Composite Risk Index (CRI) - methodology

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Background

This report has been commissioned by the Performance Review Commission (PRC).

The PRC was established in 1998 by the Permanent Commission of EUROCONTROL, in accordance with the ECAC Institutional Strategy (1997). One objective of this strategy is "*to introduce a strong, transparent and independent performance review and target setting system to facilitate more effective management of the European ATM system, encourage mutual accountability for system performance…*"

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Composite Risk Index - Methodology

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SUMMARY

This report demonstrates the utility of occurrence data to measure safety performance in Air Traffic Management.

The concept of a Composite Risk Index (CRI) that could measure the performance of European ATM systems as a whole or also its individual entities (service providers or Member States) is explained. In simple words, CRI presents a cumulative risk value calculated aggregating all reported, assessed and severity classified safety-related incidents to form an index. This measure of risk exposure is based on probability and severity that considers the human perception of equivalent risk.

The report describes the computation of the CRI, logic behind it, its use (on the example of risk exposure of all EUROCONTOL Member States), limitations and lastly areas of potential improvement.

Keywords

Safety Performance Indicator, Risk Index, Safety Performance, safety occurrence

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1 Introduction

As of 1997 and until now, the focus on safety performance within the Performance Review Commission (PRC) has been principally on safety occurrences statistics and safety studies of interest. However, in the light of changing political environment there was a need for the PRC to think about future of safety performance monitoring and how, if at all, can evolve especially in light of requirement to ensure that complementarity between the Performance Review Board (PRB) and PRC is satisfied to avoid any potential unnecessary duplication. Moreover, attention should also be paid to avoid duplication with other safety activities done in the context of the Performance Scheme and European Aviation Safety Agency (EASA) European Plan for Aviation Safety (EPAS) programme.

For this reason and considering the PRC mandate, its previous and current work and also changing institutional environment, it was necessary to assess and investigate what avenues could be explored by the PRC that would help ATM in Europe improve its safety performance.

Therefore, at PRC97, the first safety brainstorming session was organised to collect input from the PRC about the direction to go with regards to safety performance monitoring/review. In other words, what the PRC should and wants to achieve with respect to EUROCONTROL Safety Performance review.

Overall, most importantly, the PRC gave a clear message that safety performance monitoring shall remain as a constituent part of the EUROCONTROL Performance review and, consequently, the PRC shall include safety in its working programme.

At the PRC98 meeting, the PRU presented a discussion paper entitled “Safety Performance Monitoring in European ATM”. Its purpose was to explore the potential for new safety performance areas/indicators for inclusion in the PRC’s Work Programme, whilst ensuring complementarity with the work of the Performance Review Body of the EC and avoiding overlaps.

The PRC noted the paper and provided written comments which resulted in the paper that summarised potential future work in safety performance, gave overall assessment of each proposal and prioritisation of the work, based on maturity and timeframe required to deliver initial results.

One of the selected and prioritised areas of work selected by the PRC then was development of so-called Composite Risk Index (CRI).

This report represents development of the new safety performance indicator to report on the safety performance within the EUROCONTROL Member States area and also individual Member States. It describes the computation of the CRI, logic behind it, its use (on the example of risk exposure of all EUROCONTOL Member States) and limitations and lastly areas of potential improvement.

1.1 List of acronyms

Acronym	Definition
CRI / CRInorm	Composite Risk Index / Normalised CRI
EASA	European Aviation Safety Agency
OPS	Operational
PRC	Performance Review Commission
PRB	Performance Review Body
TECH	Technical

Table 1: List of acronyms used in the report

2 Composite Risk Index

2.1 Risk

Risk is the potential for mishaps or other adverse variation in the cost, schedule, or safety performance of ATM system. Safety risk therefore can be explained as the potential for mishaps that could result in injury, fatality, equipment or system damage or total loss.

Conceptually, all safety programmes desire accurate safety risk quantification in order to provide a meaningful expression of risk. As there are typically multiple safety risks associated with a system or event, the quantification of total safety risk is a major challenge.

One possible way to define and accept the total safety risk of any system is using the concept of a composite risk estimate. Current methods of obtaining this composite risk estimate use summing techniques to add the individual risks and produce a single number. This method seems natural, however, it is often difficult to determine particular occurrence probabilities or to quantify their severity. That makes the additive computation of risk difficult or impossible.

Moreover, although risk in general can be quantified, as it represents combination of probability and severity of specific occurrence happening, the human perception of risk often influences how risk is addressed. For example, on the level of decision makers the risk perception does not necessarily map directly to probability and severity in a linear fashion. That makes computation of total risk additionally difficult and subjective.

