



**ASSEMBLY — 39TH SESSION**

**TECHNICAL COMMISSION**

**Agenda Item 33: Aviation safety and air navigation monitoring and analysis**

**RISK MANAGEMENT IN AVIATION SAFETY (RIMAS)**

(Presented by Spain)

**EXECUTIVE SUMMARY**

It is somewhat surprising that while aviation remains one of the most advanced means of transportation, technology wise, the industry and regulators have implemented very scarcely modern decision analysis methodologies in this area.

The Spanish Aviation Safety and Security Agency (AESA) has developed an evidence-based framework called RIMAS to support safety risk management decisions at State level, taking advantage of safety data infrastructures available.

The framework builds forecasting models for ninety types of aviation occurrences, including not only forecasting models for the number of occurrences and their severities (ICAO scale 1-5), but also forecasting models for eight relevant consequences (deaths, minor and major injuries, delays, maintenance costs, destruction costs, cancellation costs and image costs). Additionally, the framework includes an evaluation model of such consequences based on a multi-attribute utility function.

AESA uses such information to monitor aviation safety, screen occurrences and properly allocate safety resources with an optimization model.

We discuss here the application of RIMAS in supporting the development of a State Safety Programme.

<i>Strategic Objectives:</i>	This working paper relates to the Safety Strategic Objective.
<i>Financial implications:</i>	N/A
<i>References:</i>	Annex 19 — <i>Safety Management (Second Edition)</i> L. Cox, <i>What's wrong with risk matrices?</i>

<sup>1</sup> English and Spanish versions provided by Spain.

## 1. INTRODUCTION

1.1 The total elimination of aviation accidents and serious incidents is a desirable goal, but is clearly unachievable. The idea of risk-free systems has evolved in recent years towards a perspective focused around safety risk management, aimed at supporting resource allocation processes in which a balance between “production” and “protection” is attained. In this context, ICAO defines safety as “*the state in which risks associated with aviation activities, related to, or in direct support of the operation of aircraft, are reduced and controlled to an acceptable level.*”

1.2 As required by ICAO, States must implement and develop a so-called State Safety Programme (SSP) to apply a preventive approach for aviation safety oversight and safety risk management at a State level. The SSP aims at supporting strategic decision-making in adopting better decisions when allocating limited resources to areas of greater safety concern or need.

1.3 ICAO Annex 19 establishes that States, as part of their safety management responsibilities, shall develop and maintain a process that ensures the assessment of safety risks associated with identified hazards (3.3.4.2) and should develop and maintain a process to manage safety risks (3.3.5.2). Based on such SSP processes, States may make better decisions in an uncertain environment in relation with aviation safety risks.

1.4 When the Spanish Aviation Safety and Security Agency (AESA) started implementing such processes as part of Spain’s State Safety Program (SSP), its staff realized that standard state-of-the-art safety risk evaluation techniques within the civil aviation domain, were far from being based on sound scientific quantitative risk evaluation procedures, the emphasis being on risk matrix based methods and various qualitative approaches. Therefore, AESA decided to collaborate with the Spanish Royal Academy of Sciences to develop a more robust and rigorous methodology, that supported their safety risk management decision processes. This methodology is called RIMAS (Risk Management in Aviation Safety).

1.5 RIMAS is a new methodology with full use of numerous Operations Research methods, including Decision Analysis, Risk Analysis, Simulation, Bayesian Statistics, and Optimization, and implemented in a tool (in R! Language) that has allowed AESA to better support its safety decision making and to use resources more efficiently in a number of areas.

## 2. DISCUSSION

2.1 RIMAS is a novel and systematic methodology for risk management in aviation safety, based on the principles of decision and risk analysis. The RIMAS project was divided in different parts, all of them related with the use of better decision support methodologies, when carrying out the processes corresponding to the SSP. RIMAS encompasses: models to predict the occurrences and their severity classes; models to predict and assess occurrence consequences; risk maps to screen occurrences; and, finally, a procedure for safety management resource allocation.

