Risk Observatory for data-driven safety analysis

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Short abstract: Future Sky Safety is a Joint Research Programme (JRP) on Safety, initiated by EREA, the association of European Research Establishments in Aeronautics. The Programme contains two streams of activities: 1) coordination of the safety research programmes of the EREA institutes and 2) collaborative research projects on European safety priorities.

This deliverable is produced by the Project P4 Total system risk assessment. The main objective is to describe the developed Risk Observatory, explain how it could potentially be used, and outline directions for exploitations and operational use.

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Acronyms

Acronym	Definition
ACARE	Advisory Council for Aviation Research and innovation in Europe
AD3M	Aviation Data Driven Decision Making
ADREP	Accident/Incident Data REPorting
ASCOS	Aviation Safety and Certification of Operations and Systems
ALoSP	Acceptable Level of Safety Performance
ANS	Air Navigation Service
ATC	Air Traffic Control
ATM	Air Traffic Management
ATS	Air Traffic Service
ANSP	Air Navigation Service Provider
ASIAS	Aviation Safety Information Analysis & Sharing
BRQ	Business Requirement
CAA	Civil Aviation Authority
CATS	Causal model for Air Transport Safety
CE	Critical Element
CMA	Continuous Monitoring Approach
EASA	European Aviation Safety Agency
EASP	European Aviation Safety Programme
EC	European Commission
EPAS	European Plan for Aviation Safety
EREA	Association of European Research Establishments in Aeronautics
EU	European Union
FDM	Flight Data Monitoring
FDX	Flight Data eXchange
FLORIS	Flexible Operational Repository for Integral Safety assessments
FSS	Future Sky Safety
GASOS	Global Aviation Safety Oversight System
IATA	International Air Transport Association
ICAO	International Civil Aviation Organisation

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ICT	Information and Communications Technology
IF	Influencing Factor
iSTARS	integrated Safety Trend Analysis and Reporting System
IT	Information Technology
JRP	Joint Research Programme
KLM	Koninklijke Nederlandse Luchtvaart Maatschappij
NAA	National Aviation Authority
NLR	Royal Netherlands Aerospace Centre
PPP	Private Public Partnership
PSA	Probabilistic Safety Assessment
RAIO	Regional Accident and Incident Investigation Organization
RO	Risk Observatory
ROO	Risk Observatory Organization
RSOO	Regional Safety Oversight Organizations
SAFE	Safety in Aviation Forum for Europe
SARPS	Standards and Recommended Practices
SIMS	Safety Information Monitoring System
SMI	Safety Management Implementation
SMM	Safety Management Manual
SMS	Safety Management System
SOM	Safety Oversight Manual
SOO	Safety Oversight Organization
SPI	Safety Performance Indicator
SPT	Safety Performance Target
SRIA	Strategic Research and Innovation Agenda
SSP	State Safety Programme
STEADES	Safety Trend Evaluation, Analysis & Data Exchange System
SW	Software
UK	United Kingdom
UN	United Nations
USOAP	Universal Safety Oversight Audit Programme
USR	User Requirement

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EXECUTIVE SUMMARY

Problem Area

In Europe the accident rate has stagnated at around 40 accidents per ten million flights: forty times higher than Europe's ambition. Currently safety management is done per organisation, only taking into account an organization's own domain. There is a need for a holistic, total system approach to aviation safety integrated across all components and stakeholders, supported by new safety management, safety assurance and certification techniques that account for all system developments [8]. "Tools, metrics and methodologies should be available to assess and manage proactively current and emerging risks. Safety performance indicators should be systemically linked to safety outcomes, allowing measurement of system safety performance" [9]. Being able to monitor existing and new risks (e.g. emerging from external hazards) is a prerequisite for defining and implementing appropriate mitigation measures to proactively manage risks. There is a need to enable inter-organisation and inter-domain safety management. This can be done through the realisation of a 'Risk Observatory', which acquires and integrates safety data from different domains and translates it into actionable safety information. A "Risk Observatory" provides means for collaborative and continuous safety data sharing between all aviation stakeholders to analyse safety data, thereby establishing frequent risk pictures for the total aviation system. The aim is to discover safety concerns before accidents or incidents occur, leading to timely mitigation and prevention. There is a need to automate the capture and analysis of aviation accidents, incidents, occurrences as well as flight data originating from Flight Data Monitoring.

Description of Work

Future Sky Safety P4 "Total system risk assessment" addresses the need for a more holistic total system approach to aviation safety by developing a risk observatory to assess and monitor safety risks throughout the Aviation System, and to allow frequent updates of the assessment of risks. The structured assessment of risks builds on means and models for safety risk assessment and safety performance monitoring, by providing a predictive assessment of incident/accident probabilities for the total aviation system based on routine operational data. This will allow development of a proof-of-concept of an observatory aiming to provide: key performance indicators, causal factors of that safety performance, key risk areas and safety trends. It allows benchmarking of safety performance against that of peers. It will go beyond identifying precursors to unwanted outcomes (as identified in ASCOS), and will identify routine operational behaviour that influences safety performance. The main objectives of this study are:

- To describe the Risk Observatory (RO) prototype from an end-user and customer perspective;
- To describe the key elements of the Risk Observatory and the rationale for their inclusion;
- To provide various dashboards that show how safety data is translated into safety information;
- To provide a summary of the business model for the operational deployment of the RO;
- To give recommendations for future development avenues for the RO and comparable actions.

This document gives an overview of the Risk Observatory and an outlook on further developments. Trials with the Risk Observatory are documented in more detail in other P4 deliverables (e.g. [26]).

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Results & conclusions

While the RO is a support tool for safety management, it requires an actual organisation to deliver and maintain RO services. In view of this, the key elements of a business model – value proposition, customers, customer relationships, communication channels, key activities, resources, partners and cost and revenue streams – are described. The main business drivers are the following three offers:

- Providing service providers with data-driven decision support for safety management;
- Providing regulators and authorities with enhanced capabilities for safety oversight;
- Assisting individual States with establishing and managing their State Safety Programme.

An early version of the risk observatory prototype was developed on the basis of an initial set of requirements, and demonstrated to stakeholders [17]. Feedback was taken into account in the further development of the RO based on an integrated risk assessment framework. Both the early prototype and the follow-up research prototype are described in this study. Various dashboards and visualisations of risks and safety performance indicators are provided to show how safety data can be translated into safety information. Different Use Cases are presented, explaining possible uses of the RO by service providers and the authorities in establishing and managing State Safety Programmes. The work in Future Sky Safety P4 includes the development of a risk assessment framework and the associated risk models. To illustrate the approach, two types of accidents have been considered in detail: runway excursions and mid-air collision risk, and trials have been conducted [26]. Based on publicly available occurrence data on accidents and serious incidents, three total aviation system risk pictures have been created [18], [21], [23]. This enables prioritisation of safety actions.

An outlook is presented on future next steps with the RO. This includes ideas for a data governance framework, scalability or ambition levels, and a high level roadmap covering five phases: research, development, implementation, operation, and expansion. Main challenges that are identified are:

- Development of a data governance structure in Europe will be more complex than for FAA's ASIAS, considering the number of States, different legal frameworks, different languages and cultures, and national interests. A central role for data governance should be with EASA.
- The RO has to assure that stakeholders experience sufficient benefit and added value from sharing data compared to current practices. The RO shall be complementary to similar data sharing initiatives or analyses conducted already by the stakeholders themselves.
- The RO needs to assure data quality to provide good quality analyses. Lack of data quality, lack of standardisation and other data processing issues (different taxonomies, corrupt data, lack of details, de-identification of data, etc.) may hamper quality and depth of the analyses.

Applicability

This study considers the development of a proof-of-concept of a Risk Observatory for a more holistic total system approach to aviation safety. The outcomes of the research may be used by EASA's Data4Safety initiative for its aim to collect and analyse data to support the management of safety risks at European level. In doing so, alignment with the approach that ICAO is taken with iSTARS and SIMS is recommended.

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1 INTRODUCTION

1.1. The Programme

The Future Sky Safety (FSS) programme looks at areas of significant safety risks related to aviation for Europe, with the intent of enhancing safety for European citizens. As a partnership between leading European industry and research/academic institutions it has the opportunity to make practical improvements by increasing knowledge in key areas of importance in the European aviation transport system. The focus is on:

- Reducing risk of accidents
- Improving processes and technologies to achieve near-total control over the safety risks
- Improving safety performance under unexpected circumstances
- Building ultra-resilient vehicles and improving cabin safety

The programme is structured around four themes as follows. Theme 1 (New solutions for today's accidents) aims for breakthrough research with the purpose of enabling direct, specific, significant risk reduction for two main accident categories. Theme 2 (Strengthening the capability to manage risk) conducts research on processes and technologies to enable the aviation system actors to achieve near-total control over the safety risk in the air transport system. Theme 3 (Building ultra-resilient systems and operators) conducts research on the improvement of organizations, systems and the human operator with the specific aim to improve safety performance under unanticipated circumstances. Theme 4 (Building ultra-resilient vehicles), aims at reducing the effect of external hazards on the aerial vehicle integrity, as well as improving the safety of the cabin environment.

1.2. Project context

In the FSS project P4 "Total System Risk Assessment", which fits within Theme 2, a prototype Risk Observatory (RO) is developed as an enabling tool for safety management. The risk observatory will acquire, fuse and structure safety data and translate it to actionable safety information: output that helps the user to distil safety intelligence to allow the implementation of appropriate measures to positively influence safety - i.e. reducing the serious incident and accident probability. The core of the risk observatory is formed by a risk assessment framework that integrates risk assessment models specifically developed to represent a certain domain. The framework is fed by different safety data inputs: e.g. normal operation data from the aircraft operator domain (e.g. originating from Flight Data Monitoring (FDM)) and Air Navigation Service Provider (ANSP) domain, but also occurrence and incident data. The risk observatory offers insights in safety performance to safety analysts, which can be used in the risk assessment of new aircraft and systems and in safety assurance by identifying safety trends, key risk areas, and efficient mitigation measures. The risk observatory's scope is the EASA Member States and the operations performed by service providers within the EASA Member States. Project P4 has as main objective to develop a working and practical Risk Observatory prototype to assess and monitor safety risks throughout the Total Aviation System and allow frequent update of the assessment of risks.

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1.3. Research objectives

The main objectives of this study are:

- To describe the Risk Observatory (RO) prototype from an end-user and customer perspective;
- To describe the key elements of the Risk Observatory and the rationale for their inclusion;
- To provide various dashboards that show how safety data is translated into safety information;
- To provide a summary of the business model for the operational deployment of the RO;
- To give recommendations for future development avenues for the RO and comparable actions.

1.4. Approach

For the development of the Risk Observatory, first the regulatory context is considered. In particular, this concerns ICAO Annex 19 Safety Management (2nd Edition) [12], the ICAO Safety Management Manual (4th Edition) [13], and the new EU basic regulation for aviation safety [5]. It will be relevant to consider how the RO may assist national authorities in establishing and managing their State Safety Programme (SSP) for the individual member states and how the RO may assist service providers with establishing their Safety Management System (SMS). For example, it will be discussed how the RO can be used for application of ICAO's concept of Acceptable Level of Safety Performance (ALoSP).

Interviews with stakeholders and analysis of the regulatory context and requirements have led to a first set of requirements for the RO [16]. This concerns business requirements, user requirements and system requirements. The system requirements have been further divided into general system requirements, functional system requirements, quality system requirements, and data and interface requirements. These requirements have subsequently been used for the design and development of an early version of the RO [17]. The resulting conceptual approach is sketched in Figure 1-1 below.

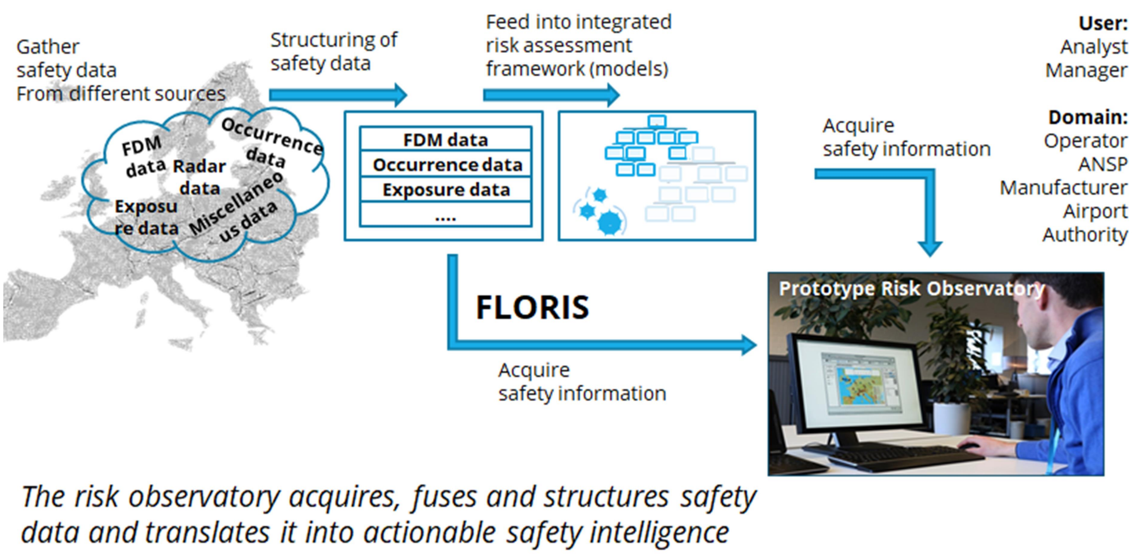

Figure 1-1 Risk Observatory approach

It is important to note that FSS P4 performs research and intends to develop a proof-of-concept of a (prototype) Risk Observatory only. An operationally deployed Risk Observatory is expected to result from EASA's Data4Safety initiative, to which the FSS RO should contribute. In this context, it will be highlighted what needs to happen in the future as next steps.

The Risk Observatory uses a variety of techniques to process aviation safety data (e.g. occurrence data, exposure data, operational data, etc.) into safety information for monitoring and prediction of safety performance on the basis of Safety Performance Indicators (SPIs). Techniques could e.g. include risk modelling, and text/data mining, which is part of the machine learning and artificial intelligence spectrum (Figure 1-2).

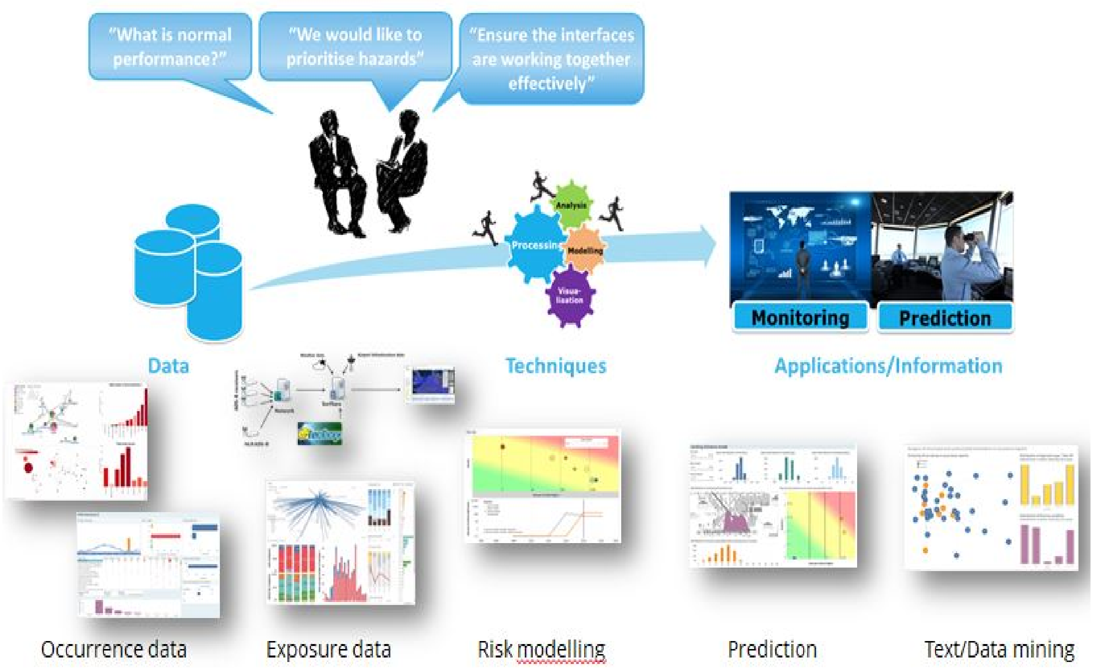

Figure 1-2 Using safety data to monitor and predict safety performance

It is possible that some input data for the RO is not available or the data provision has inadequate periodicity, since full deployment of the RO is not envisaged within the scope of FSS. To mitigate this risk, operational and safety data sources available within NLR's Flexible Operational Repository for Integral Safety assessments (FLORIS) can be used and combined for use in the RO.

The RO and associated tools (such as FLORIS) will enable to quantify safety performance indicators for the main operational issues defined in the European Plan for Aviation Safety (EPAS). This includes SPIs to measure (monitor and predict) progress with respect to: runway excursion; mid-air collision; Controlled Flight Into Terrain; loss of control in flight; runway incursions; fire, smoke and fumes.

1.5. Structure of the document

The document is structured as follows. While the current Section 1 introduces the context of the report,

Section 2 provides the regulatory context and the needs and requirements for a data-driven approach to aviation safety. This Section also motivates why a Risk Observatory and other tools for safety data analysis can be useful for national aviation authorities and service providers in their safety management activities.

Section 3 addresses the key elements of the business model for the operational deployment of the RO.

Section 4 presents the developed Risk Observatory.