For all these reasons, the concept of a Composite Risk Index (CRI) that could measure the performance of European ATM systems as a whole or also its individual entities (service providers or Member States) is proposed. In simple words, CRI presents a cumulative risk value calculated aggregating all reported, assessed and severity classified safety-related incidents to form an index. This measure of risk exposure is based on probability and severity that considers the human perception of equivalent risk (Figure 1).

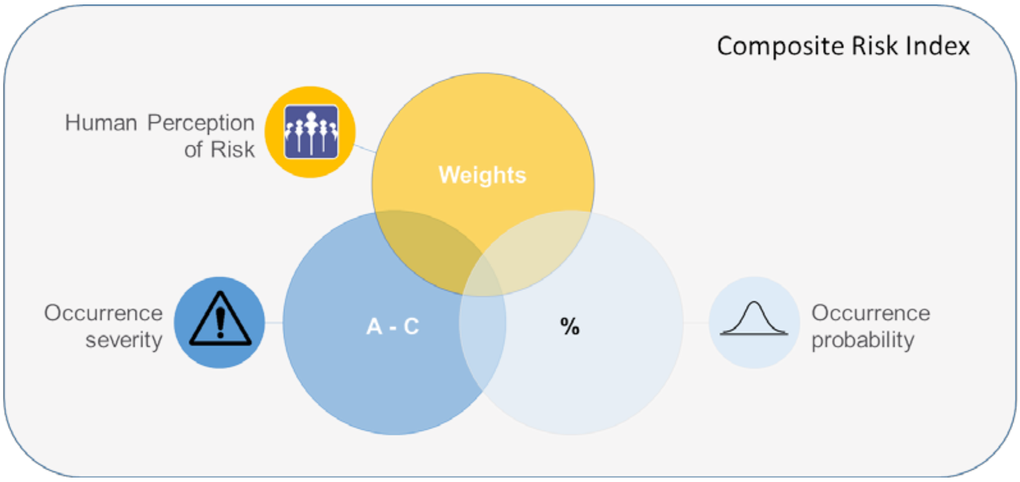

Figure 1: Composite Risk Index components

2.2 Data

In order to calculate composite risk, each historical, reported occurrence had to have assigned severity and probability. Safety information about reported events was acquired through EUROCONTOL Annual Summary Template (AST) reporting system.

The AST reporting mechanism captures information on Air Traffic Management (ATM) related occurrences, both ATM operational and technical occurrences. By definition, these ATM occurrences include:

- accidents;
- (serious) incidents:
  - Near collision (encompassing specific situations where one aircraft and another aircraft/the ground/a vehicle/person or object is perceived to be too close to each other):
  - Potential for collision or near collision (encompassing specific situations having the potential to be an accident or near collision, if another aircraft is in the vicinity).
- altitude deviations reported within the EUR RVSM airspace (above FL285);
- ATM-specific occurrences (encompassing those situations where the ability to provide safe ATM services is affected, including situations where, by chance, the safe operations of aircraft has not been jeopardised);
- Other defects or malfunctioning of an aircraft, its equipment and any element of the Air Navigation System which is used, or intended to be used, for the purpose or in connection with the operation of an aircraft, or with the provision of an air traffic management service or navigational aid to an aircraft.

The safety data, related to the reported occurrences in the AST, included occurrence category (accident or incident) and its severity reported by the States and calculated using severity classification risk assessment methodology (RAT).

For modelling of Weights and CRI methodology development, AST data are provided by EUROCONTROL AST Team for period 2015-2017.

Nevertheless, it has to be noted that modelling of Weights can be customised additionally to local environment, it can be performed using different source of safety occurrences data, as long as the input satisfies the minimum data requirements

2.2.1 Severity definitions

The classification scheme for safety occurrences in ATM specifies six severity categories for ATM related occurrences impacting the safe operations of the aircraft. They are as follows:

- Accident,
- Serious Incident (AA / A),
- Major incident (B),
- Significant incident (C),
- Not determined (D),
- No safety effect (E)

2.2.2 Frequency definitions

The RAT classification scheme specifies five qualitative frequency categories (repeatability). However, as these values are not commonly reported through the AST. Moreover, each State in principle should develop their own quantitative boundaries, which should consider national traffic volumes and specific operating conditions of the national ATM system. However, these values were not available.

Therefore, the occurrence probability was calculated using historical data from the past three years separately for each State in order to simulate/take into consideration local conditions.

2.3 Methodology

As a proxy of safety risk within certain airspace or a State, the concept of exposure to risk, based on reported / historical safety information was proposed. This *Composite Risk Index* (CRI) presents a cumulative risk value calculated aggregating all reported, assessed and severity classified safety-related incidents to form an index.