2.2 Despite the high safety level in the aviation industry, occurrences continue to emerge. Specifically, in RIMAS case, 90 different occurrence types were considered, ranging from bird strike to runway excursion, going through engine failure. Five occurrence classes were used depending on their severity: Accident (1); Serious Incident (2); Major Incident (3); Significant Incident (4); and Occurrence without safety effect (5). Additionally, safety occurrences entail consequences. Each State must examine those of interest to them for safety risk management purposes. In our case, after a brainstorming process

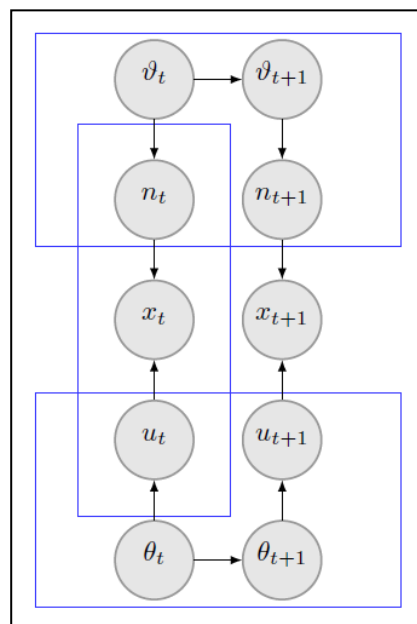
and a literature review, we decided to focus on the following eight consequences identified as most relevant in aviation safety risk management at state level: 1. Fatalities associated with the functioning of the aviation system; 2. Minor wounded persons associated with the functioning of the aviation system; 3. Severe wounded persons; 4. Delays caused by safety occurrences; 5. Cancellations caused by safety occurrences; 6. Maintenance and repair operations produced by safety occurrences; 7. Destroyed aircrafts; and, 8. Image loss due to negative perception of occurrences.

2.3 Given the current configuration of the aviation system, and taking as a starting point the current level of aviation safety, a change in the resources allocated by the State to different types of occurrences may have a global impact over such level of aviation safety by means of changes produced on the distribution of:

- the occurrence rates, aiming at making them smaller and, therefore, making occurrences less frequent;
- the proportions of occurrence severities, in an attempt to make the more severe occurrences less likely; or
- the consequences, reducing the associated impacts, if these were to occur.

The final aim is to minimise the total expected loss -cost (see paragraph 2.6) associated with the SSP resource allocation strategy. That is to say, to minimise the aggregation of consequences associated to occurrences by means of reducing occurrences, their severity or their related impacts.

2.4 *Predicting the number of occurrences.* RIMAS implements a class of models in which both the number of operations (n) and the occurrence rate (u) may evolve dynamically. For such purpose, we combine, in a novel way, several standard models. Specifically, we use a Dynamic Linear Model (DLM), to predict the number of operations (upper block); a Poisson model to predict the number of occurrences (x) given the rate and number of operations (midblock); and, finally, a DLM to predict the evolution of the occurrence rate (lower block). With this class of models, we are able to deal with the effects we have found in the evolution of rates for all occurrence types, mainly the possible presence of seasonal and trend components.



2.5 *Prediction of occurrence classes.* Conditional on the number  $x_t$  of occurrences, we must also predict the corresponding occurrence classes (severities) which, as mentioned in Section 2.2, are five. For forecasting occurrence classes, we used the following multinomial-Dirichlet model, assuming that the data  $D_t$  available until the beginning of the  $t$ -th period are  $((s^1_1, s^2_1, \dots, s^5_1), \dots, (s^1_{t-1}, s^2_{t-1}, \dots, s^5_{t-1}))$ , and where  $s^j_i$  represents the number of occurrences of class  $i$ ,  $i \in \{1, 2, 3, 4, 5\}$ , in period  $j$ ,  $j \in \{1, \dots, t-1\}$ :

$$p|D_t \sim \text{Dir} \left( \alpha_1 + \sum_{i=1}^{t-1} s^1_i, \dots, \alpha_5 + \sum_{i=1}^{t-1} s^5_i \right)$$