Section 5 presents a variety of possible use cases, and explains how these can be used in the context of a State Safety Programme (SSP) of national aviation authorities.

Section 6 provides an outlook of envisaged next steps and anticipated follow-up activities.

The main conclusions and recommendations are given in Section 7.

Finally, Appendix A contains the key (highest priority) requirements for the FSS Risk Observatory.

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2 REGULATORY CONTEXT

It has been a while since the aviation community started to recognize the importance of data-driven safety analysis. Not only internationally, but also domestically (and possibly regionally too) the needs of decision-making practices on the basis of information out of analysis of data has been recognized. To guide individual States to enhance the use of data-driven safety analysis, ICAO provided norms which include detailed guidelines and ideas to assist Member States. Within Europe, EASA also provides guidelines. This chapter provides an overview of data-related norms and policy directions.

2.1. ICAO

As one of the UN agencies that specifically deals with international civil aviation, ICAO mandates Member States and aviation service providers to implement State Safety Programmes (SSP) and safety management systems (SMS). ICAO Annex 19 to the Chicago Convention [12] contains Standards and Recommended Practices (SARPS) regarding safety management. ICAO Doc 9859, the Safety Management Manual (SMM) [13], provides detailed guidelines for implementation of the standards provided in Annex 19. On the basis of these documents, ICAO also shares its policy directions which assist States to safeguard aviation safety.

2.1.1. ICAO Annex 19

ICAO Annex 19 to the Chicago Convention is dedicated to safety management and contains SARPS which particularly assist States and aviation organisations in managing aviation safety risks. Annex 19 was developed relatively recently and collects information previously contained in other Annexes. It discusses the need for and content of SSP and SMS, as well as related elements including the collection and use of safety data and safety oversight activities. Having the material in a single Annex is giving proper attention to the importance of integrating safety management activities.

An SSP is an SMS for a State. It is *an integrated set of regulations and activities aimed at improving safety* (ICAO 2016), which individual States should establish and maintain. Elements in an SSP most relevant to data-driven safety analysis are **Safety Risk Management** and **Safety Assurance**.

Safety Risk Management in the annex is defined as management of safety risk, which includes licensing, certification, authorization and approval obligation, States making sure that its aviation service providers have an SMS, accident and incident investigation, hazard identification and safety risk assessment, and management of safety risks by establishing mechanisms for the resolution of safety issues.

Safety Assurance is fulfilment of the surveillance obligation and establishing *acceptable level of safety performance* (ALoSP). States should document surveillance processes which include definition and planning of inspections, audits and monitoring activities on a continuous basis and implement these processes. The purpose of surveillance is to proactively assure compliance with the established requirements. Meanwhile, an ALoSP is related to state safety performance. An ALoSP can be achieved not only through the implementation and maintenance of the SSP, but also through the usage of safety

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performance indicators (SPIs) and targets (SPTs). SPIs and SPTs shall show that safety is effectively managed within the State and is built on the foundation of implementation of existing SARPs. Detailed guidance on establishment of an ALoSP, safety performance indicators and targets is provided in the Safety Management Manual (SMM).

2.1.2. ICAO Safety Management Manual

The ICAO Safety Management Manual (SMM) is guidance material, which supports implementation of effective SSPs. The support includes ensuring the implementation of SMS for service providers. The SMM covers three themes, which are safety management fundamentals, development of safety intelligence and safety management implementation. The focus is on intended outcome of all SARPs while avoiding to be overly prescriptive.

The important point of this manual is that the implementation of safety management is achieved by emphasizing that the creation of an SMS or SSP should be commensurate to the size and complexity of the organisation concerned. As additional support for States, ICAO has developed the Safety Management Implementation (SMI) website [14] which is a repository for practical tools and examples of safety implementation.

One important change in the 4th edition of the SMM is a deepening of the concept of **ALoSP**. SMM defines the ALoSP as '[t]he level of safety performance agreed by State authorities to be achieved for the civil aviation system in a State, as defined in its State safety programme, expressed in terms of safety performance targets and safety performance indicators.' ALoSP reflects the expected level of safety performance which one State should deliver. Stakeholders of the aviation industry within the State should understand how the State manages aviation safety from ALoSP.

SMM stipulates the importance of safety performance indicators and safety performance targets next to the establishment of the ALoSP. While an ALoSP demonstrates a goal of one State, an SPI reflects a specific operational environment. An SPI also highlights considerable factors to be used in identification of the way safety risks are controlled. ICAO depicts the relationship between ALoSP, SPIs and SPTs in the following figure.

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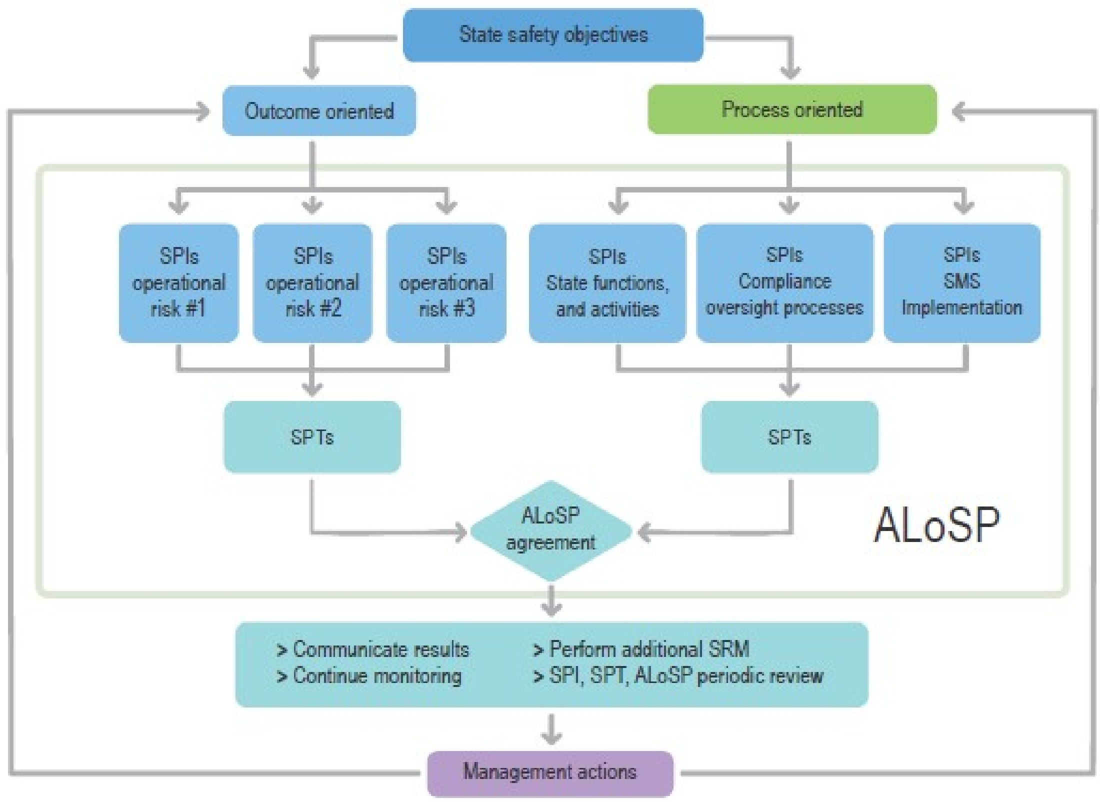

Figure 2-1 Acceptable Level of Safety Performance (ALoSP) [34]

2.1.3. ICAO Safety Oversight Manual

As a guidance manual next to ICAO SMM, ICAO provides States with the Safety Oversight Manual (SOM), which outlines duties and responsibilities of ICAO Member States regarding safety oversight [34], [35]. ICAO defines safety oversight as a 'function performed by a State to ensure that individuals and organizations performing an aviation activity comply with safety-related national laws and regulations'. Generally speaking, oversight forms a safety regulatory process dedicated to ensuring that applicable regulatory requirements are met, and to the monitoring of the safety provision of services. Unless prescribed otherwise, safety oversight in aviation is one of the State responsibilities.

The generic components of a national safety oversight system are as below;

- Monitoring of safety performance;
- Verifying compliance with applicable safety regulatory requirements;
- Safety regulatory auditing;
- Oversight of new or changed systems, operations, products or procedures;

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- Publication of regulatory instructions or advisory material based on findings of oversight activities; and
- Generation and maintenance of safety oversight records.

As a support for States, ICAO has also established the Universal Safety Oversight Audit Programme (USOAP), which aims at verifying, through formal audits, States' safety oversight arrangements and capabilities. ICAO introduced eight Critical Elements (CE), which are used in various safety activities including safety oversight and establishment of an SSP. The elements below are highly relevant to the data-driven safety analysis.

- CE6 - Licensing, Certification, Authorisation and Approval Obligations
- CE7 - Surveillance Obligations
- CE8 - Resolution of Safety Concerns

These elements are important components of the SSP, as part of State Safety Risk Management and State Safety Assurance.

2.1.4. Global Aviation Safety Oversight System (GASOS)

ICAO has also opened the door for delegation of safety management functions and activities to other States or organizations. In 2018, the Secretariat of ICAO proposed to establish a new global aviation safety oversight system (GASOS) [15]. The GASOS is a system to assess, recognize and continuously monitor the competence of Safety Oversight Organizations (SOO), with the objective to strengthen State Safety oversight capabilities and make State oversight organisations more effective and efficient. The main methodology to be used is the USOAP CMA (Continuous Monitoring Approach). Regional Safety Oversight Organizations (RSOOs), Regional Accident Investigation Organisation (RAIOs) or any other organizations which offer oversight services can become SOOs. Once ICAO recognizes the competences of an SOO, States may delegate their oversight activities to them.

There are three different levels of delegation. Level 1 is for advice and coordination. At this level, a national authority chooses an organisation from the GASOS directory which can develop regulations, manuals, checklists and other guidance materials and coordinate a pool of inspectors or experts. Level 2 is for operational assistance. At this level, an organisation listed in the GASOS directory may provide training to inspectors and perform certification and surveillance tasks such as inspections, audits or reviews. At Level 3, States can fully delegate any safety oversight function to the recognized organisation. Tasks include issuance, amendment or revocation of certificates, licenses and approvals on behalf of the State.

Using GASOS will help States to meet the safety oversight obligations even if there are limited financial and technical resources.

2.2. EASA

Within the European Union, with the needs of having an evidence-based and proactive system as well as a systemic approach, the concept of the safety management has also been implemented, together with attention towards reporting, analysis and follow-up of occurrences.

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2.2.1. Regulation (EU) 2018/1139

Regulation (EU) 2018/1139, which is known as the 'New Basic Regulation' is a binding legislation which forms the European Aviation Safety Agency (EASA) and aims to establish and maintain a high uniform level of civil aviation safety in Europe [5]. Certification, licensing, aerodrome operations and ATM/ANS, authorisation and oversight of third country commercial operators and ATM/ANS operators and ATC training organisations are the responsibilities of EASA.

Article 7 of this Regulation specifically points out that Each EASA Member State shall establish and maintain an SSP, following Annex 19 to the Chicago Convention. However, Article 7 of Regulation 2018/1139 additionally requires that this SSP 'shall be consistent with the European Aviation Safety Programme.' The same article still points out that safety management responsibilities related elements in Annex 19 should be included.

2.2.2. European Aviation Safety Programme (EASP)

EASP is an EU equivalent of an SSP, which aims to aid EASA Member States in meeting their legal obligations and further improving safety. EASP has proposed an approach on the basis of three elements, which are the strategy, program and finally a high level safety issues assessment and related action plan. The strategy consists of a set of policies and objectives from political authorities. The programme consists of an integrated set of regulations and activities aimed at improving safety.

One particularity of the EASP is that it has the format of an SSP. However, it has not been updated yet according to the latest edition of the SMM. The gap may be filled by European Plan for Aviation Safety (EPAS) which contains progress made in addressing identified safety risks at EU level and which is updated by EASA.

2.2.3. European Plan for Aviation Safety (EPAS)

EPAS is a document that contains the safety management process which is carried out at the European level [10, 11]. The EPAS is the action plan that describes specific actions designed to solve specific safety issues. The EPAS is issued once every 5 years and EASA reviews and updates the document yearly.

The current EPAS, which is valid during 2019-2023, states that key actions of EASA in improving safety are to support States in implementing SSPs and State Safety Plans, to improve harmonisation of SMS implementation and the application of human factor principles, to ensure that State competent authorities have the ability to evaluate and oversee operators' management systems, and finally to incorporate safety management requirements in initial and continuing airworthiness.

EPAS identifies areas in which coordinated action of European States makes a difference in avoiding accidents and serious incidents. The current EPAS states that SPIs and SPTs shall monitor safety outcomes. Main inputs of outcome-based indicators are numbers of fatal accidents, numbers of fatalities and numbers of non-fatal accidents and serious incidents. EPAS also proposes States not to set safety performance targets but to define baseline performance in order to monitor safety performance more effectively.

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3 PRELIMINARY BUSINESS MODEL

3.1. Introduction

While the Risk Observatory (RO) is a support tool for safety management, it requires an actual organisation to deliver and maintain the RO services. This requires a business model describing organisational, operational, financial and legal aspects of setting up and maintaining an organisation that manages the RO. This should include incentives for stakeholders to assure data sharing.

Four sources of information are used for the business model. Firstly, a Business Model Canvas is used to describe its key elements. Next, a review of identified business requirements [16] is conducted. Thirdly, a review of the ASIAS programme, the EASA feasibility study into a big data programme for aviation safety, and mandatory occurrence reporting schemes is performed to identify lessons learned. Finally, interviews with three stakeholders (KLM, Lufthansa, CAA UK) are conducted. The business model describes the value proposition, customers, customer relationships, communication channels, key activities, resources, partners and the cost and revenue streams [25].

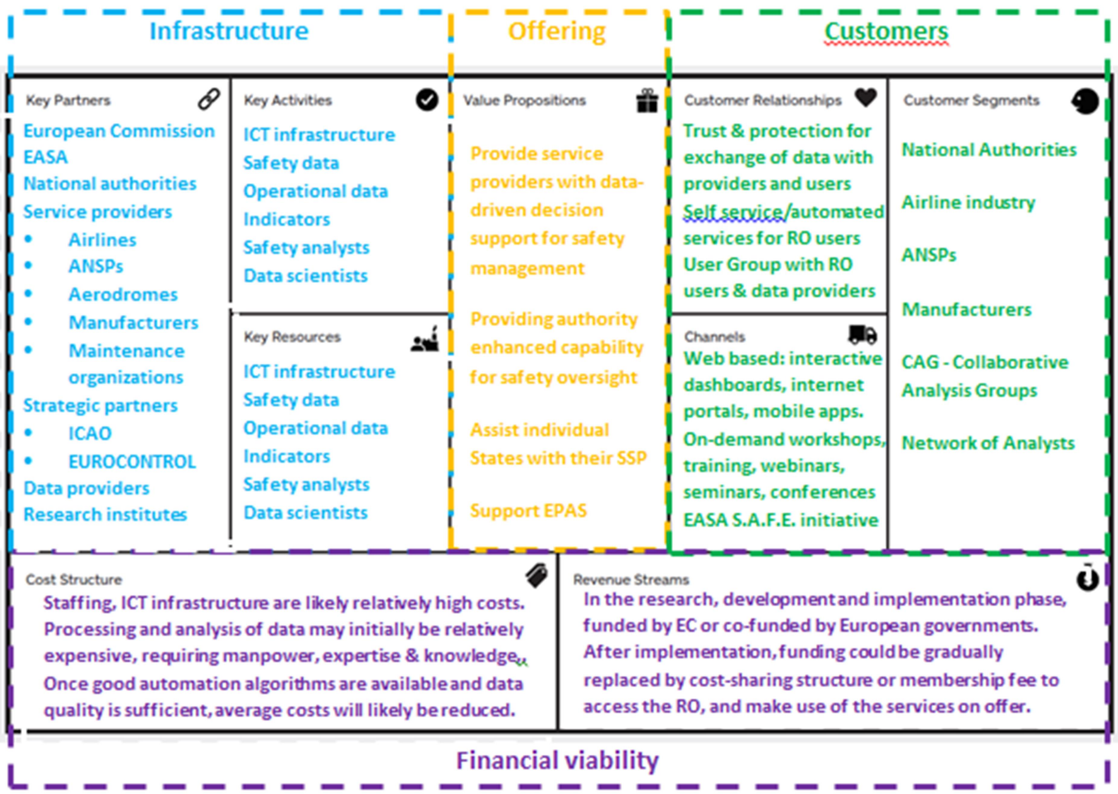

Figure 3-1 Business Model Canvas: nine business model building blocks

The Canvas business model template has been used to create a baseline to describe and develop the various elements of the business model. All the elements of the business model are considered. Success factors and risks for the viability and for achieving the value proposition will be identified.

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3.2. Offering and value propositions

The three main drivers for the business model are the following offers (value propositions):

a) Providing service providers with data-driven decision support for safety management;
b) Providing regulators and authorities with enhanced capabilities for safety oversight;
c) Assisting individual States with establishing and managing their State Safety Programme.

The value proposition is essential for the success of the RO. The RO value proposition has to strengthen related initiatives run by ICAO (iSTARS), EC and EASA (Data4Safety), IATA (e.g. STEADES and FDX), and the FAA (ASIAS). Primary incentives for stakeholders to share data to the RO are:

- Provision of substantially enhanced safety intelligence, enabling risk analysis and defining safety performance indicators;
- Provision of safety intelligence in systemic risks across multiple operators and domains (i.e. total aviation system approach) that has been largely unavailable to date;
- Access for aviation senior managers to specialist analysts to dedicated safety studies, benchmark analyses, shared lessons learnt, and best practices.