At the preliminary stage of development, for the purpose of this feasibility study, it was decided to base CRI calculations on (Figure 2):

- Accidents,
- Operation occurrences (high/medium risk incidents with Severity A to C):
    - runway incursions,
    - separation minima infringements,
    - unauthorized penetrations of airspace,
- Other operational occurrences;
- Technical occurrences (high/medium risk incidents with Severity AA/A to C).

Lastly, to take into account the local conditions within each Entity, the total number of flight hours within each State were used as an additional input (CRI normalised results).

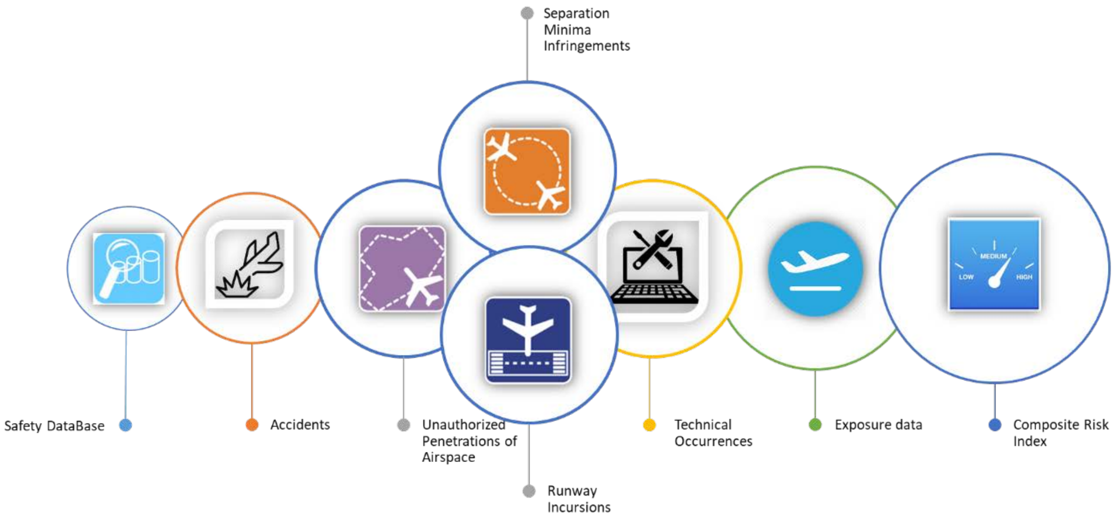

Figure 2: Data input for calculation of CRI

2.3.1 Occurrences with no severity classification

All severity unclassified/not assessed events (Severity Category D) were distributed into groups A to E (Figure 3), based on historical distribution (determined using the last three years of AST data).

The probability of occurrence being assigned to specific severity category was calculated using historical data, separately for each State in order to simulate/take into consideration local conditions.

