled category, but the frequencies of precursor incidents and the reliabilities of modelled barriers are also available. The metric for the causal breakdown is the "contribution" (i.e. relative importance) to the fatal accident frequency arising from each causal factor and influence.

The model is implemented in a spreadsheet, which quantifies the fault trees and influence models, and presents the risks and causal breakdown, based on defined user inputs.

The model is also capable of predicting the risks and causal breakdown for any specific situation (airport, flight, ATC sector) represented through the user inputs, although these predictions have not yet been validated.

The following improvements in the methodology are recommended for future work:

– Modelling other accident categories (e.g. loss of control, landing accidents) and scenarios (e.g. runway incursion of vehicles), to which ATM may contribute. At present these are neglected;

– Risk weighting of the accident categories. At present, all fatal accident involvements are considered equivalent, although some types (e.g. mid-air collisions) may be more likely to result in multiple fatalities than others (e.g. taxi collisions);

– Explicit analysis of accident frequencies on turboprops, small Western jets and Eastern built jets. At present these are assumed to have accident frequencies the same as the basic dataset, which was large Western jets;

– Modelling the influences of operating environment. At present, only major environmental factors such as visibility and terrain are modelled in the fault tree, and more diffuse influences are neglected;

– Modelling the maturity of safety management. At present, the average performance score for influences is set at 70, but this could be altered 50 to match the average safety management maturity score;

– Modelling the effects of safety management. At present, user inputs on safety management quality are used as a simple control on pilot and controller performance, but the specific influences of safety management systems on actor and equipment performance are not modelled;

– Analysis of precursor data. At present, the risk model uses "AIRPROX" and runway incursion data. It would be desirable to make use of more extensive ATC, airport or airline incident data;

– Analysis of exposure and conflict data, to improve the modelling of the positive aspects of ATM safety prior to occurrence of incidents and accidents. At present these aspects are represented only in an approximate way;

– Modelling case-specific risks. In principle, the risk model is capable of modelling specific cases such as flights, sectors, airports etc. It would be desirable for the assumptions underlying this modelling to be validated through a series of case studies.

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Received 8 November 2012.

**В.П. Харченко[1], Ю.В. Чинченко[2]. Методологія комплексного дослідження ризиків в системі організації повітряного руху в Європі**
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Проаналізовано методологію комплексного дослідження ризиків. Розглянуто переваги концепції, експлуатаційну документацію та потенційних користувачів методології комплексного дослідження ризиків. Показано вплив принципів впровадження методології на систему організації повітряного руху. Запропоновано загальні рекомендації, що можна використовувати в умовах аеронавігаційної системи України.

**Ключові слова:** безпека польотів, європейська програма організації повітряного руху, методологія комплексного дослідження ризиків, моделі ризиків, організація повітряного руху, оцінка ризиків, техніки моделювання ризиків в авіації.

**В.П. Харченко[1], Ю.В. Чинченко[2]. Методология комплексного исследования рисков в системе организации воздушного движения в Европе**
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Проанализирована методология комплексного исследования рисков. Рассмотрены преимущества концепции, эксплуатационная документация и потенциальные пользователи методологии комплексного исследования рисков. Показано влияние принципов внедрения методологии на систему организации воздушного движения. Предложены общие рекомендации, которые можно использовать в условиях аэронавигационной системы Украины.

**Ключевые слова:** безопасность полетов, европейская программа организации воздушного движения, методология комплексного исследования рисков, модели рисков, организация воздушного движения, оценка рисков, техники моделирования рисков в авиации.

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