3.3. Customers

3.3.1. Customer segments

Several customer segments have been identified, of which the airline industry is considered to be the data provider that probably brings most data to the RO. ANSPs are the second stakeholder group that could provide significant data to the RO. It is expected based on ASIAS experiences that airlines will gain benefits from the RO due to its wide scope of interfaces with other airlines, airports, ANSP’s, ground service providers and manufacturers. Therefore, initial promotional activities should be focused on airlines and thereafter extended to other customer segments in the aviation industry. Manufacturers and authorities could also benefit directly from safety information shared by airlines. The authorities could be provided with enhanced capabilities for safety oversight, and the data collected and analysed with the RO could assist States with establishing and managing their SSP. The RO safety information could help them in the interaction with ICAO in relation to the USOAP. Working Groups that may benefit from access to the RO include the Collaborative Analysis Groups (e.g. CAT CAG and ATM CAG) and Network of Analysts (NoA). To ensure an attractive proposition to the RO customer base, a detailed customer analysis is needed.

3.3.2. Customer relationships

In defining and developing customer relationships, a distinction has been made between data providers and data users. The customer relationship with data providers has to be built on mutual trust and protection mechanisms for data exchange and proper usage of data. When this basis of trust is guaranteed, data providers and the staff for the RO work in close coordination to build a secure and reliable RO. For data users that receive output, the customer relationship mainly consists of self-service or automated services (i.e. the RO interactive dashboards and safety publications). User group meetings or representation of the organization hosting the Risk Observatory in sector communities have to be used for promotional activities and for delivering RO output that goes beyond the scope of the outputs provided

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by the dashboards. Coordination and interaction between the ROO, European or national safety initiatives, academia and research institutes has to be established to ensure maximum benefit for all stakeholders and to continue providing beyond state-of-the-art safety intelligence.

3.3.3. Channels

The primary channel for the RO for sharing data and safety information will have to be web-based, using interactive dashboards, internet portals, apps for mobile devices, or targeted e-mails. For marketing purposes, various channels may be used, which depend on the decisions made with regard to the focus of promotional activities. Information provided on these platforms should be regularly updated with news, analysis results, etc., to keep attracting potential customers. Expansion of the activities of the RO may introduce other channels, like (on-demand) workshops, training, webinars, seminars and conferences. Dissemination through the EASA S.A.F.E. initiative is an option.

3.4. Infrastructure

3.4.1. Key activities

Several activities have been defined that are required to achieve the value proposition, to continue service provision and to improve the service quality, maintain customer relationships and acquire new customers. Initial activities include acquisition, processing and fusion, storage and access, analysis and visualisation of data, and distribution of safety information. Additional activities, based on the maturity of the RO and size of the host organisation, may include guidance and training.

ICAO has defined eight steps for Aviation Data Driven Decision Making (AD3M) (Figure 3-2). The process starts with the definition of the problem that needs to be solved (Step 1), the associated definition of the objectives of collecting and analysing data (Step 2), and the determination of the analyses that would achieve the objectives (Step 3). These form the basis of Use Cases for the RO.

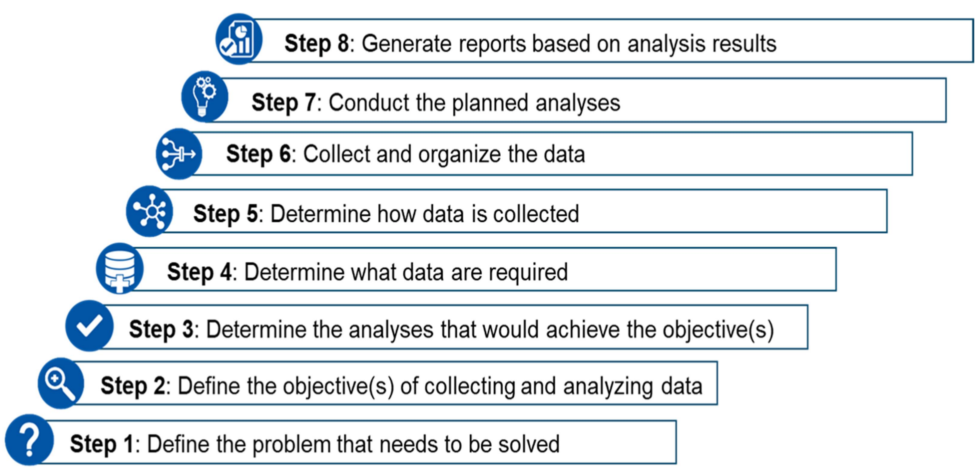

Figure 3-2 ICAO Aviation Data-Driven Decision Making steps

The RO should provide support to both regulators/authorities and service providers (airlines, ANSPs, operators, manufacturers) in conducting different steps in Aviation Data-Driven Decision Making.

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For the national aviation authorities, Use Cases could e.g. include:

- Understanding of top risks in their country
- Identification of hazards and causal factors
- Support for definition of safety objectives
- Support for oversight of service providers
- Support for performing surveys and inspections

For service providers (e.g. airlines, ANSPs, manufacturers), Use Cases could e.g. include:

- Quantification of Safety Performance Indicators (SPIs)
- Monitoring of safety performance
- Providing alert(s) in case safety performance deteriorates
- Support for preparing and organizing data for statistical analysis
- Support for reporting and visual representation of analysis results

To ensure continuous service delivery and support, the host organisation of the RO needs knowledge development, maintenance of the technical ICT infrastructure (hardware, software), access to risk models and dashboards, data analysis techniques, system administration and ICT-management.

3.4.2. Key resources

The Risk Observatory Organization (ROO) has two key resources that are fundamental to the RO objectives: on the one hand the data, and on the other hand, the risk models and analysis techniques that transform the safety data into safety information or intelligence. Typically aviation data feeds for the RO cover the following:

- Accidents and incidents
- Traffic information
- Airport information
- Flight schedules
- Fleet information
- Terrain and weather data

The risk models and data analysis techniques ideally should cover all of the occurrence categories in aviation[1]. The EPAS identifies operational issues in commercial air transport by aircraft[2]:

- Loss of control in-flight
- Design and maintenance improvements
- Mid-air collisions
- Runway safety (runway excursions and incursions)

[1] The ICAO ADREP distinguishes between 33 occurrence categories, of which 15 primary and 18 secondary.
[2] The EPAS 2016-2020 has been used for this study, and production of the FSS Risk Pictures 2016 and 2017. The latest EPAS covers the period 2019-2023, and introduces a slight renaming of the operational safety issues.

- Ground safety (ground collisions and ground handling)
- Controlled flight into terrain
- Fire, smoke and fumes (on ground and in the air)

Other resources at the host organisation are staffing, IT infrastructure, software, office space, budget/funding and intellectual property. The team shall include (safety) analysts with a proper aviation and aviation safety knowledge from different domains (airline operations, air traffic management, ground operations, maintenance, etc.) to understand, interpret and validate data and analysis results. Staffing, IT related hardware, and software costs are likely relatively high costs in the business model for the RO. These should be defined more precisely in the final business model.

3.4.3. Key partners

Key partners of the host organisation for the RO have been identified, and can be subdivided into data providers, users, strategic partners and academia, research and development institutes.

Data providers and users are directly involved in the key activities of the RO. They are usual operational stakeholders from the aviation community: airlines, Air Navigation Service Providers (ANSP), manufacturers, National Aviation Authorities (NAA), pilots, maintenance organisations, airports, etc. These organisations have access to a wide variety of safety data and experience.

Partnerships with research establishments and academia will ensure that the RO is, and remains, a centre of excellence in safety data analysis. These organisations typically have data scientists and risk modellers, and knowledge on how to use Big Data and other IT technologies (such as text/data mining, a form of machine learning) for aviation safety data analysis. Furthermore, these have in depth knowledge on future and emerging technologies, and have advanced capabilities for predictive risk assessment.

3.5. Financial viability

3.5.1. Cost structure

Staffing, IT related hardware, and software costs are likely relatively high costs in the business model for the RO. Processing data and analysis of data may initially be relatively expensive as well, potentially requiring a lot of manpower, expertise and knowledge, as these could be complex and time consuming activities. These costs will usually increase commensurate with the amount and content of the data provided to the RO and its host organisation, and with the number and content of the activities intended to be delivered (e.g. number of directed studies, guidance and training activities). However, once good algorithms are available for automated data analysis and the datasets are of sufficient quality (i.e. it is necessary to handle missing data), the average costs associated with data processing will be reduced.

3.5.2. Funding source and revenue streams

In the research, development and implementation phase, the RO needs to be funded by the EC or co-funded by the European national governments. After implementation, funding could be gradually replaced

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by cost-sharing structure or membership fee to access the RO, and make use of the services on offer. This idea needs further evaluation on feasibility and support amongst stakeholders.

Additional revenue can be generated from services such as providing guidance and training on safety management with the RO, or supporting safety studies. It is expected that the RO always needs to be partially funded by the EC or governments to ensure its independence, stability and continuity.

3.6. Summary

The three main drivers for the business model are the following offers (value propositions):

a) Providing service providers with data-driven decision support for safety management;
b) Providing regulators and authorities with enhanced capabilities for safety oversight;
c) Assisting individual States with establishing and managing their State Safety Programme.

The RO should receive aviation safety data under formal agreement with the aviation community, and analyse the safety data for safety information and safety intelligence.

Primary incentives for stakeholders to share data to the Risk Observatory are:

- Provision of safety intelligence, enabling risk analysis and defining safety performance indicators;
- Provision of safety intelligence in systemic risks across multiple operators and domains (i.e. total aviation system approach);
- Access to dedicated safety studies, benchmark analyses, shared lessons learned, and best practices.

Critical success factors for the RO to become and remain viable have been identified:

- Provide significant benefit and added value to stakeholders over existing data sharing and analysis activities;
- Establish data protection and data usage agreements that ensure that data are solely used for safety;
- Set-up a data governance structure that balances the interests of different stakeholders and assures the use of proprietary data solely for the interest of safety;
- Minimise efforts for stakeholders to share data;
- Establish a cost-effective organisation with a long term funding strategy.

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4 RISK OBSERVATORY PLATFORM

4.1. Introduction

The development of an early version of the risk observatory prototype was conducted in five steps:

- First, business, system and user requirements for an operational risk observatory have been defined.
- As second step, the requirements were reviewed to identify the functionalities and design aspects that would be considered in the early prototype development. This review led to the development of five main functionalities of the early prototype: the homepage, the occurrences dashboard, the risk dashboard, the search dashboard and the what-if analysis dashboard.
- In the third step, two use cases were defined to demonstrate the functionalities of the early prototype with existing risk models and data.
- The fourth step involved the implementation of the early prototype design in a software tool to be able to demonstrate functionalities and potential outputs of the Risk Observatory. As part of this step, data visualization tools were evaluated for implementation of the prototype. The software application Balsamiq was selected to implement the early prototype.
- Finally, sessions were organized with stakeholders to demonstrate the early prototype and to receive feedback on the prototype's functionalities and design. The following stakeholders were interviewed and involved in the evaluation: 5 aircraft/helicopter operators, 1 authority/regulator, and 2 ANSPs.

The early prototype was further developed using a set of risk assessment models and an integrated risk assessment framework, and was then implemented in a new software environment [20], [22], [24].

4.2. Requirements

An initial set of high level requirements (business, user, and system requirements) for development of the risk observatory has been defined [16]. The definition of the requirements has been sequenced through a series of standard steps starting from analysing business scope to derive business requirements, proceeding with formalizing user requirements and ending with system requirements. User needs have been collected and formalized. The current system requirements provide a high-level view of the main functions and of the quality and security requirements. The requirements, summarized in Appendix A and given in full detail in [16], provide inputs to the development of a look-and-feel early prototype and are used for the RO design. In the following, the product perspective of the RO, the main functionalities and the user characteristics are described.

<u>Product perspective</u>

A Risk Observatory (RO) should be able to collect aviation safety data from stakeholders such as airlines, ANSPs, aircraft manufacturers, airports, aviation authorities and it should allow analyses to individual organizations on wider sources of data than currently done. The Observatory also offers the potential for enhancing shared common intelligence between the regulator and those being regulated, with the opportunity of extending safety culture towards a common vision, aiming for accident/incident reduction.

Future Sky Safety develops a *research prototype RO*, which is tested, verified and validated through a variety of use cases. The experience gained with the research prototype RO is useful for Data4Safety, which aims to organise collection of all the safety data of the different organisations in Europe. Data4Safety plans to integrate that data into a Big Data platform, and then use algorithms to process the data and produce safety information.

<u>Product Functions</u>

The Risk Observatory should have the following main capabilities (Figure 1-1):

- Access to aviation safety data (and the associated operational data);
- Analysis of the safety data for safety implications and derivation of safety information;
- Provision of safety information to service providers, national aviation authorities and EASA;
- Provision of summary data on aviation safety (e.g. risk pictures based on occurrence categories);
- Integration of multiple data forms to enable analysis of a complete risk picture.

The RO functions are mapped to two of the safety management pillars identified in ICAO's Safety Management Manual.

Safety risk management:

- Hazard identification: identify all hazards (existing, new and emerging) that can cause feared events
- Risk assessment and mitigation. It provides information on the actual safety level and suggests possible actions to decision makers, i.e. define and implement safety controls to mitigate risks.

Safety assurance:

- Safety performance monitoring and measurement, e.g. through provision of safety information for application of the concept of Acceptable Level of Safety Performance (ALoSP). It provides quantified Safety Performance Indicators (SPIs), which are compared with defined Safety Performance Targets.

<u>User characteristics</u>

Potential users of the product are safety staff at different level of responsibilities in the domains:

- Aircraft manufacturers safety key actors, flight operational departments
- Aircraft operators: safety departments, executive management (post-holders, accountable manager)
- ANSPs: safety departments, executive management (post-holders and accountable manager)
- Airports: safety departments, executive management (post-holders and accountable manager)
- Aviation authorities: policy makers, incident/accident investigation, safety oversight department

4.3. The initial prototype

4.3.1. Design

The design of the early prototype was conducted iteratively and incrementally by the project team. The early prototype has several dashboards and a Login page:

- Login page
- Homepage
- Occurrences dashboard

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- Risk dashboard
- Search dashboard
- What-if analysis dashboard

Two versions of the early prototype were developed; one for airlines and one for air navigation service providers. It was decided to develop these two versions to show a representative version of the early prototype to the stakeholders that were involved in the evaluation of the early prototype. The objective of the use cases is to demonstrate the early prototype functionalities and design with existing (risk) models and data. The use cases were selected so that they address two of the six accident types mentioned in the user requirements (runway excursion, mid-air collision, controlled flight into terrain, loss of control in flight, runway incursion, and fire/smoke/fumes). The two use cases are:

- The SPI “Unstable Approach”, associated with the accident type “Runway Excursion”.
- The SPI “Loss of Separation”, related to the accident type “Mid Air Collision”.

Both accident types are interesting for multiple stakeholders. The safety performance indicators associated with the two use cases can be monitored and analysed with different types of combined data, so that the use cases also demonstrate the data integration aspects of the Risk Observatory. For the implementation of functionalities and design of the dashboards in the early prototype existing risk models were used, i.e. the Causal Model for Air Transport Safety CATS [29] and bow-tie model elements from the CAA UK significant seven bow-ties [30].

Several commercial software packages for visualisation of data and building dashboards were qualitatively evaluated for implementing the early prototype[3]. They were evaluated based on ease of use, flexible data access, functionalities (e.g. customisable visualisations, interactive analysis, embedding, sharing, security etc.) and licence costs. It was decided to use the software tool Balsamiq to implement the early prototype in the form of a mock-up of web-based dashboards. A portion of the RO’s required features can be developed using existing, commercial software applications. E.g. development and hosting of an occurrence dashboard can be easily performed using Tableau. Other more advanced features are more difficult to implement and realize using a commercial available software package for data visualization.

The following figures show screenshots of the early prototype dashboards. Figure 4-1 shows a screenshot of the homepage which shows the trends in SPIs and risks (traffic light “arrows” indicators). By clicking on the indicator or accident type the user can directly drill down into the underlying safety data and trend analysis. The homepage also provides access to the search dashboard and what-if analysis dashboard.

Figure 4-2 shows a view of the occurrence dashboard, where the user can monitor the number or frequency of a particular safety performance indicator or precursors (e.g. unstable approach). The user has a few functionalities available, for example filtering settings, ability to access the underlying data (records) or link to the risk dashboard to view the risk associated with the occurrence type. The occurrences dashboard presents data from actual reported occurrences, observations, measured events etc.

[3] Tableau, Pentaho, SiSense, Qlik, MicroStrategy, TIBCO Spotfire, YellowFin, Balsamiq are evaluated [17]. Microsoft Power BI is also possible.