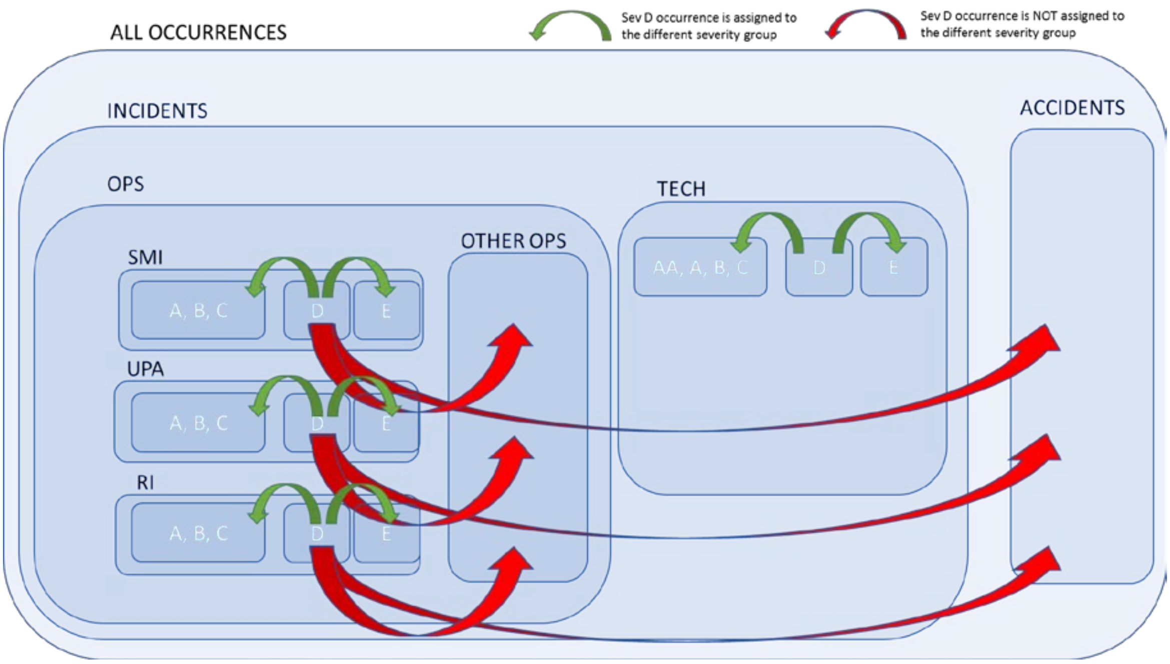

Figure 3: Severity D distribution into other severity groups

2.3.2 Estimated numbers of occurrences

The formula how the numbers of occurrences of specific type were estimated is presented below.

$$No\_occ\_est_i = \left((No\_D_i * P_i) + No\_occ_i\right)$$

$No\_occ\_est_i$ *– estimated number of safety occurrence type i*

No_D_i *– number of reported occurrences of Severity Classification D (not determined) for occurrence type i*

P_i *– probability of safety occurrence type i*

No_occ_i *- number of reported safety occurrences of type i*

Probability of each type of occurrence was calculated suing simple principle:

$$P_i = \frac{No_{occ_i}}{Total\ No_{occ_i}}$$

No_{occ_i}*– number of reported safety occurrences type i in a year*
$Total\ No_{occ_i}$ *- total number of reported safety occurrences type i in a group in all years*

2.3.3 CRI calculation using human perception of risk

Using estimated number of occurrences and adding human perception of their risk it was possible to calculate CRI[1] for each EUROCONTROL Member State separately. The simple formula to calculate CRI is presented below.

$$CRI_i = No_{occ\_est\_i} * w_i$$

$$CRI = \sum_i \frac{CRI_i}{Total\ N_{occ}}$$

CRI_i – CRI index for occurrence type i

W_i – weight (based on severity and human perception) assigned to specific type of safety occurrence

$Total\ N_{occ}$ – total number of all occurrences in a year

In the formula above *Weights* added to each equation represent additional human perception of risk for specific event, introduced so that CRI can at the end consider the human perception of equivalent risk.

Accepted methods of quantifying severity include monetary amounts. However, although expressing severity in terms of cost establishes consistency, it is still difficult to put an amount on human life or injuries, or failure or loss of certain functionalities of the system. Furthermore, perception of what constitutes "high" risk may vary from entity to entity and State to State.

Therefore, introduction of Weights to express severity of event allows their description in non-monetary terms which have meaningful and easy understandable explanation in human perception.

Each weight value for specific Severity category was determined using optimisation technique, with the aim to select combination of weights that will not disturb the computation of the CRI from year to year if significant changes in reporting are introduced. In other words, find which combination of weights result in the lowest standard deviation of CRI values between the years for each State.

Due to a large number of variables involved and enormous number of combination possible, optimisation and selection of Weights was done in several stages:

1. Selection of Weights for accident, all OPS occurrences and TECH occurrences;
2. Selection of Weights for OPS occurrences based on their type (RI, SMI, UPA, OTHER), taking into consideration overall OPS Weight determined in Step 1;
3. Selection of Weights for OPS and TECH occurrences based on their severity (AA/A, B, C), taking into consideration overall OPS Weight determined in Step 2.

In addition, each type of weight selection had predefined weight ranges, to allow for incremental Severity classification order based on human perception of risk (from accident to Severity C incident, i.e. from high risk to low risk). In other words, each range has an expectation value associated with it.

[1] Note that CRI can be calculated for any given entity, provider or the State.

The following ranges for selection of weights in different steps are presented below:

