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Overall safety performance of Air Traffic Management system: Forecasting and monitoring

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ABSTRACT

Defining means to assess safety performance and delve into their causes is one of the current and future challenges of the air transport sector. This paper develops an improvement of the Air Traffic Management (ATM) safety evaluation in order to develop proactive safety indicators, based on Aerospace Performance Factor and Analytic Hierarchy Process. The research aims to carry out a statistical model of safety events in order to predict safety performance, combining in a Monte Carlo simulation the results emerged from the literature analysis with the analytical models of historic data interpretation. Through the analysis of the possible scenarios, assessing their impact on equipment, procedures and human factor, this model will address the interventions of the decision maker.

1. Introduction

Based on international regulations, ANSPs must plan a rugged and proactive process of addressing current and emerging safety risks, in order to ensure that air traffic development is carefully managed and supported through strategic regulatory and infrastructure development (ICAO, 2013).

Historically, ANSPs used basic metrics as traffic counts, number of accidents and incidents to gauge safety performances. Anyway, these standard indicators fail to represent effectively the overall safety perspective and do not constitute a system-wide performance measurement tool.

In October 2009, the EUROCONTROL Performance Review Commission (PRC) and the US Federal Aviation Administration (FAA) identified common information and performance indicators (EUROCONTROL and FAA, 2012) to monitor safety in each region. EUROCONTROL Safety Regulatory Requirements (ESARRs) proposed a standard occurrence reporting and assessment scheme. In particular, ESARR 2 Appendix A (and B) (EUROCONTROL, 2009) provides the minimum contextual/factual ATM related (and no-ATM related) to be collected and recorded for each safety occurrence.

The core idea of ESARRs is based upon Reason Swiss Cheese model, which relates a system's failure to an alignment of all the metaphoric barriers' weakness, permitting "a trajectory of accident opportunity", so that a hazard passes through all of the holes in all of the defences, leading to a failure (Reason, 1990; Stranks, 2007). Fig. 1 represents this core concept, according to a possible safety event.

In ATM context, for example, even when many things go wrong in case of a separation infringement between aircrafts, i.e. the situation is not recognized or resolved by ATC, pilots or TCAS, the aircraft still only have a small chance to hit each other, due to the fact that there is a lot of space in the sky. In other words, there will be many near midair collisions compared to the number of midair collisions, although the differences of these events may only be coincidence (the aircraft colliding in midair had exactly the wrong position and velocity with respect to each other). The difference between such a near midair collision and a midair collision might be therefore just be the lining up of the small hole in the last geometry slice of cheese. Note that other factors may cause the difference between a near collision and a collision, e.g. pilot adequately performs a good TCAS instruction.

Therefore, it is evident that the evaluation of global safety performance cannot disregard the contribution of any safety related event, especially the ones with smaller consequences. As less serious events happen more often, statistics based on their occurrences have more potential than accident statistics. Investigations of occurrences less serious than accidents might also be available more quickly. This concept leads to the metaphor of an iceberg where the most serious occurrences -accidents and serious

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incidents- constitute a small but visible subset of these occurrences, while, the "non-serious" incidents and other safety relevant events constitute a large subset of the iceberg, which however largely remain invisible (Reason et al., 2006). Both ESARR 2 (EUROCONTROL, 2009) and EU 2003/42/EC (2003) recognize the relevance of such occurrences.

2. Reactive safety: ATM safety indicators

FAA and US Naval Safety Center (Futron Corporation, 2010), with the contribution of EasyJet (Lintner et al., 2009), developed the Aerospace Performance Factor (APF), a methodology capable of combining different safety occurrences' counts in a single value.

The APF aggregates multiple operational safety risks, expressed as the weighted sum of incidents into one single indicator (a Safety Index) capable of showing macro changes in performance trends. Although this unique value gives the overall risk, according to the methodology, it can be broken down into its components to analyze specific causal factors.

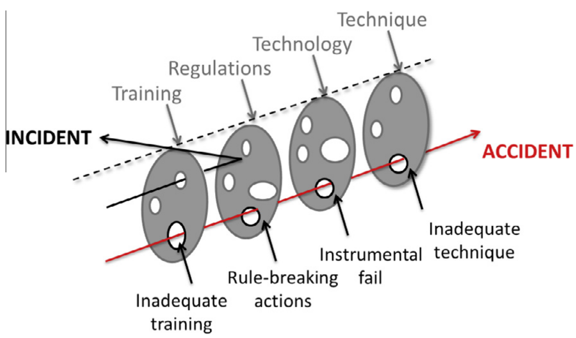

Fig. 1. Reason Swiss Cheese model's core idea.