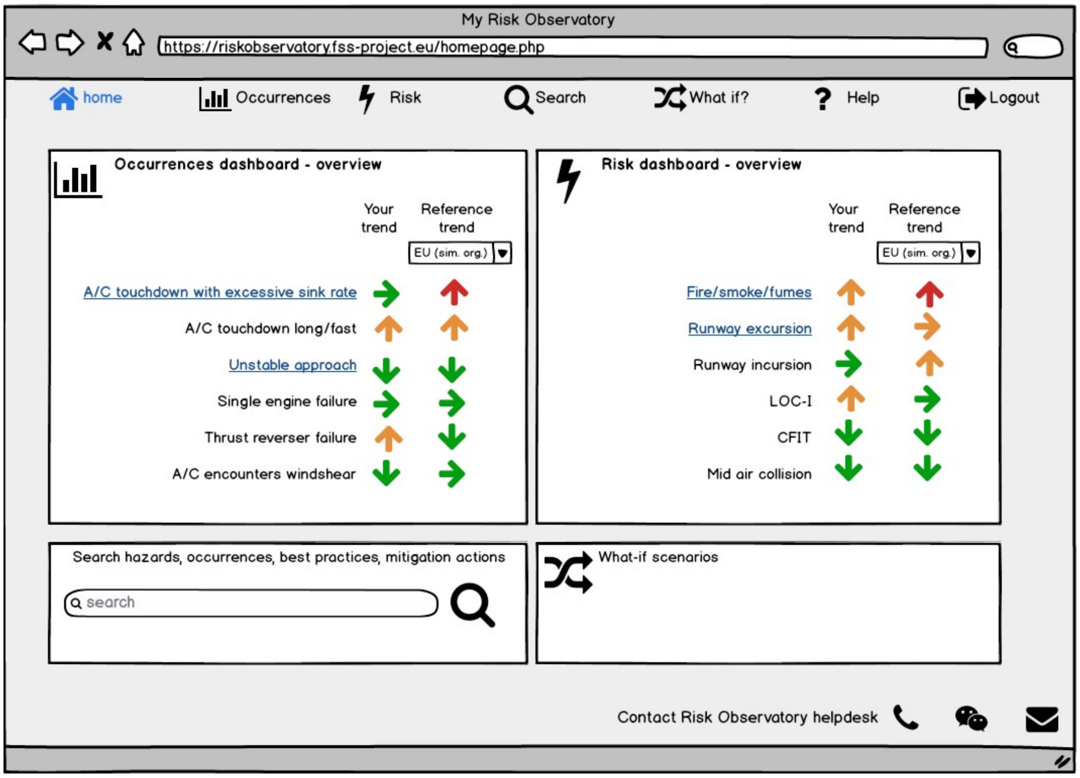

Figure 4-1 Homepage

Figure 4-3 shows the risk dashboard where the user can observe the accident risk probability and trend for a particular accident type for their own organisation, and compare that against for instance the EU safety level and an user defined alert level. The data shown in the dashboard is derived from combining actual reported occurrences, observations, and measured data with risk models to estimate an accident probability. In other words the risk dashboard combines data and risk model based information. An individual organisation may have no or too few events to calculate directly an accident probability. Therefore, the risk models are used to estimate an accident probability using event data on precursors to feed the risk model.

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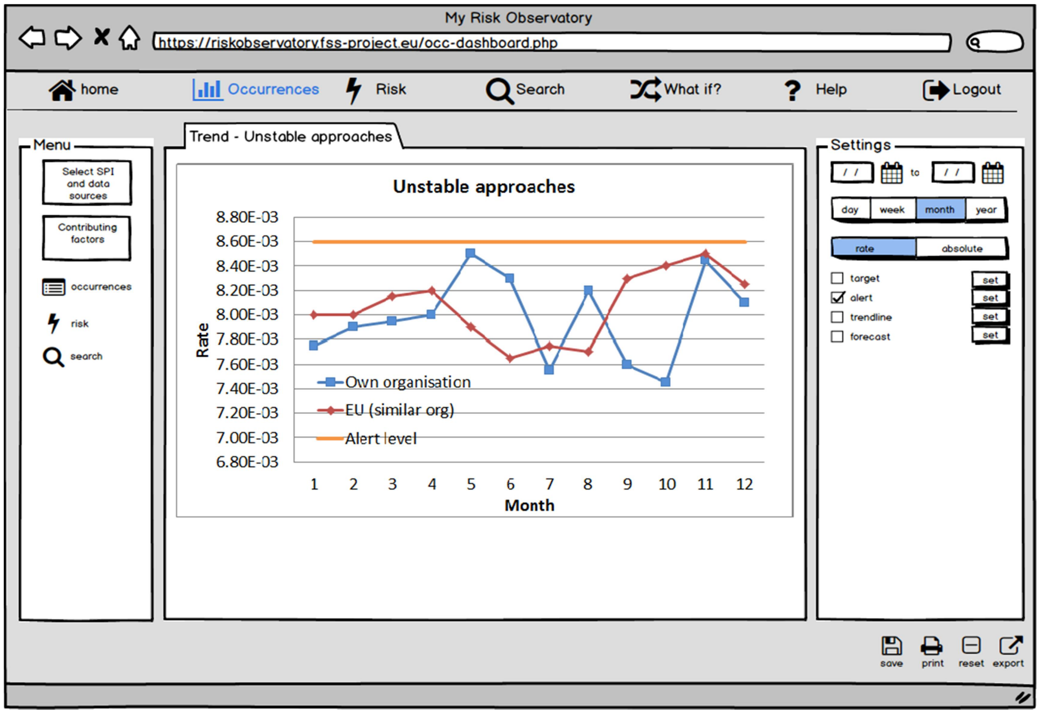

Figure 4-2 Occurrences dashboard

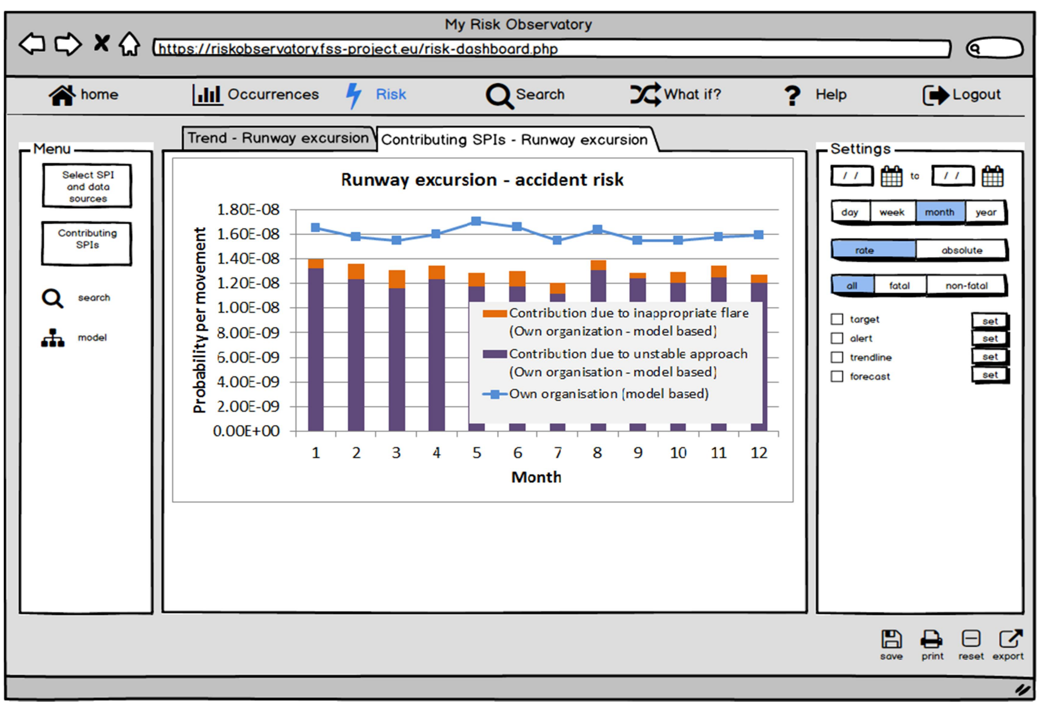

Figure 4-3 Risk dashboard

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Figure 4-4 shows a screenshot of a dashboard that can be used to search for hazards, occurrences, best practices, mitigation actions stored in a database in the Risk Observatory. The idea is that other stakeholders share such information and best practices, which are made available to other organisation through the search dashboard. A "Google" type of search engine is intended.

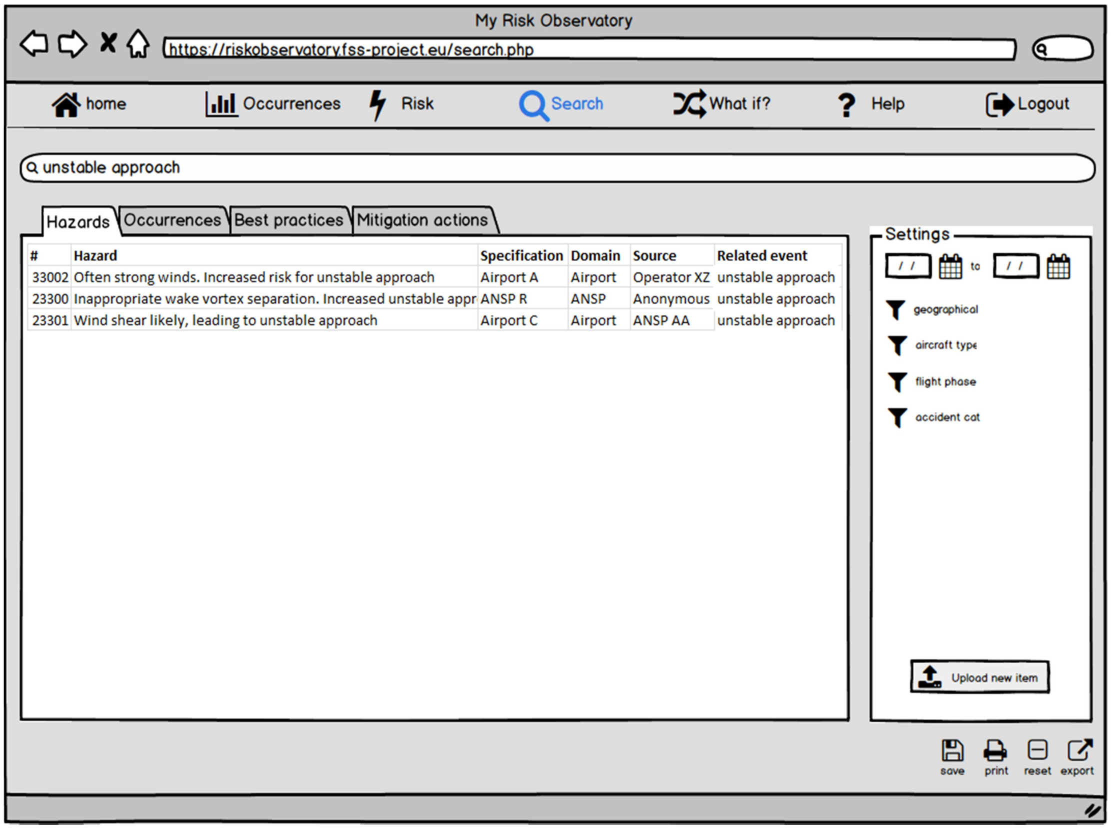

Figure 4-4 Search dashboard

Figure 4-5 shows the what-if analysis dashboard where the user can perform comparative analysis of different SPIs and their effect on accident risk. This shows the relative importance and effect of a change in SPI on accident risk. The user can select SPIs and associated accident risks (accident types) and then assess the impact of changing the frequency of occurrence of certain SPIs on the accident risk level. The what-if analysis functionality makes use of risk models in the background.

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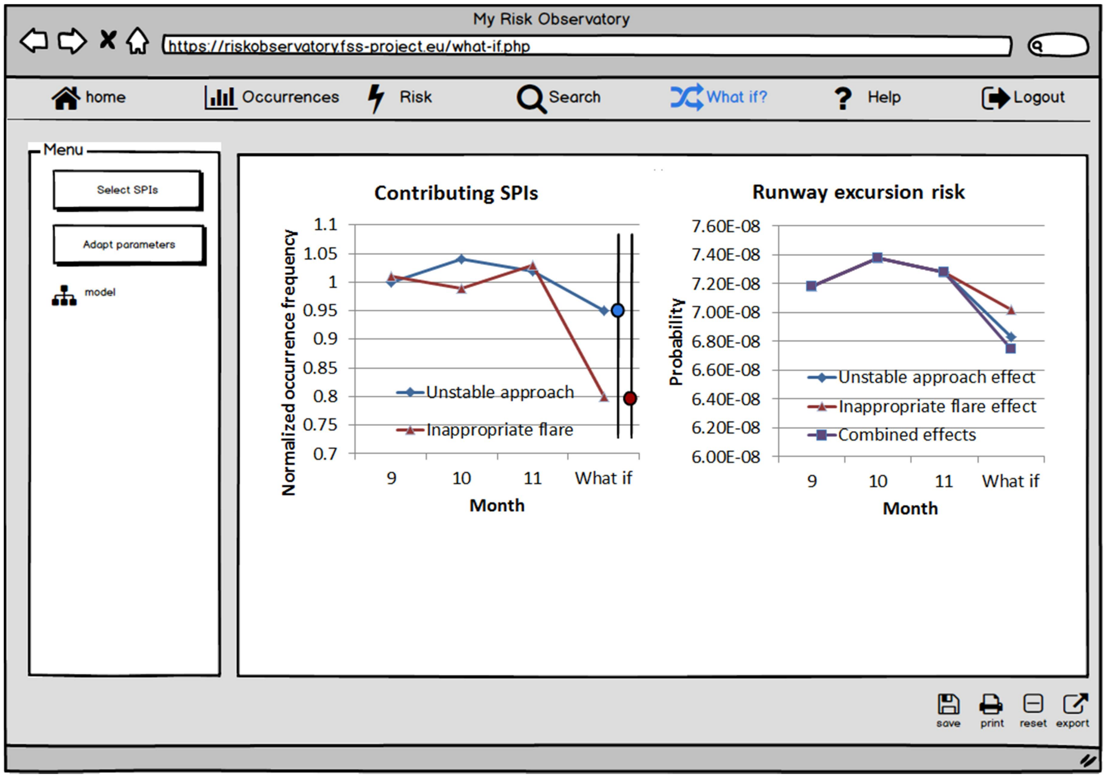

Figure 4-5 What-if analysis dashboard

4.4. The updated prototype

4.4.1. Overview

The Risk Observatory (RO) is realised as a Software (SW) platform that serves as a support tool for safety management. Based on the requirements raised from the most relevant stakeholders and following the architecture and functional designs, the most important functionalities were selected to be developed and implemented into a prototype that is able to illustrate the full potential and benefits of such a SW platform for safety management. The RO is built in order to be able to acquire, fuse and structure safety data and translate it into actionable safety information: output that helps the user to distil safety intelligence to allow the implementation of appropriate measures to positively influence safety - i.e. reducing the serious incident and accident probability.

Software aspects of the Integration of the backbone model into the Risk Observatory: Currently the Backbone models are manually developed as standalone excel files that cannot easily be integrated in a web-based architecture for the Risk Observatory.

- **Software architecture:** propose a software architecture that enables the integration of the backbone models in a web-based implementation of the Risk Observatory;

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- **Guidance for the inclusion of Backbone models into the Risk Observatory:** explain how to use existing tools to implement the integration of the Backbone models into the Risk Observatory implementation.

In the Risk Observatory it is the intention to combine risk models in order to compute safety indicators. Domain specific models for the ground segment of the ANSP domain and for the Aircraft manufacturer domain could be described as fault-trees. It is considered that in the RO it would be simpler to describe all the models at all levels of description using the fault-tree notation. Modern fault-tree tools are able to deal with fault-trees including negations and multiple top-level events.

4.4.2. Software architecture

The previous figure was used to illustrate the software architecture proposed for the implementation of the Backbone models into the Risk Observatory. The figure shows two streams of activities that relate with the two main functionalities studied in FSS P4:

- The bottom stream relates collected data (FDM data, occurrence data) and the occurrence dashboard of the RO,
- The upper stream relates the results of domain specific risk models with Risk index computation and visualization in the RO.

Hence explanations will be provided about the items of the figure that are labeled from 1 to 8 in orange or yellow circles. The orange circles are used to label the inputs or outputs of the integrated risk assessment framework. Yellow circles are used to label the internal functionalities of the integrated risk assessment framework.

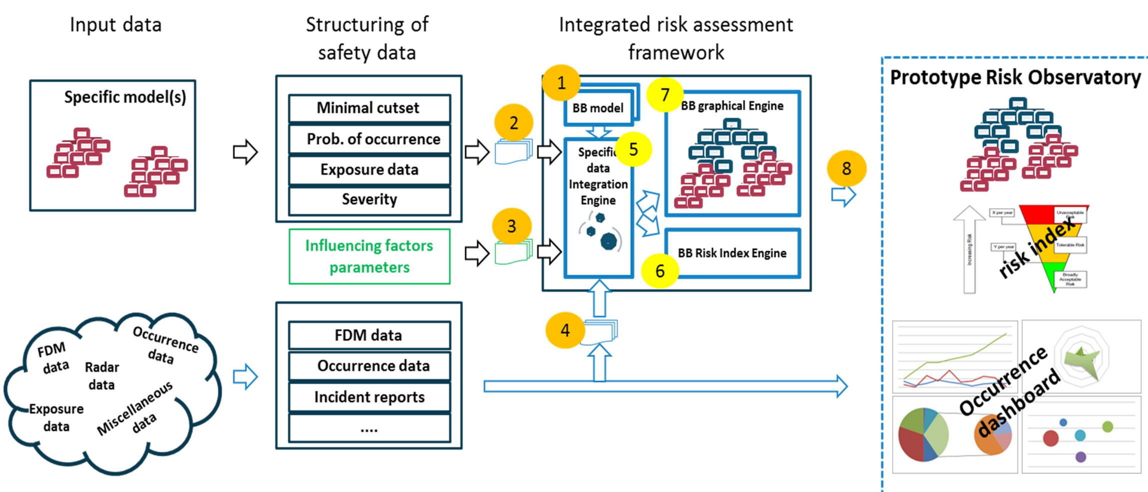

Figure 4-6 Implementation of the integrated risk assessment framework

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Inputs and outputs of Integrated Risk Assessment Framework:

1 **A library of predefined Backbone models**: each backbone model can be described as two open PSA files (one describing the logic and the other one the default probabilities of generic contributors)

2 **Results from the domain specific models**: each domain specific result can be described as two open PSA files (logic, probabilities). Each domain should also provide information needed to perform unit conversion (average flight time, average number of aircrafts controlled by one ATS unit, average exposure time).