- Base Weights selection:
  - w_acc <- (0.5, 0.7)
  - w_ops <- (0.3, 0.5)
  - w_tech <- (0.05, 0.4)
- Occurrence type Weights selection:
  - w_ops_upa = (0.15 * w_ops, 0.25 * w_ops)
  - w_ops_smi = (0.4 * w_ops, 0.55 * w_ops)
  - w_ops_ri = (0.25 * w_ops, 0.35 * w_ops)
  - w_ops_other = (0.05 * w_ops, 0.1 * w_ops)
- Occurrence severity Weights selection:
  - w_ops_ri_a <- (0.3 * w_ops_ri, 0.7 * w_ops_ri)
  - w_ops_ri_b <- (0.1 * w_ops_ri, 0.5 * w_ops_ri)
  - w_ops_ri_c <- (0.05 * w_ops_ri, 0.3 * w_ops_ri)
  - w_ops_upa_a <- (0.3 * w_ops_upa, 0.7 * w_ops_upa)
  - w_ops_upa_b <- (0.1 * w_ops_upa, 0.5 * w_ops_upa)
  - w_ops_upa_c <- (0.05 * w_ops_upa, 0.3 * w_ops_upa)
  - w_ops_smi_a <- (0.3 * w_ops_smi, 0.7 * w_ops_smi)
  - w_ops_smi_b <- (0.1 * w_ops_smi, 0.5 * w_ops_smi)
  - w_ops_smi_c <- (0.05 * w_ops_smi, 0.3 * w_ops_smi)
  - w_tech_aa <- (0.4 * w_tech, 0.5 * w_tech)
  - w_tech_a <- (0.3 * w_tech, 0.4 * w_tech)
  - w_tech_b <- (0.1 * w_tech, 0.3 * w_tech)
  - w_tech_c <- (0.04 * w_tech, 0.08 * w_tech)

Optimisation results indicate that, for this setup, the best combination of Weights are as follows (Table 2):

Type of occurrence	Weight index	Value
Weight for accident	w_acc	0.5242424
Weight for OPS incident	w_ops	0.3
Weight for TECH incident	w_tech	0.1757576
Weight for RI incident	w_ops_ri	0.1043878
Weight for SMI incident	w_ops_smi	0.1209184
Weight for UPA incident	w_ops_upa	0.045
Weight for OTHER OPS incident	w_ops_other	0.02969388
Weight for serious RI incident (A)	w_ops_ri_a	0.05668652
Weight for major RI incident (B)	w_ops_ri_b	0.0422189
Weight for significant RI incident (C)	w_ops_ri_c	0.005482339
Weight for serious SMI incident (A)	w_ops_smi_a	0.06336735
Weight for major SMI incident (B)	w_ops_smi_b	0.0515051
Weight for significant SMI incident (C)	w_ops_smi_c	0.006045918
Weight for serious UPA incident (A)	w_ops_upa_a	0.0225
Weight for major UPA incident (B)	w_ops_upa_b	0.01486025
Weight for significant UPA incident (C)	w_ops_upa_c	0.007639747
Weight for serious TECH incident (AA)	w_tech_aa	0.07955343
Weight for serious TECH incident (A)	w_tech_a	0.06921148
Weight for major TECH incident (B)	w_tech_b	0.01941659
Weight for significant TECH incident (C)	w_tech_c	0.007576077

Table 2: Weights based on severity and human perception

Finally, to allow applicability of CRI to airspaces with different traffic levels, the CRI was normalised by flight hours for each State. The CRInorm was calculated based on the following formula:

$$CRInorm = \frac{CRI}{Number\ of\ Flight\ Hours}$$

3 Preliminary Results

Using methodology described in previous section, the CRI for all EUROCONTROL Member States for 2017 (for which data was available, 39 Member States) is calculated and shown at Figure 4.

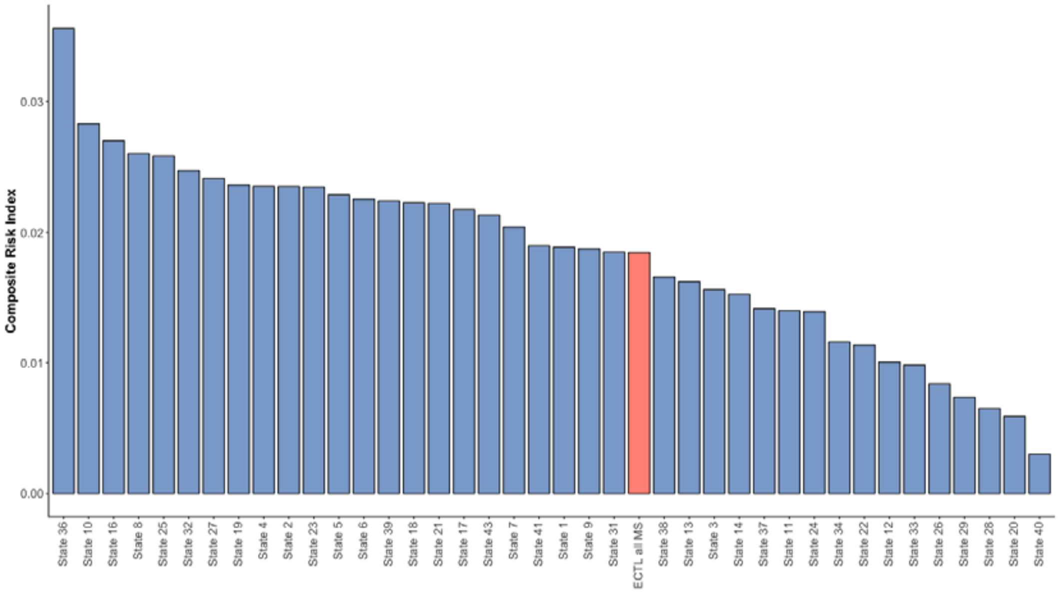

Figure 4: CRI in EUROCONTROL Member States (2017)