2.6 *Prediction of consequences and Loss function.* We also must evaluate the consequences of various types and classes of incidents. We introduced a multiattribute utility function over eight identified consequences (see Section 2.2) and assessed it for all cases, together with a methodology to update it, as consequence data accumulated. RIMAS predicts the eight consequences for the different types of occurrences and five severity classes. The kind of issues we need to address is, for example, assuming that there has been a bird strike occurrence of severity 2, forecast the number of minor injuries produced. In some cases, we will need to make a distinction between the types of aircraft involved (*i.e.* general aviation, aerial works, or business aviation; regional flights; continental flights; intercontinental flights) to predict more accurately the number of minor injuries. From these models, by aggregation, we can obtain the distribution of the consequences associated with a suggested Aviation Safety Action Plan. We use the concepts of measurable multi-attribute value function (cost) and relative risk aversion to obtain a *-Loss function*. First, we aggregate the consequences through a measurable value function and we then assume that the regulator has constant risk aversion, with respect to such value function.

2.7 *Safety mapping and occurrence screening.* Based on our forecasting and consequence models, RIMAS uses simulation techniques to provide safety maps for all aviation occurrence types, as well as a methodology for occurrence screening. A first use of RIMAS models allows for the screening of occurrences on which to focus the greatest efforts in safety risk management. To avoid some of the problems associated with risk matrices<sup>2</sup>, RIMAS uses risk maps in which the X axis refers to the likelihood of aviation occurrences and the Y axis conveys consequences associated with such occurrences. However, as risk matrices are somewhat of a standard in aviation safety, we developed a method to transform a risk map into a risk matrix for communication purposes with other aviation agencies. Based on the map, we draw cells to separate the occurrences taking into consideration cut-off points for losses and frequencies proposed by the problem owner. We later adjust the levels so that they are equidistant, according to the definition of risk matrices, achieved through simple affine transformations. Finally, we specify the colours of cells, according to the standard proposed by ICAO.

2.8 *Safety resource allocation.* RIMAS presents two versions of the general model: a) stochastic (using Monte Carlo simulation techniques); and b) deterministic (based on the expected values of the relevant random variables), to be implemented depending on the level of accuracy required and the available computational resources.

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<sup>2</sup> L. Cox, *What's wrong with risk matrices?*

### 3. CONCLUSION AND FUTURE CHALLENGES

3.1 In striking contrast with the technological sophistication achieved in the aviation system from the aeronautical engineering perspective, aviation safety risk management is pervaded by unsophisticated methods evolving around the concept of risk matrix, with its potential pitfalls. Spain has developed a methodology for safety risk management based on sound principles of risk and decision analysis.

3.2 As described, RIMAS is a truly ground-breaking approach to aviation safety risk management, based on the application of numerous Operations Research techniques and tools. Indeed, RIMAS allowed identifying and ranking the areas of greater aviation safety risk in Spain, and then to allocate resources, assigning them as aviation execution programs within the Aviation Safety Action Plan (ASAP). The Spanish Agency is now capable of better supporting their decisions and discussing them convincingly with the numerous stakeholders involved (air carriers, traffic controllers, pilots, airport service providers, other national aviation safety agencies, to name but a few). Its practical implementation has been facilitated by an R! tool supporting all the phases of the RIMAS methodology.

3.3 As part of its SSP, each State shall require that the aviation service providers under its authority implement a Safety Management System (SMS). SMS main processes –safety risk management and safety assurance– are similar to the SSP processes implemented at State level. Thus, the techniques used in this project might be launched under the Safety Management Systems framework at the aviation industry level. This will allow exciting possibilities for service and product providers in the areas of safety risk assessment, safety risk control, and decision-making within the aviation sector.

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