3 **Influencing Factors parameters**: the weight, probabilities and values of an Influencing Factor (IF) should be stored in the Integrated Risk Assessment framework, this will enable the computation of the rectified weight of the IF and use this in the computation of the risk index;

4 **Alternative quantitative information computed from collected data**: it could be possible to directly compute the probability of some generic contributors on the basis of collected data, in that case these probabilities could be stored in a new open PSA file.

8 **Risk index**: the results from the computations performed by the integrated risk assessment are sent to the RO in order to be visualized.

Functionalities of the Integrated Risk Assessment Framework:

5 **Data Integration Engine:** this tool integrates the backbone and specific models and prepares all the inputs needed by the Risk Index Engine (integrated fault-tree, probabilities, relevant IF, etc.).

6 **Risk Index Engine:** this tool takes as input the fault-tree prepared by the Data Integration Engine and computes risk index in the form of probabilities of occurrence, importance factors, sensitivity analysis results, etc.

7 **Graphical Engine:** this tool graphically displays the integrated fault-tree representing the combination of the backbone model and the domain specific models.

4.4.3. Software overview

At this stage, the RO prototype provides two major functionalities, namely: Risk based SPI (Safety Performance Indicators) analysis and “What if” analysis. Besides these functionalities, a set of generic functionalities are put in place to allow, for instance, user authentication and personalization of the RO.

All the major functionalities are accessible through a specific section available in the main menu. The main menu is fixed bar, positioned at the top of each page, allowing the navigation between major functionalities throughout the entire application.

Within each functionality context, a specific auxiliary menu, the options menu, will be available, if needed. This menu is visible as an expandable column positioned in the left side of the page. This menu will allow

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for filtering, criteria setting and load or save of previously defined scenarios. For each functionality, the specific options available in this menu will be described in the following chapters.

4.4.4. Login page

The login page, as shown in Figure 4-7, is the first page shown in the RO. It functions as a gatekeeper for the platform, presenting the user with a simple form to insert his/her access credentials. These credentials, a set of email and password, shall be manually attributed to the user by the RO administration to authorized individuals.

Upon validated request the system will redirect the user to the home page, otherwise, if the credentials are not correct the "Login page" will be presented again, with an error message alerting the user that "The email or password are not correct, or the user does not exist. Please try again or contact the administration."

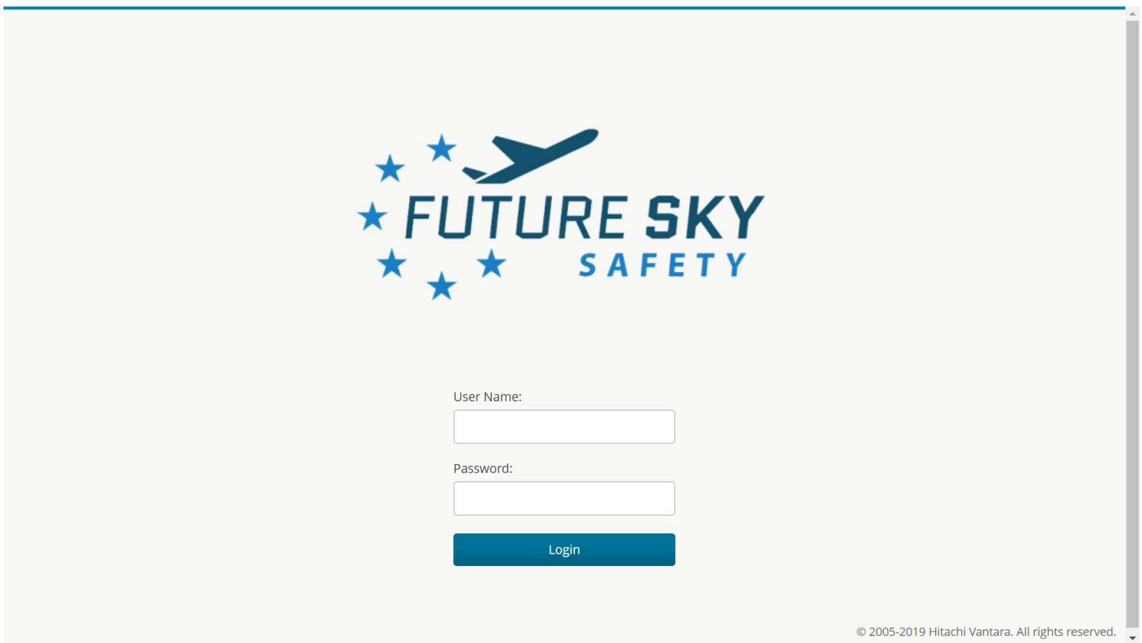

Figure 4-7 Login Page

4.4.5. Main menu

The navigation through the RO functionalities is assured by the main menu. The main menu is a horizontal bar, fixed at the top of each page, and it is present in every page of the platform thus allowing the user to choose between the available major functionalities at all times. Figure 4-8 illustrates the main menu.

Figure 4-8 Main menu

The main menu is composed of five items:

- Future Sky Safety will redirect the user to the home page;
- Risk will present a submenu showing the available risk models. When clicking in any item of this sub menu the user will be redirected to a dashboard analysing that specific SPI;
- What if will load a page where the user will be able to set specific conditions to any of the available risk models and compare the results against results stored within the RO;
- Settings. This item has a submenu showing the available setting options to the user. The options available will depend on the user's role. A regular user is only able to edit their Account information. The Administrator role is able to edit their own "Account" information and to access the system back office from this menu.
- Logout will end the user's session.

4.4.6. Home page

The home page is the main page of the RO, and it is the first page the user will be redirected to, after a successful login. The main goal of this page is to provide an overview of the system and to provide interaction and navigation means to further explore each result in detail, or to show any specific, but important, dashboard. For instance, the homepage can be set to provide an overview showing a trend-line or historic perspective of the most important risk and occurrence based SPIs. These visualizations can also provide a simple comparison between the generic scenario and a saved user scenario, and have click-through actions targeting to a dedicated page of the selected SPI.

Currently, by default, the home page is showing the Total Aviation System Risk Picture. The Home Page content space is configurable, meaning that any adaption if what is described in this section is possible. However, the main objective of this page should remain the same. Figure 4-9 shows an example of the Home page.

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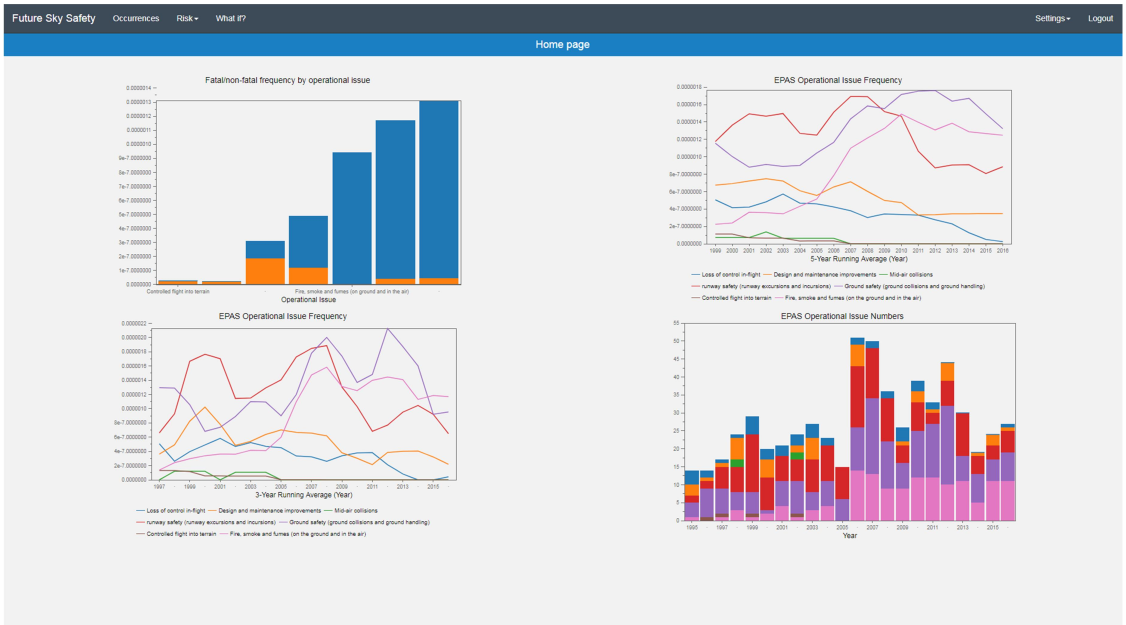

Figure 4-9 Home Page

4.4.7. Risk dashboards

One of the fundamentals of the RO is to integrate a complex integrated risk framework, that is capable of integrating domain specific models and inputs into a cross-domain, but risk specific engine, providing a model based risk analysis to the user. The risk dashboards provide, for each of the available risks, an overview of the risk analysis over time. The user can access these dashboards by accessing the "Risk" button on the menu. A sub menu will drop, presenting to the user all the available risk models. When selecting one of the risks the corresponding risk dashboard will load.

4.4.8. What if scenario

The "What if?" functionality allows the user to set specific conditions for all the available variables for each risk model. The objective is to simulate new scenarios and to be able to compare the result against the baseline and previously saved results. This functionality is available through the "What if?" button present in the main menu.

As in the other dashboards, the "What if?" page is divided in two vertical spaces: the larger area on the right side is the main area, in which the results of the configurations set by the user will be shown and the smaller section on the left side of the window is the Options menu.

In the main area of the 'What if?' dashboard, the user may find the results of the calculations based on the selected options. This area will be updated whenever an option or input value is changed.

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4.5. Evaluation of the prototypes

A positive response on the demonstrated functionalities and design of the early prototype was received from interviewed stakeholders [17]. The most interesting features were found to be the risk dashboard, the search dashboard and the what-if analysis dashboard. The general opinion on the occurrences dashboard is that this sort of analysis is already done by most organisations. The possibility to benchmark safety performance in the occurrences and risk dashboards received mixed feedback. Some stakeholders appreciate this feature, whereas others are more reluctant to compare safety performance and question the feasibility and added value of benchmarking their operations. During the feedback sessions, concerns were raised on different topics, including accessibility of data, reliability and validation of risk models, lack of standardisation and criteria, and lack of context information to understand the occurrence and associated risk.

Today, the challenge for the aviation industry is to conduct safety risk management and safety performance monitoring from a systemic perspective, not from the perspective of a single organisation or single domain. The Risk Observatory could create added value in this system-wide risk assessment by addressing questions like: what are the risks that have to be dealt with system-wide? What risks can be dealt with together and which ones by each organisation? Airlines are required to report certain safety related events to authorities (as required by EU directive 376/2014 [6]). The Risk Observatory is a type of tool that will be needed to put the reported data to good use and get useful information out of the data repository.

During the evaluation of the initial RO with stakeholders, recommendations were given. These included:

- Develop an approach to build trust in the risk models and their output used in the RO. Therefore, it is recommended to address validation and verification of the risk models applied in the RO, especially the risk models that generate results for the risk dashboard and what-if analysis dashboards.
- Identify software applications on the market for implementation of the Risk Observatory prototype, and assess the need and feasibility to develop specific software applications for the implementation of (specific aspects of) the Risk Observatory prototype's functionalities and design.
- Consider a method to ensure that contextual information can be maintained during data fusion and made available in the RO dashboards. It is recommended to demonstrate in the RO prototype (e.g. through use cases) the way in which contextual information will be available to the end user.
- Address data collection to populate the RO prototype as soon as possible to ensure timely access to data needed for further development of the RO prototype, including the demonstration of use cases.

A portion of RO's required features can be developed using existing, commercial software applications. The development of an occurrence dashboard can for example be easily performed using Tableau. On the other hand, the prototype RO has some innovative functionalities (e.g. risk models, a risk picture, the what-if analysis) which are most likely not available in current software applications, and require dedicated software development. This has led to the further development and implementation of an updated RO. The result of trials by service providers with the updated RO is documented in a separate study [26]. This concerns the RO evaluation by an airline (KLM) and an aircraft manufacturer (Airbus).

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5 USE CASES

5.1. Introduction

Having a true knowledge of the level of safety is important in order that risks can be appropriately managed. Clearly for safety to be improved, a key process is the monitoring of key parameters with the intention of improvement and this is one of the primary purposes of the RO. It is possible to divide the potential use of RO into three different themes. First of all, it is possible to understand the top risks using RO. This can be used for prioritization of safety actions. Second of all, it is possible to identify hazards and causal factors in more detail. This is particularly useful for service providers, who are looking for mitigations of risks in their operations. Examples of such analyses are provided in a separate document (trials of service providers with the risk observatory [26]). Last but not least, RO should be able to provide support for defining safety objectives and surveillance, and for risk based oversight.

This chapter discusses and presents examples of five different possible use cases by the authorities[4].

1. Understanding of top risks in a country;
2. Support for definition of safety objectives;
3. Support for oversight of organizations;
4. Integral Safety Assessment related to the airport growth;
5. Enrichment of occurrence data from Mandatory Occurrence Reports.

5.2. Use Case 1: Understanding of top risks in a country

5.2.1. Approach

States can prioritize operational risks for a working SSP. In order to understand top risks of a State, it is necessary to define operational risk categories which cover the aviation system of a State. Once the categories are defined, RO can assist States to establish historical trends for each of the operational risks and create yearly risk pictures for the aviation system. As an outcome, States will be able to prioritize operational risks for the particular SSP. This can be done by producing Total Aviation System Risk Pictures.

This approach is illustrated through an analysis of incident/accident data in European Member States. A similar approach can be conducted for an individual Member State by considering only data for that State.

The approach is to quantify safety performance indicators that measure the actual progress with respect to main safety issues. This study is to 'Produce a safety indicators commentary at regular intervals with respect to the main safety issues in aviation (e.g. loss of control in-flight, mid-air collisions, runway safety, ground safety, controlled flight into terrain and fire, smoke and fumes).' Note that an annual European high-level safety analysis is undertaken by EASA which also provides a comprehensive risk view. To satisfy the objective to produce a safety indicators commentary at regular intervals with respect to main safety

[4] Trials of service providers are performed with the existing RO [26]. The Use Cases for the authorities are based on publicly available occurrence data combined with (simulated) data, using NLR's FLexible Operational Repository for Integral safety assessment (FLORIS).

issues in aviation, quantification of accident scenarios has been performed according to the Event Sequence Diagram methodology used in the Causal model for Air Transport Safety (CATS) [29]. The quantification process to create the Baseline Risk Pictures is built on previous work conducted by NLR in the ASCOS project [27]. Quantification was done on the basis of the operational issues in commercial air transport by aircraft as defined for the EPAS 2016 – 2020 [5]:

- Loss of control in-flight
- Design and maintenance improvements
- Mid-air collisions
- Runway safety (runway excursions and incursions)
- Ground safety (ground collisions and ground handling)
- Controlled flight into terrain
- Fire, smoke and fumes (on ground and in the air)

The data analysis performed assigns frequencies per flight to each operational issue and thereby provides a prioritisation of actions, based on accident/incident frequency and fatal accident rates[6].

Table 5-1 Basic data query

Data	Criteria
Occurrence class	Accidents and Serious incidents
Operation type	Scheduled revenue ops, Non-scheduled revenue ops
Aircraft category	Fixed wing
Aircraft mass group	> 5,700 kg maximum take-off weight
Aircraft propulsion type	Turboprop, Turbofan, Turbojet

5.2.2. Risk picture 2016

To calculate the probability of occurrence of the main operational issues, the total number of accidents and serious incidents related to the operational issues has been divided by the exposure data. The exposure data of flights in EASA member states with commercially operated (scheduled and non-scheduled) turbine aircraft with a maximum take-off mass of 5700 kg or heavier is calculated to be 138,937,650 flights. The exposure data has been derived from the NLR database and complemented with Eurostat data [31] for scheduled and unscheduled flights in EASA Member States. The frequencies of the operational issues are presented in Table 5-2.

[5] The EPAS 2016-2020 has been used for this study, and production of the FSS Risk Pictures 2016 and 2017. The latest EPAS covers the period 2019-2023, and introduces a slight renaming of the operational safety issues.
[6] The analysis considers Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, United Kingdom, Iceland, Liechtenstein, Norway, Switzerland.

Figure 5-1 also provides an indication of the share of fatal accidents in the total number of accidents and serious incidents.