From the Figure 5 it can be seen that approximately half of the EUROCONTROL Member States has higher risk exposure in comparison to EUROCONTROL average. Nevertheless, this calculation did not take into account the local conditions. Therefore, CRInorm was calculated, taking into account the total number of flight hours within each State. Figure 5 shows the exposure to risk in 2017 using normalised CRI.

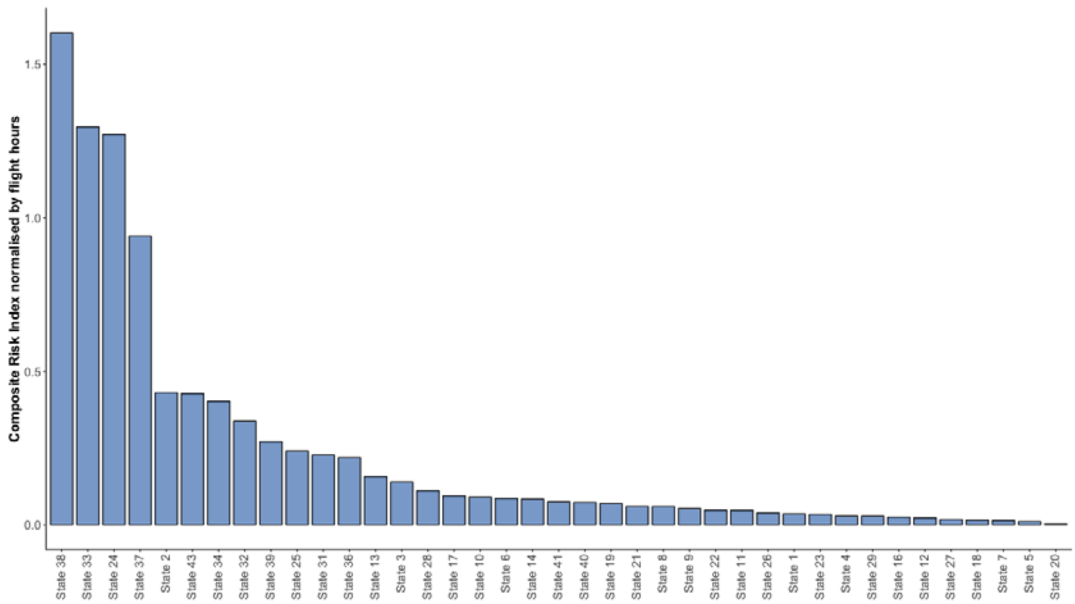

Figure 5: CRI normalised by flight hours in EUROCONTROL Member States (2017)

The further analysis of 2017 CRInorm results indicates that over 75% of EUROCONTROL Member States have CRInorm below 0.25 (Figure 6). With only four States having higher CRInorm (above 0.5)

One possible reason for this positive result could be that this is somehow related to the reporting culture of the State. Therefore, CRI normalised was also correlated with the total number of reports reported by each State. Figure 7 shows that the States with a good reporting culture (red dots - total number of reports) tend to have a low CRInorm (bars).