Table 1
Safety Indexes' structure.

	Airport (APT)	En Route (ENR)
All events	Safety Index 1 APT	Safety Index 1 ENR
ATM contribution events	Safety Index 2 APT	Safety Index 2 ENR

The APF Safety Index building process relies on the Analytic Hierarchy Process (AHP), a multi-criteria decision making tool developed by Saaty in the early 1970s (Saaty, 2008).

In this research, the building process has specifically consisted in the linear combination of the weighted events, normalized by the traffic count as shown in Eqs. (1) and (2). The normalization has permitted comparisons of results that do not depend on the specific monthly movements but are gradable in a general context.

$$Event_i \text{ APF Safety Index} = \frac{Event_i \text{ annual count}}{\text{TOTAL traffic count}} Event_i \text{ AHP weight} \tag{1}$$

$$\text{APF Safety Index}_j = \sum_i^n Event_i \text{ APF Safety Index} \tag{2}$$

AHP has therefore made possible to integrate tangible events (data and quantitative measures) with intangibles (general indications, experiences, estimations, qualitative evaluations of experts) to create an effective safety monitoring system that could take into account both perceptions and events.

Di Gravio et al. (2014) used this mathematical development in order to define several different Safety Indexes, replicating ESARR 2 requirement of differentiating the flight phase (Airport, APT and En Route, ENR). They developed also a further partition, according to the ATM's role in the event (ATM contribution and No ATM contribution). Table 1 defines the different Safety Indexes, according to their features.

By way of example, Fig. 2 shows the structure of Safety Index 1 ENR that collects all the events regardless the contribution of ATM, highlighting also its main clusters. ESARR 2 Appendix A (EUROCONTROL, 2009) describes all the analyzed safety events, according to the HEIDI (Harmonization of European Incident Definitions Initiative for ATM) tool. Table 2 just summarizes the acronyms used in Fig. 1.

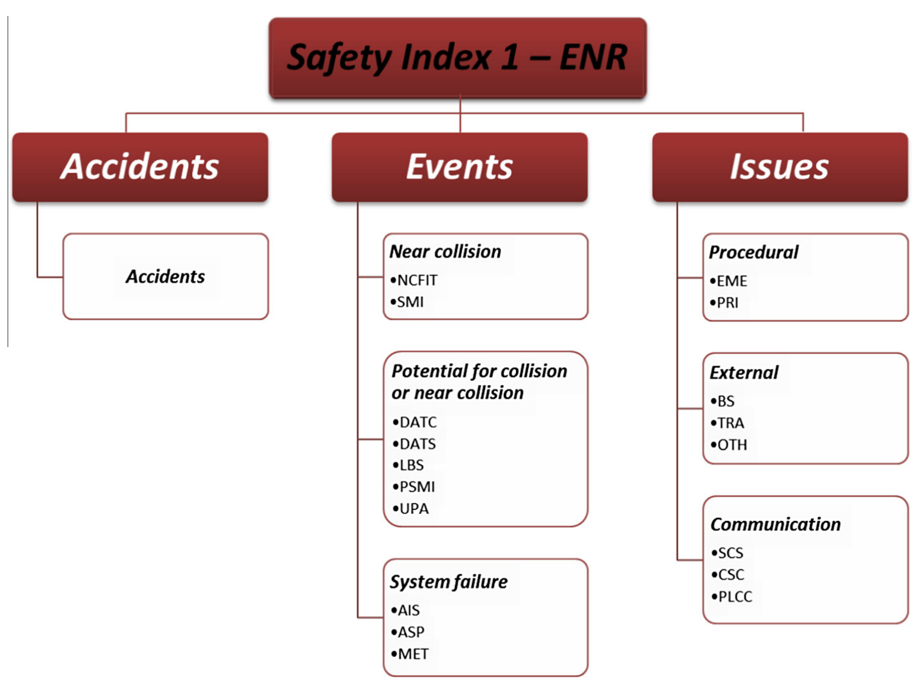

Fig. 2. Safety Index 1 ENR's structure.