Table 5-2 Frequencies of operational issues

EPAS operational issues	Accident/serious incident frequency per flight	Fatal accident frequency per flight	# fatalities (1995-2015)
Loss of control in-flight	3.24E-07	1.8E-07	513
Design and maintenance improvements	5.10E-07	1.24E-07	277
Mid-air collisions	2.88E-08	1.44E-08	86
Runway safety (runway excursions and incursions)	1.21E-06	4.32E-08	241
Ground safety (ground collisions and ground handling)	1.36E-06	5.04E-08	7
Controlled flight into terrain	2.91E-08	2.91E-08	249
Fire, smoke and fumes (on ground and in the air)	9.22E-07	3.6E-10	0

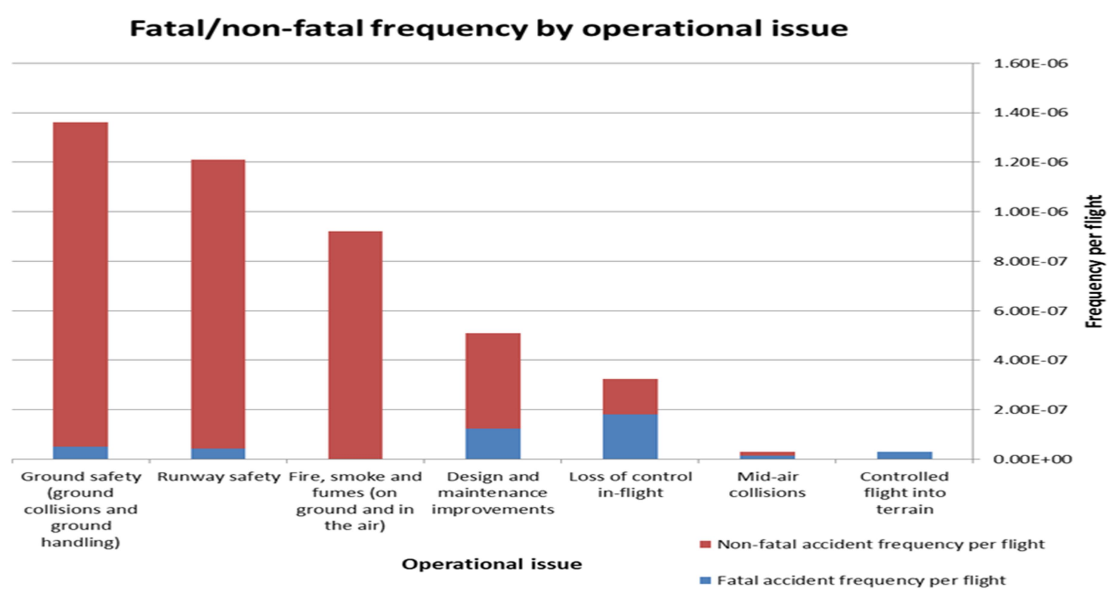

Figure 5-1 Fatal/non-fatal frequency by operational issue

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5.2.3. Risk Picture 2017

To calculate the probability of occurrence of the main operational issues, the total number of accidents and serious incidents related to a specific operational issue has been divided by the exposure data, which has been calculated to be 150,470,286 flights. The exposure data has been derived from the NLR database and complemented with Eurostat data [31] for scheduled and unscheduled flights in EASA Member States. Frequency of operational issues is given in Table 5-3.

Table 5-3 Frequencies of operational issues

EPAS operational issues	Accident/serious incident frequency per flight	Fatal accident frequency per flight	# fatalities (1995-2016)
Loss of control in-flight	3.12E-07	1.86E-07	628
Design and maintenance improvements[1]	4.91E-07	1.21E-07	279
Mid-air collisions	2.66E-08	1.99E-08	86
Runway safety (runway excursions and incursions)	1.17E-06	3.99E-08	128
Ground safety (ground collisions and ground handling[2])	1.31E-06	4.65E-08	7
Controlled flight into terrain	2.69E-08	2.69E-08	249
Fire, smoke and fumes (on ground and in the air)	9.44E-07	3.32E-10	0

To include the occurrence severity, a severity classification is added to the accident/serious incident frequency. A distinction is made between the severity classes of accidents and serious incidents. A risk matrix is compiled in Figure 5-2, which combines the severity and frequency of the EPAS issues. It should be noted that the risk matrix would look different in case the number of fatalities is used on the vertical axis. This may lead to a different prioritization of operational issues. This is addressed in Section 5.2.4.

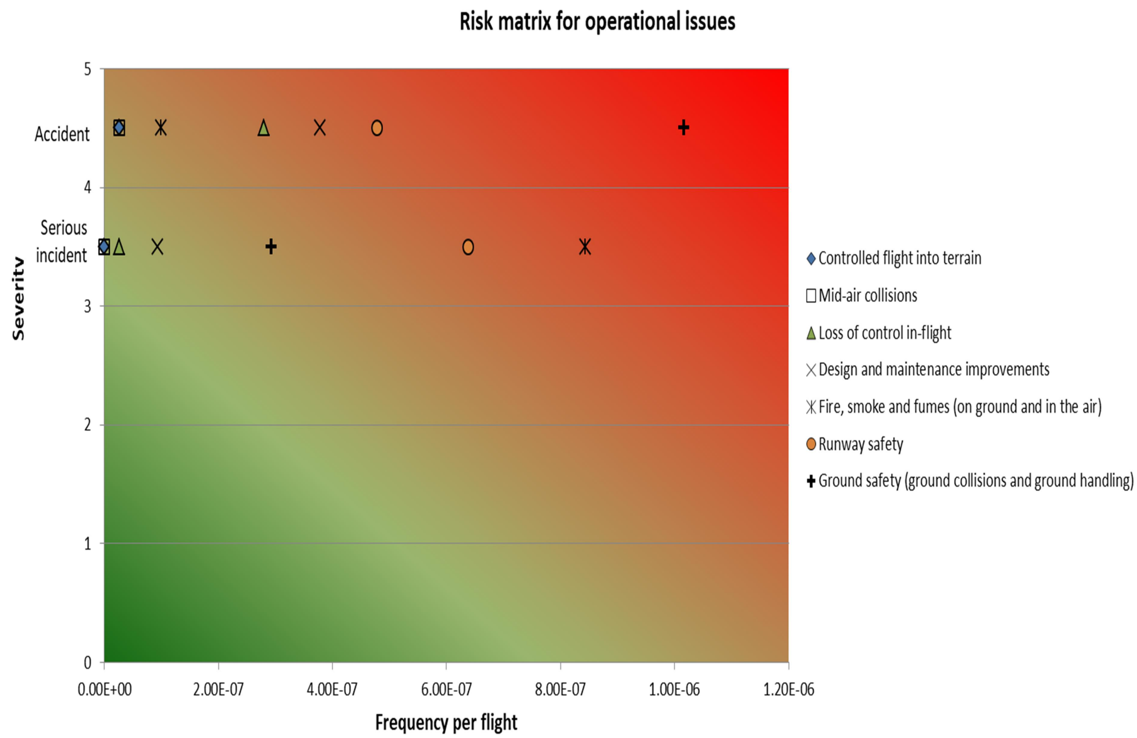

Figure 5-2 Risk matrix of operational issues

5.2.4. Risk Picture 2018

The basic data query resulted in a total of 1594 occurrences for the year 1995-2016, which was expanded by occurrences for 2017 (8 accidents and 5 serious incidents in scope) and 2018 (14 accidents and 76 serious incidents in scope). The final dataset on which the quantification of the main operational issues is based contains therefore 1697 accidents and serious incidents [23]. Figure 5-3 shows the progress of accident/serious incident frequency by operational issue as running average over 3-year intervals and Figure 5-4 as a running average over 5-year intervals.

A downward trend is observable for most operational issues in period 2015-2018[7].

[7] Only the LOC_I seems to move a bit upward but the frequency is still rather low.

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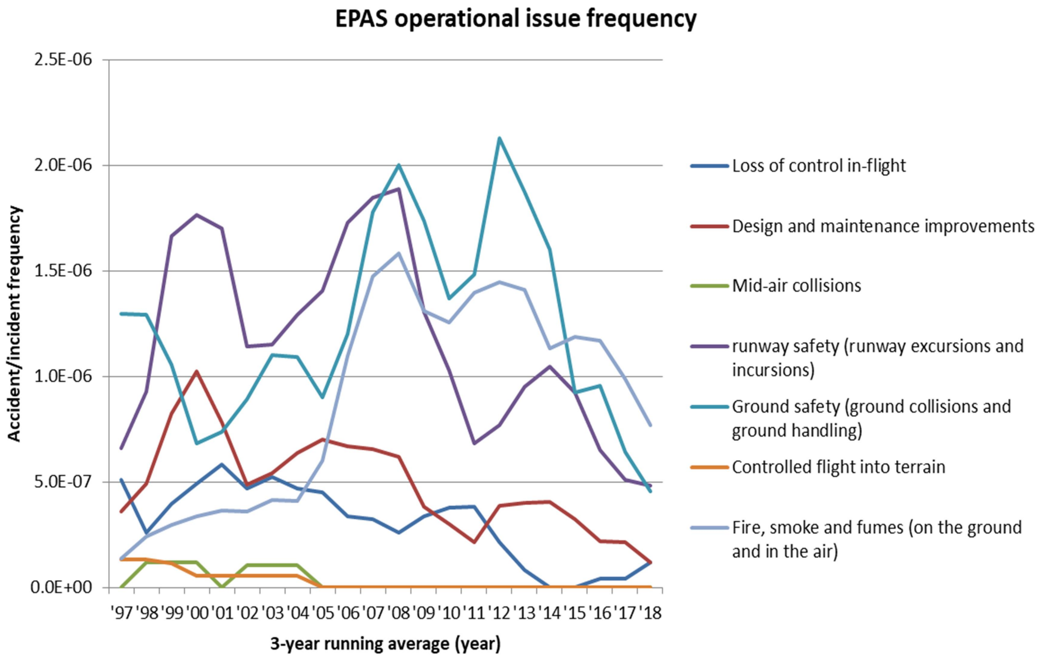

Figure 5-3 Accident/serious incident frequency by operational issue as 3-year running average

These Figures suggest a prioritisation of actions to lower the risk. Purely based on accident/serious incident frequency in the time interval 2014-2018, the following prioritisation may be applied:

1. Ground Safety (for the first 3 years) and Fire, smoke and fumes (for last 2 years)
2. Runway safety
3. Design and maintenance improvements
4. Loss of control in-flight
5. Controlled flight into terrain
6. Mid-air collisions

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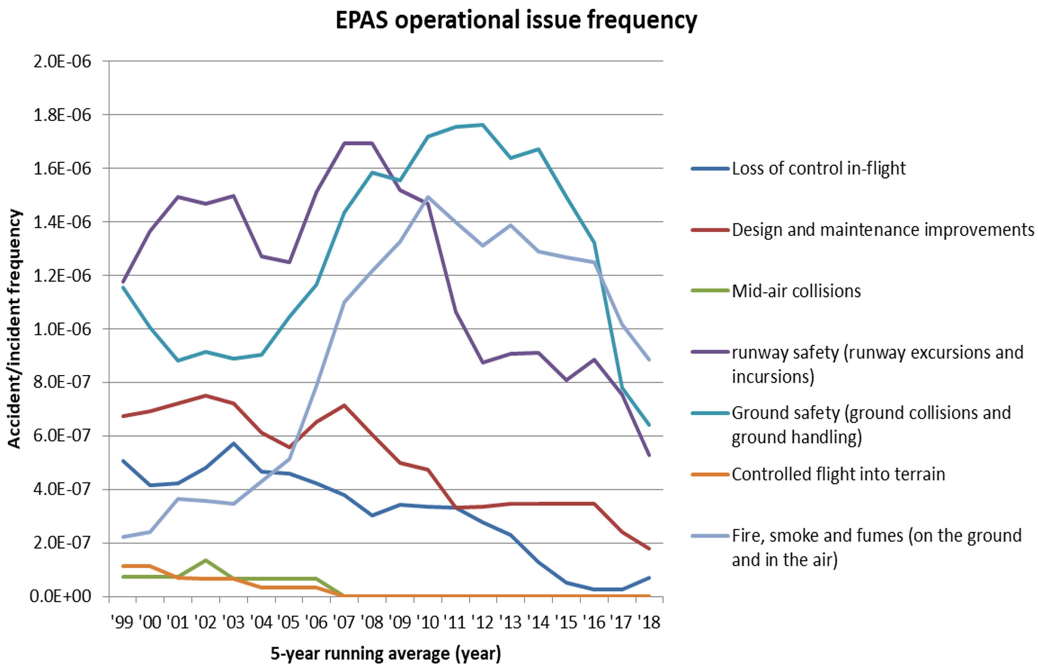

Figure 5-4 Accident/serious incident frequency by operational issue as 5-year running average

However, when the risk of operational issues is based on the fatal accident rate since 1995 [23], the following prioritisation is applied[8]:

1. Loss of control in-flight (648 fatalities)
2. Design and maintenance improvements (279 fatalities)
3. Ground safety (7 fatalities)
4. Runway safety (128 fatalities)
5. Controlled flight into terrain (249 fatalities)
6. Mid-air collisions (86 fatalities)
7. Fire, smoke and fumes (0 fatalities)

5.2.5. Summary & recommendations

The operational issues defined in the EPAS 2016-2020 have been used to create Risk Pictures. Such approach, taken for individual States, can be used to prioritise actions in State Safety Programmes[9].

The following recommendations regarding the RO and future Risk Pictures are given:

[8] To put this prioritisation into perspective, note that all Controlled flight into terrain accidents are fatal and a large share of the Loss of control in-flight and Mid-air collisions have fatal consequences. Reason why Ground safety accidents and serious incidents are listed as third priority is because each accident involves 1 fatality.

[9] Note that the latest EPAS, which covers the period 2019-2023, introduces a renamed of operational safety issues into: Aircraft upset in flight (LOC-I), Design, production and maintenance improvements, Airborne conflict (Mid-air collisions), Runway Safety, Ground Safety, Terrain collision, and Aircraft environment.

- Provide for more granulation of data by including low-severity, high frequency occurrences to enable proactive interventions by organisations using the Risk Observatory and to increase the trend monitoring capability of the Risk Observatory.
- A future European RO should follow the common European Risk Classification Scheme (ECRS) that the European Commission has developed according to Regulation (EU) No 376/2014 on reporting, analysis and follow-up of occurrences in civil aviation [6]. As regards quantification of operational safety issues, consistency with the definitions in the EPAS should be targeted.

5.3. Use Case 2: Support for definition of safety objectives

This Use Case demonstrates how the RO can help States achieve the ALoSP. Figure 2-1 demonstrates the relationship between the ALoSP and SPTs and SPIs and shows how these three factors represent the achievement of the State safety objectives[10]. Based on the safety objectives, the State or service provider plans or intends SPTs for SPIs over a given period of time[11].

Determining safety objectives requires to ultimately reach the ALoSP. Given a set-up threshold of unacceptable level of Safety (determined by a State or by EASA for the European region), it is possible to derive safety objectives by using the RO.

The RO is a tool where States can collect and analyse data to help identify the safety performance with one of its basic functions to present a dashboard with information. An example is presented in ICAO SMM. Figure 5-5 illustrates an objective for a 50% reduction of runway excursions by the year 2022.

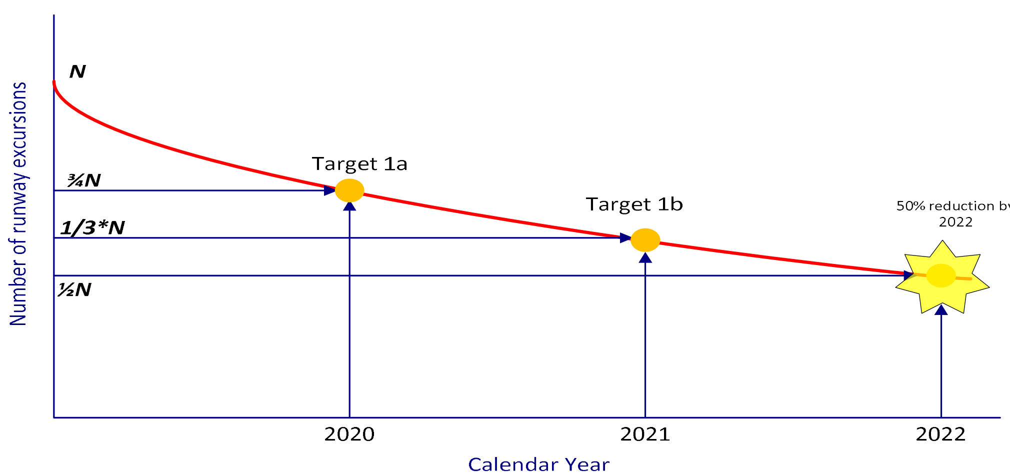

Figure 5-5 Example safety objective with different SPTs for SPI – number of runway excursions

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[10] State safety objective is a brief, high-level statement of safety achievement or desired outcome to be accomplished by the State safety programme or service provider's safety management system [ICAO Doc 9859].
[11] Generally speaking the State Safety Programme is valid for the duration of five (5) years. However, the safety targets and objectives may be adjusted throughout time.

The relevant SPI applied is 'the number of excursions each year. For the years prior to 2022, the SPT per year is set to monitor the development of the number of runway excursions.

ICAO further provides three SPTs.

- SPT 1a: Less than 78 runway excursions per million movements in 2019
- SPT 1b: Less than 64 runway excursion per million movements in 2020
- SPT 1c: Less than 55 runway excursion per million movements in 2021.

On the RO, an example like Figure 5-6 presenting the occurrences dashboard with the number of short landings can be provided. Using the visualised data, the State can conclude that the number of short landing occurrences is too high compared to other occurrences. Then the objective may be established as '50% reduction of number of short landings at the distance where they happen most frequently'.