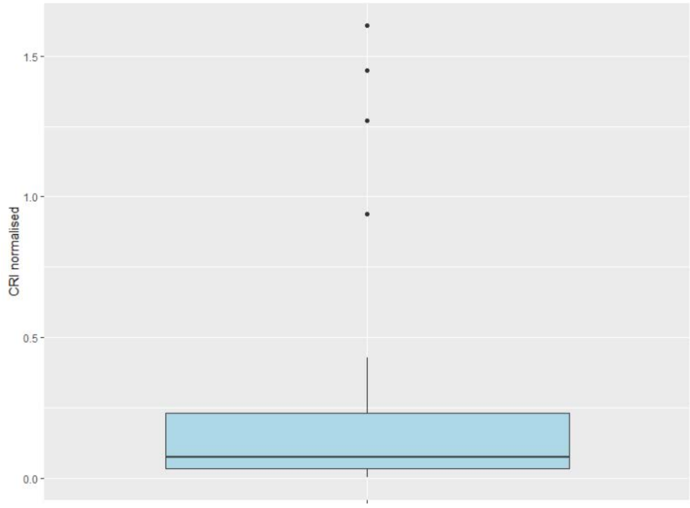

Figure 6: Boxplot of CRInorm 2017

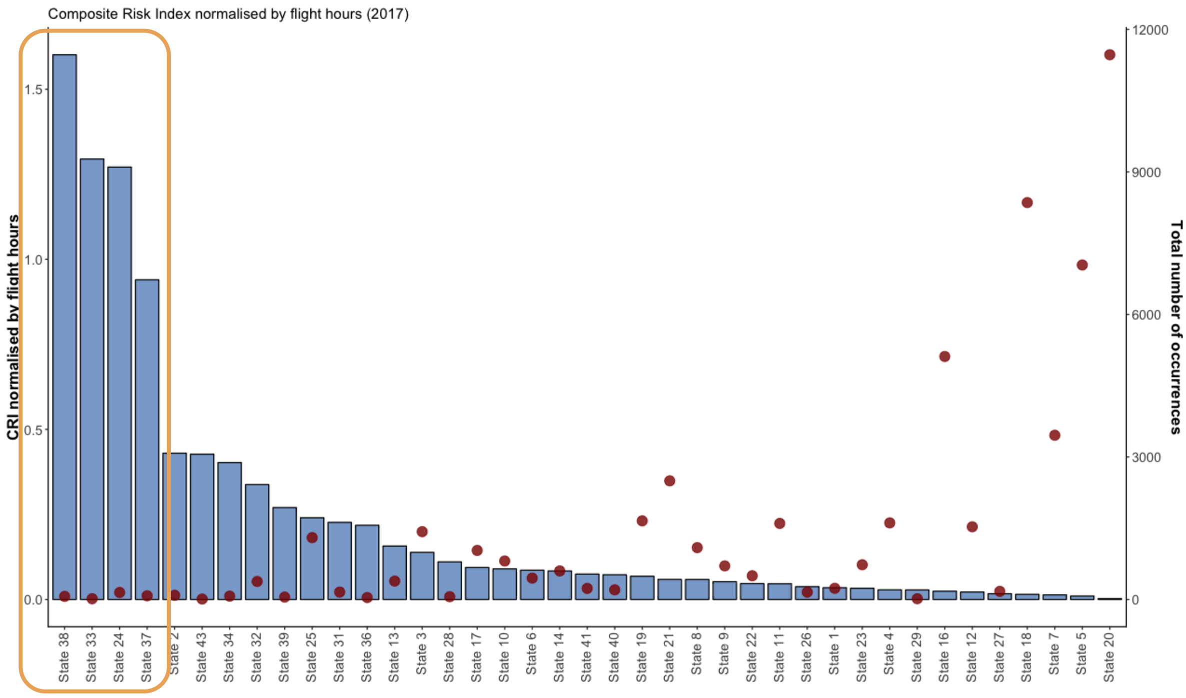

Figure 7: CRI normalised vs total number of reports (2017)

3.1 CRI trend

Figure 8 shows how the CRInorm is changing in period 2015-2017. In 2016 CRInorm overall has increased comparing to the previous year, which was mainly influenced by high CRInorm of several States. In 2017 the CRInorm has improved overall even though there was a huge increase in the total number of reported occurrences (approximately 38%). In addition, the number of States with extreme CRInorm has decreased.