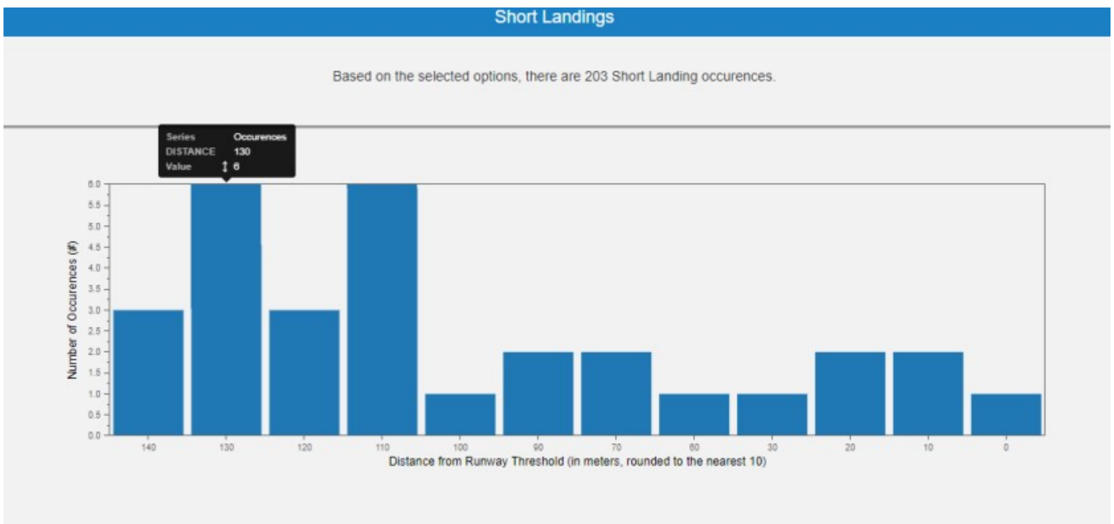

Figure 5-6 RO occurrences dashboard with information on short landings

The figure demonstrates that, for a given period, at the distance of 130 meters and 110 meters short landing occurrences happen the most frequently. The quantitative SPT can be established as 'the number of short landing occurrences at a distance of 130 and 110 meters.

Accordingly, SPTs like below can be created.

- SPT 1a: fewer short landings at a distance of 130 meters
- SPT 1b: fewer short landings at a distance of 110 meters

After having settled the objectives, SPIs and SPTs, States can even create an objective tree.

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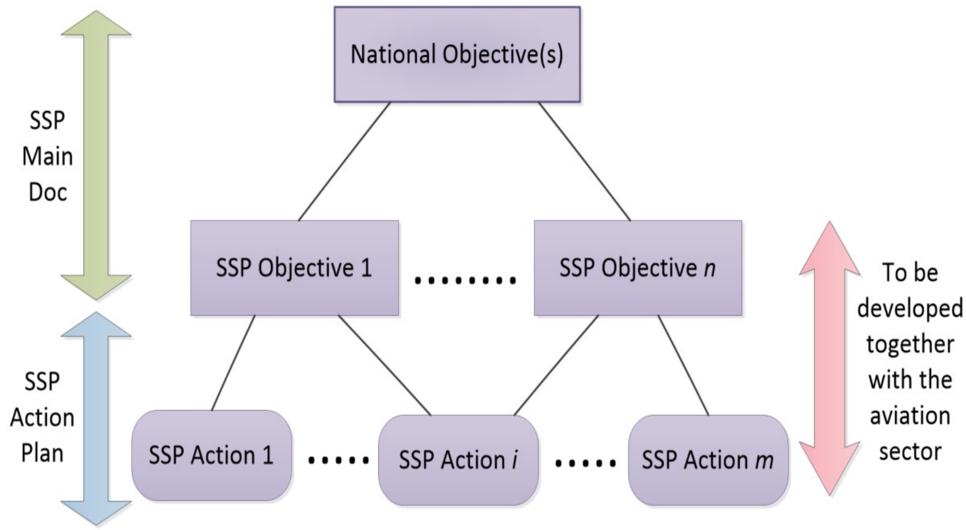

Figure 5-7 Example structure Objectives-Tree

To help explain where the national objectives originate, and to make sure that they are unambiguously formulated and scoped, an Objectives-Tree can be developed for use in (the establishment of) an SSP. An Objectives-Tree can clarify the relationship between different objectives, and avoid a mix of various objectives and actions in one single list. In Figure 5-7, an example structure of an Objectives-Tree is given [36]. At the top of the tree the National Objectives are described, which are then subdivided into several small objectives (SSP Objectives) that can ultimately branch into various specific actions to be addressed in the SSP Action Plan.

5.4. Use Case 3: Support for oversight of organizations

Continuous oversight is one of the responsibilities of States to ensure operational safety. This is demonstrated in the ICAO legal framework. As the concept of risk-based oversight has emerged since some time ago, the oversight practices are titling from checking compliance on a regular basis to continuous pro-active assessment and evaluation of potential risks whenever determined to be necessary. Depending on the probability and severity, oversight authorities can adjust human resources and oversight cycles.

States can assess and evaluate potential risks quantitatively and qualitatively. On the one hand, quantitative methods can be understood as computation and statistics, which are represented in equations and numbers. In this case, subjective judgments are the least required. On the other hand, qualitative methods require expert judgments on the basis of the knowledge and knowledge of inspectors. Both methodologies can independently play a role in States' oversight, but ultimately they can dependently but also effectively support each other's role in the oversight. In this sense, the RO can be a good quantitative method which may support inspectors' decision making.

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One of the outcomes of the RO support is visualisation of the quantitative risks. States should have prioritized operational risks or the list of indicators per operational issue to use the RO as a quantitative tool for the oversight.[12] After the prioritization, States can establish SPIs. While there are various SPIs that can be complex and contain difficult algorithms, there are also simple SPIs. Examples of simple SPIs are 'the number of certifications per different operations', 'the number of employees' or even 'the number of aircraft'.[13]

According to the described Use Case 2, State Y has determined that Risk X should be prioritised. Under the category, the national authorities have established SPIs per service provider for Operators A, B and C.

Table 5-4 Hypothesized situation of Operators in State Y using the SPIs selected

	No. of certificates	No. of employees	No. of aircraft
Operator A	5	12	3
Operator B	2	50	11
Operator C	5	10	1

With the help of the RO, it should be possible to create the following charts.

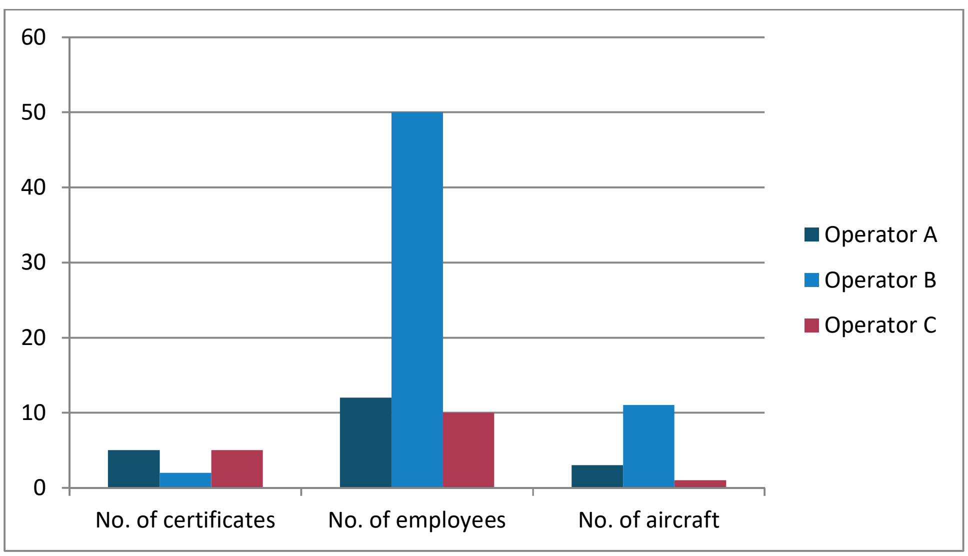

Figure 5-8 A visualised situation of Operators in State Y using the SPIs selected

[12] How to prioritize operational risks is described in Use Case 1 (described in sub-section 5.2).
[13] In Canada, such indicators are used to score service providers' risk level: https://www.tc.gc.ca/en/services/aviation/reference-centre/advisory-circulars/ac-sur-004.html.

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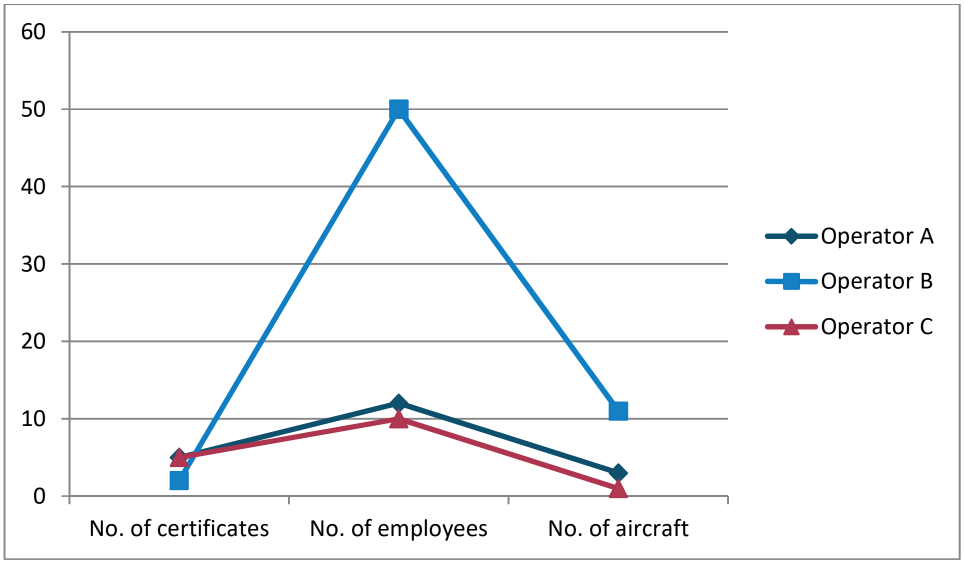

Figure 5-9 A visualised situation of Operators in State Y using the SPIs selected

Inspectors of national authorities may use these aids and determine that, for example, Operator B would require a shorter oversight cycle, in terms of the number of employees in comparison to Operators A and C.

If States would like to give specific scores in each SPI, it is also possible to grade and rank operators based on the scores given. For instance, Canada uses the point rating provided below.

Table 5-5 Impact value criteria and pointing rate of Canada

Criteria	Point rating
Number of certificates in different categories (including non-AOC certificates)	1 = 1 point 2 = 2 points 3 or more = 3 points
Number of employees	1-10 = 1 point 11-50 = 2 points 51 or more = 3 points
Number of aircraft	3 or less = 1 point 4-10 = 2 points 11 or more = 3 points

Accordingly, Operators A, B, and C may receive the grades as follows in Table 5-6.

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Table 5-6 Scores given according to the criteria of Canada

	Score for the no. of certificates	Score for the no. of employees	Score for the no. of aircraft	Overall
Operator A	3	2	1	6
Operator B	2	2	3	7
Operator C	3	1	1	5

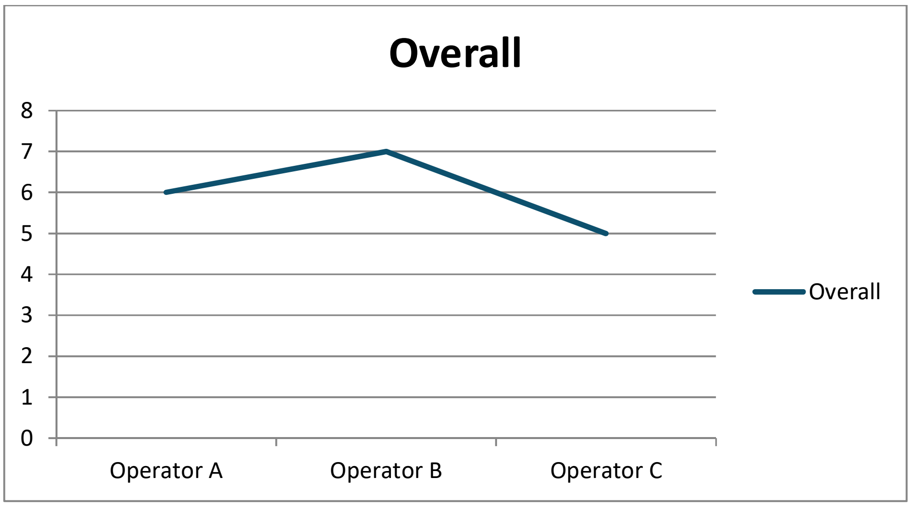

Figure 5-10 Overall grades of different operators

According to the chart above, national authorities may confirm that operator B requires the most frequent oversight and a higher number of inspectors.

5.5. Use Case 4: Integral safety assessment related to airport growth

Currently in the Netherlands, a discussion is ongoing on the maximum number of flights allowed per year at Amsterdam Schiphol airport. One of the prerequisites for growth is that the current level of safety is maintained. The Dutch Safety Board has analysed in detail the safety and operations at Amsterdam Schiphol Airport. The Board has raised a number of safety issues and recommended that an Integral Safety Assessment has to be conducted when Schiphol undergoes a major change in operation, like a growth of the number of flights per year. The study has been performed by NLR [37].

The associated Use Case is explained in Figure 5-11 below. The approach is based on assessing the impact on 36 aviation occurrence categories, as defined by the CAST/ICAO Common Taxonomy Team (CICTT) [38]. In the study report for Schiphol, 18 occurrence categories were selected as being relevant. These relevant occurrence categories have been grouped and summarized in Table 5-7.

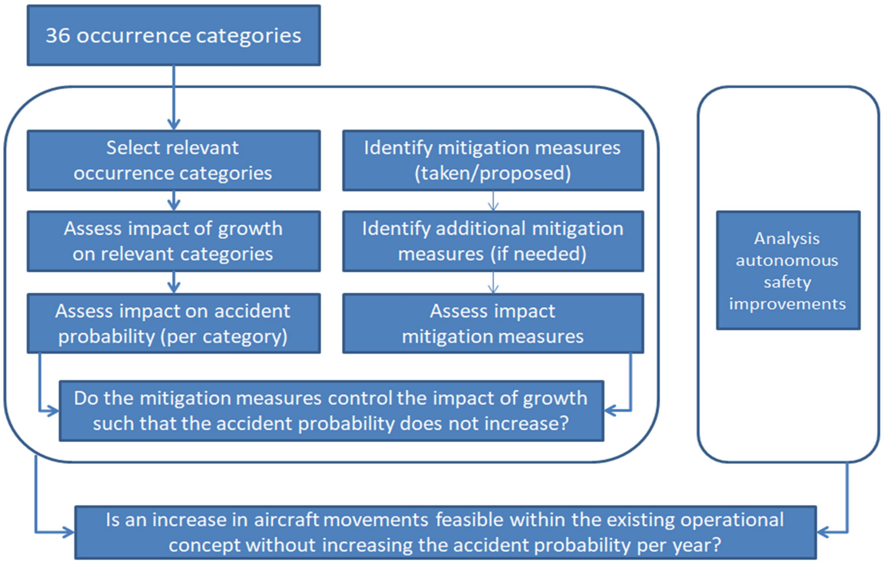

Figure 5-11 Approach to assess impact of growth on accident risk [37]

Table 5-7 Grouping of relevant occurrence categories [37]

Start and landing phase
Abnormal Runway Contact (ARC)
Runway Excursion (RE)
Undershoot/overshoot (USOS)
In the air
Airprox/TCAS Alert/Loss of Separation/(Near) Midair Collisions (MAC)
Controlled Flight In Terrain (CFIT)
Loss of Control – Inflight (LOC-I)
Fuel related (FUEL)
Turbulence Encounter (TURB)
On the ground
Ground Handling (GROUND – *note that the CICTT uses the term RAMP*)
Ground Collision (GCOL)
Runway Incursion (RI)
Loss of Control-Ground (LOC-G)
Other
Abrupt Manoeuvre (AMAN)
Aerodrome (ADRM)
ATM/CNS (ATM)
Birdstrikes (BIRD)
Navigation Errors (NAV)
System/Component Failure or Malfunction (Powerplant) (SCF–PP)

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In principle, the RO can play a role in such discussion and it could help to identify which occurrence categories are affected by growth. Looking at the past, the RO would need to register the type of occurrences taking place at an airport and record the frequency per occurrence type. This capability is in particular useful for risk analysts to monitor the development of each occurrence type in relation with the airport development. The outcomes of the RO-tool can then help to define appropriate mitigation measures, should the experienced growth have had a negative effect on certain occurrence categories. This can be done based on occurrence data (if this is available).

However, it would be preferable if the RO can also help to determine the impact of *future* changes. Unfortunately, for predicting the future (expected) impact of further airport growth, the possible use of the existing RO is less clear. The RO would need to be able to predict the impact of each of the relevant occurrence types on the risk of an accident or serious incident. At present, only predictive backbone models for runway excursion and mid-air collision are implemented in the FSS research prototype RO. It would require a huge effort to develop similar predictive RO backbone models for all types of occurrences. NLR's study to support the Dutch government in deciding the way forward has used a more practicable and qualitative approach. This approach is supported by NLR's Flexible Operational Repository for Integral Safety assessment (FLORIS), instead of making use of the FSS RO.

5.6. Use Case 5: Enrichment of occurrence data

In the early stages of FSS, the risk that some input data for the RO is not available or the data provision has inadequate periodicity was identified. It was concluded that to mitigate this risk, operational and safety data sources available within NLR's Flexible Operational Repository for Integral Safety assessments (FLORIS) can be used and combined for use in the RO. In fact, this leads to new Use Cases, in which FLORIS can be used to generate input for the RO. One of these Use Cases is 'enrichment of occurrence data'. This relies on various forms and types of data and used data integration techniques for the enrichment of occurrence data from MOR's (Mandatory Occurrence Reports). To demonstrate the approach, and with approval of the Dutch CAA (Civil Aviation Authority), NLR used a dataset containing de-identified occurrence reports of occurrences reported in the national Dutch aviation system as mandated by EU Regulations No. 996/2010 and No. 376/2014. The dataset contained a wide variety of more 40,000 reports from the years 2014, 2015 and 2016. Even though the amount of occurrence reports was extensive, data quality of the dataset was identified as one of the drawbacks. For example, the free text parts of the occurrence reports were written in different languages contained spelling mistakes, domain specific vocabulary and many abbreviations. The structured text parts of the reports often contained no information at all and labelling was performed inconsistent. For these reasons, the data integration capabilities of FLORIS were used to contextualize the data and provide information that was initially not included in the occurrence reports. The following datasets were integrated in the occurrence data: air traffic data, ADS-B tracks and METAR data and radar data. In the following two sections, two example use cases to which the data integration process with FLORIS support contributed are described in more detail.