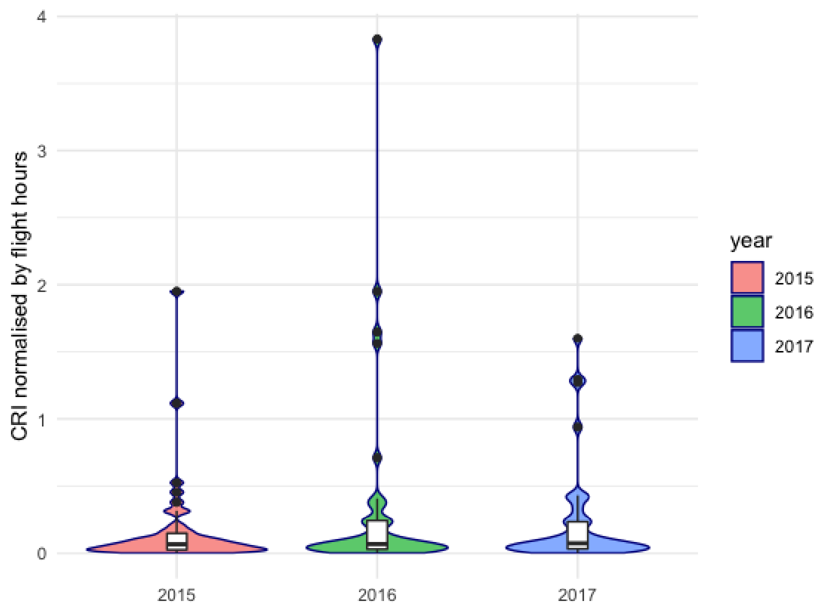

Figure 8: Normalised CRI 2015-2017

3.2 CRI of key risk events

The nature of CRI computation also allows calculation and monitoring of CRI of a single specific type of occurrences, e.g. the key risk occurrences within an airspace or organisation.

The following graph (Figure 9) shows an example of CRI calculated for separation minima infringements (SMIs) for all EUROCONTROL Member States.

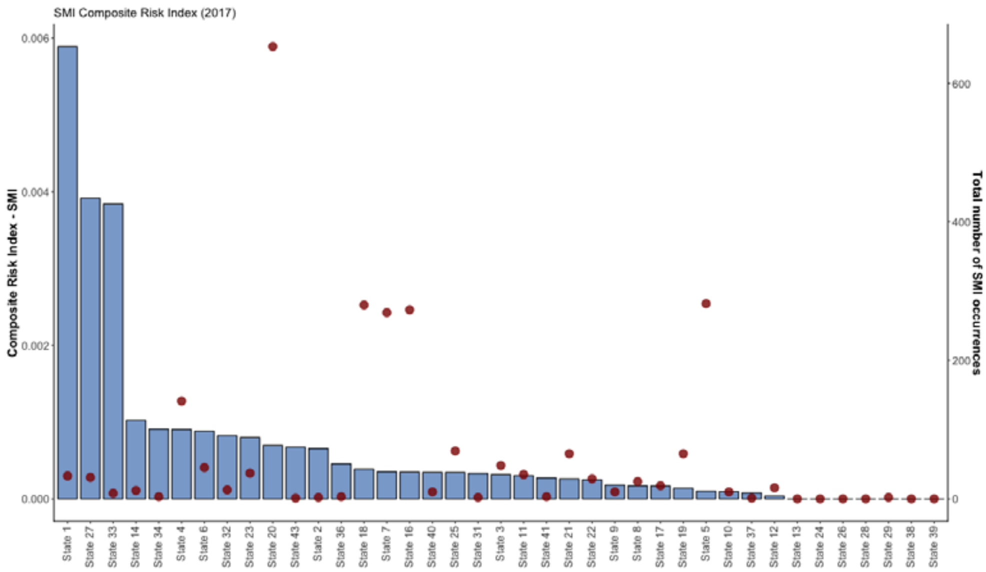

Figure 9: Key risk occurrence CRI (SMI example)

Note: As the number of the key risk events is much smaller than the total number of reported events, for presentation purposes and if needed, the CRInorm values should be presented using log scale. Moreover, to avoid negative values of CRInorm, normalisation should be done per million of occurrences and million of flight hours in order to get CRInorm as positive values.

4 Conclusion

The concept of a Composite Risk Index (CRI), as a cumulative risk value calculated aggregating all reported, assessed and severity classified safety-related incidents, has potential to become a proxy of exposure to risk within certain airspace for top management information and decision making.

Preliminary analysis shows that it could be used to measure the performance of European ATM systems as a whole and also its individual entities. Moreover, this scaling possibility allows to measure CRI of individual types of safety occurrences as well.

The CRI however, should not be construed as an absolute measuring stick. It is only as good as the fidelity of the data that supports it. In general, specific probabilities of occurrence are not precisely known, and there is some subjectivity in the assessment of severity of the occurrence.

4.1 CRI Customisation

As mentioned before, besides the fact that CRI methodology can be customised to local environment, i.e. Weights can be re-modelled using local safety data, CRI methodology can be scaled up or down to satisfy monitoring of individual entities.

Based on individual local safety data availability, the CRI calculation can be improved by using higher granularity of safety-related data used to compute CRI, so that Weights are computed separately for each different type of occurrence (e.g. providing separate weights for different OTHER types of OPS occurrences).

In addition, initial proposed ranges of different Weights could be fine-tuned based on collective expert opinion via dedicated expert group, both locally and within aviation community. This would also help to better understand potential concept limitations and added value.

Finally, the CRI normalisation could be done per different metrics, in order to allow inclusion of airspace size, capacity and/or complexity (for example, normalization per sector or number of flights). This could allow adding additional local specific operating conditions into equation.