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5.6.1. Example 1: Pushback occurrences

The pushback procedure is one of the procedures during the turn around that is most prone to hazards. During the pushback there are various procedures to be followed, decisions to be made and communications to be done (according to a standardized protocol). On top of that, during the pushback, the workload on the flight deck is high since the flight crew must prepare the aircraft for taxi, communicate with ATC, communicate with the pushback crew and monitor the pushback procedure as a whole.

Any mistakes made during the pushback can result in incidents, serious incidents and even accidents as a faulty pushback may result in damaged equipment, injuries or even ground collisions. A safe and correct pushback relies on three different parties to be alert, vigilant, communicate and work according to the procedures, as illustrated in Figure 5-12.

With help of a machine learning technique called text mining, an algorithm was able to identify any occurrence reports related to the pushback phase. These occurrence reports were then extracted from the dataset and contextualised with help of data integration. Thanks to the data integration, additional information was added to the occurrence reports such as: aircraft destination, origin and registration, gate position of the pushback, lighting conditions and weather type. This use case did not make any use of ADS-B data, as most aircraft do not yet have their transponder on in this phase and ADS-B data on ground is considered inaccurate in most cases.

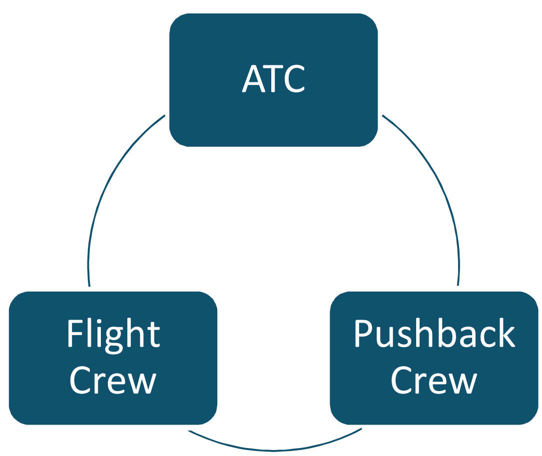

Figure 5-12 The three parties primarily involved with the pushback

Since occurrences occur at a certain moment in time, at a specific place, and usually with a specific aircraft or flight involved, it is possible to integrate occurrence data with other data with help of these common factors. For example, to integrate additional traffic data with pushback occurrences a date and time of the occurrence is required together with either: the flight number, call sign or aircraft registration. With help of these common factors, traffic data can be linked with the occurrence data since these same common factors are usually also incorporated in traffic data. This reveals additional information such as: gate position of the occurrence, aircraft destination or origin, aircraft type and nearby surrounding traffic

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at nearby ramps. Examples of the SPI's that can be generated with data integration are given in Figure 5-13 and Figure 5-14 (note: these plots are based on simulated data and do not present any actual data).

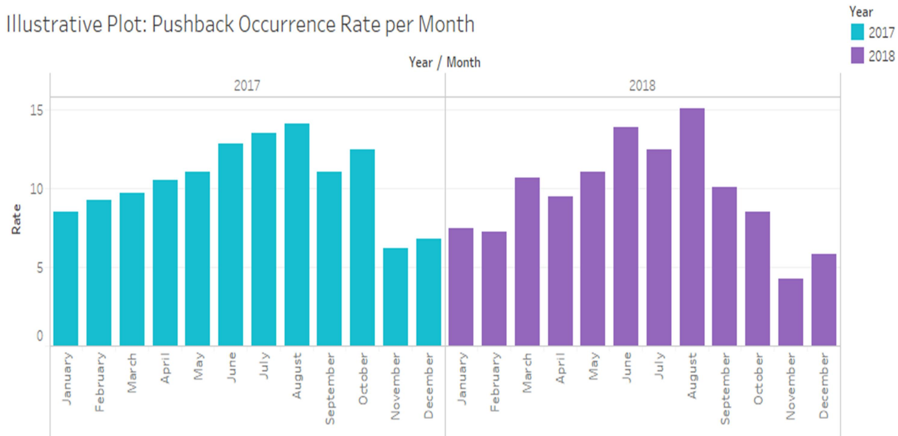

Figure 5-13 Illustrative plot displaying the occurrence rate for pushback occurrences per month

Figure 5-14 Illustrative plot displaying the occurrence rate for pushbacks per runway

With help of the data integration techniques of FLORIS, it was possible to attain additional information and insights regarding pushback occurrences. Among other things, it was possible to calculate occurrence rates besides just absolute occurrence numbers. These rates could then be filtered and sliced into various formats such as the pushback occurrence rate per: aircraft type, hour of the day, gate position, lighting condition and weather conditions. By doing so, additional causal factors related to pushback occurrences can be identified and based on a data driven approach. This example shows that the risk that input data for the RO is not available or has insufficient quality can be mitigated by enrichment using e.g. FLORIS.

5.6.2. Example 2: Go-around occurrences

Aircraft performing a go-around is nothing out of the ordinary. In fact, it is a standard procedure for unstable approaches or other operational drawbacks such as loss of separation, occupied runways and weather related phenomena (reduced visibility and wind shear). Due to these various factors that prompt flight crew to initiate a go around, there are numerous occurrence reports from both flight crews and ATC reporting this procedure.

However, due to the operational commonality of a go-around, reporters do not always feel the need to extensively describe the context in which the go-around occurred. This leaves lots of information missing for safety analysts that try to identify casual factors related to go-arounds. Also, for occurrence reports where the reporter does provide an extensive description of what happened, factual information like the runway used and weather conditions are not provided. Besides, depending on what the safety analyst is actually interested in, information might be situated in the free text part of the report, while it would be better to have it in the structured text part of the report as this prevents the analyst from having to read and label the report manually.

With help of keyword queries on the free text parts of occurrence reports, a subset of the occurrence reporting dataset was composed of several go-around occurrences. Thereafter, the data integration capability of FLORIS was used to compose a contextualised dataset with integrated additional information such as: aircraft destination, origin and registration, nearby air traffic, radar tracks, flight track, runway used, METAR and lighting conditions.

Just as with the data integration of pushback occurrences, the time and date of the occurrence were combined with flight number, call sign or aircraft registration to integrate traffic data in the occurrence dataset. Besides the traffic data, weather data and radar tracks were also integrated in the dataset by using the same data fields as with the traffic data. The data integration of the traffic data, radar tracks and weather data enabled extensive contextualization of go arounds that were reported with MOR's. The traffic data supplied valuable information concerning nearby traffic, the weather data provided information concerning wind (gusts), visibility, cloud base and thunderstorms and the radar tracks supplied an exact visualisation of the flight path the aircraft had flown. Some of the example visualisations are provided in Figure 5-15 and Figure 5-16 (note: these plots are based on simulated data and do not present any actual data).

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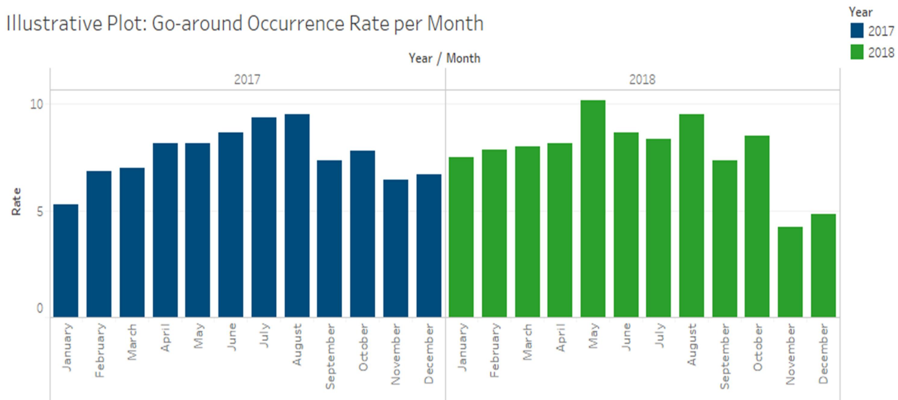

Figure 5-15 Illustrative plot displaying the occurrence rate for go-around occurrences per month

Figure 5-16 Illustrative plot displaying the occurrence rate for go-arounds per runway

Thanks to the data integration techniques of FLORIS it was possible to identify possible casual factors related to specific go arounds. Where information was lacking or more information, FLORIS provided additional insights from other sources. Moreover, it was possible to calculate go-around rates for various situations such as wind and visibility conditions. Also, thanks to the radar tracks that were integrated in the dataset, it was possible to visualise the actual flight track flown during the go-around and the subsequent landing.

Again, this example shows that the risk that input data for the RO is not available or has insufficient quality can be mitigated by enrichment using e.g. FLORIS.

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6 OUTLOOK

6.1. Introduction

The European Aviation Strategy anticipates that a Big Data project by EASA will 'enable a significant enhancement of analysis capabilities and sharing of large volumes of data, helping to improve safety in aviation through the use of information and communication technologies' [1]. Availability of this data is a prerequisite for development of a performance/risk-based regulatory framework [2]. A key decision will be the selection of the host organisation to house a 'Risk Observatory'. The host organisation, the Risk Observatory Organization (ROO), shall offer practical and technical support, academic credibility, and aviation industry acceptability. It will be important to ensure that the organisation is perceived as independent and with assurance that the output is of state-of-the-art quality, indeed substantially better than individual aviation organisations will be able to do by themselves. Also trust and neutrality is important since a lot of the data of different service providers can be used to gain an competitive advantage if used indiscreetly It is most likely that the host organisation will operate in the not-for-profit sector to minimise ethical concerns. The selection of the physical location of the RO would ideally be co-located with the host organisation but need not be if good communications and acceptable administrative arrangements can be constructed.

Different options for the organisation hosting a European RO can be identified [25]:

- <u>Option 1</u>: Establish a new, central body in the EU tasked to carry out the Risk Observatory. This body should be independent, not-for-profit, with good administrative arrangements.
- <u>Option 2</u>: Accommodate the RO in an existing, independent, not-for-profit organisation. This option is used in the USA, where MITRE is responsible for ASIAS. There are different not-for-profit organisations in Europe that may be used in a similar way, including the JRC.
- <u>Option 3</u>: Accommodate the RO in an existing organisation that is part of the government, industry, or part of government-industry cooperation (such as Data4Safety). As minimum, these partners should have access to the RO and be part of the data governance framework.
- <u>Option 4:</u> Accommodate the RO in EASA, within an independent part of the organisation, as feeder for the EPAS and as a basis for supporting new rulemaking or certification activities.

The European Commission considers it necessary 'to have a centralised system and to ensure that the data are used for safety only (guarantee without which the data owners, primarily the airlines, would not accept to share their data)' and states that this 'calls for a management by an independent authority that EASA can embody (sole aviation authority at European level that can guarantee that data will not be used for commercial purposes)' [2]. This brings forth the need for a data governance framework, describing who can take what actions with what information, and when, how and under what circumstances, using what methods. This framework should cover the overall management of the availability, usability, integrity and security of the data used. When data is shared and analysed, a total aviation system approach in the data analyses should be ensured.

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It will be beneficial to investigate to what extent use can be made of ICAO's integrated Safety Trend Analysis and Reporting System (iSTARS) toolset. The iSTARS is a web-based platform of safety and air navigation tools for States and industry to explore and analyse ICAO datasets, e.g. Accident/ Incident Data Reporting (ADREP) and the Universal Safety Oversight Audit Programme (USOAP). This data is typically provided by National Aviation Authorities, key providers and users of aviation safety data.

6.2. Data governance framework

Stakeholder involvement in the oversight and (strategic) management of the activities with a Risk Observatory is a key success factor. A challenge could be to develop and implement a governance structure in Europe, considering the number of Member States and possibly national interests. It is suggested that the steering group is formed by a limited number of representatives of the aviation community, from both industry and government. For instance, the seats in the committee could be occupied by: EASA and a few national authorities, unions, association of European airlines, airports and ANSPs. Steering group areas of responsibility could cover [25]:

- Define terms of reference, policy and procedures (e.g. on data protection, data handling, use of data, dissemination of results).
- Prioritisation and approval of studies and dissemination of study results.
- Determine the development/deployment strategy and future expansion goals.
- Oversee the management of the RO.
- Coordination with strategic partners and safety initiatives worldwide (e.g. ICAO's iSTARS, FAA's ASIAS, IATAs' STEADES, similar data sharing initiative in other regions of the world).

It is suggested that a user group is formed of members that provide data to the RO and/or make use of the RO dashboards/results. Figure 6-1 shows a potential data governance structure for the RO.

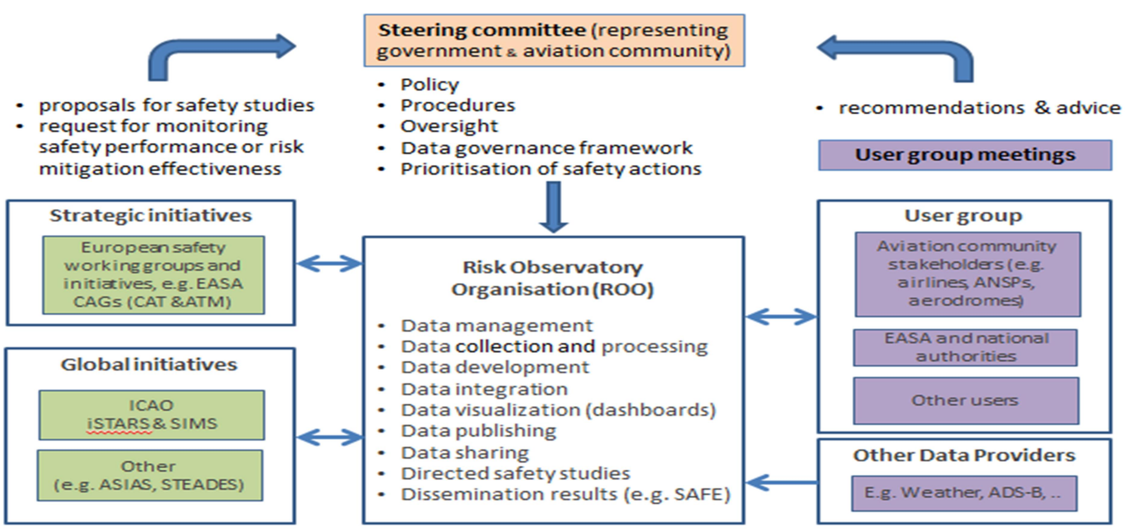

Figure 6-1 Potential data governance structure for a Risk Observatory

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Data4Safety considers setting up a Private Public Partnership (PPP) – a partnership between public bodies such as EASA or NAAs and the private sector, like airlines or manufacturers. Such a PPP would then support the alignment with, and support of, the European Commission strategy for transport (including synergies with maritime and railways strategies) and the EU Digital Agenda [7].

6.3. Scalability or ambition levels

The expectations and possible ambitions of stakeholders with respect to the RO were addressed in FSS P4 [25]. It was concluded that "The Risk Observatory shall be designed to be scalable against the growing number of users with respect to, at least: data processing times, data storage capacity, and availability. An incremental growth of the Risk Observatory usage is foreseen and essential to achieve the required effectiveness." It was recommended to use an evolutionary approach, starting small with the explicit intention of demonstrating usefulness of the RO. The scalability in ambition level applies to value proposition, services provided, and activities conducted. Apart from that, without changing the ambition level, the RO will be affected by an increasing participation by data providers. Technically, this requires capabilities to handle increasing data volume and data variety. Although in general all business model canvas building blocks could be affected by the level of ambition and scalability, this report will focus on the most relevant elements. For now, three levels are defined: a small, medium and large scale RO. Table 6-1 specifies expectations regarding the activities in safety management that the RO shall support for each of these ambition levels.

Table 6-1 Ambition levels for the RO: small, medium, large

SCALE		S	M	L
Value proposition	Analyse the safety data for directed studies and dashboards	■	■	■
	Provide individually tailored results to stakeholders		■	■
	Provide safety data to CAAs, EASA, EC		■	■
	Undertake safety studies on a cost recovery basis			■
Customer relationships	Self-service dashboard	■	■	■
	Automated or dedicated safety information		■	■
	Personal assistance			■
	User group meetings and communities	■	■	■
	International cooperation	■	■	■
Channels	Web-based dashboard	■	■	■
	Manual upload and processing of data	■	■	■
	Automatic B2B upload of data		■	■
	Regular safety info publications		■	■
	On demand safety studies	■	■	■
Customer segments	Remains equal for all scales	■	■	■
Key activities	Key activities	■	■	■
	Provide training, guidance and consultancy			■
Key resources	Key resources	■	■	■
Key partners	Remains equal for all scales	■	■	■
Cost structure	Fixed costs: increasing with scale	■	■	■
	Variable costs: increasing with scale	■	■	■
	Costs of safety publications		■	■
	Costs of dedicated safety studies			■

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Revenue streams	Government funded (Fully (F) or possibly Partly (P))	F	P	
	Revenue streams (possibly)			
	Fully self-supporting financially (possibly)			

6.4. Roadmap

To describe the roadmap, five phases are used: research, development, implementation, operation, and expansion. The success factors and five phases have been combined in more detailed roadmaps that describe the activities to be performed [25]. Figure 6-2 shows the proposed timeline.

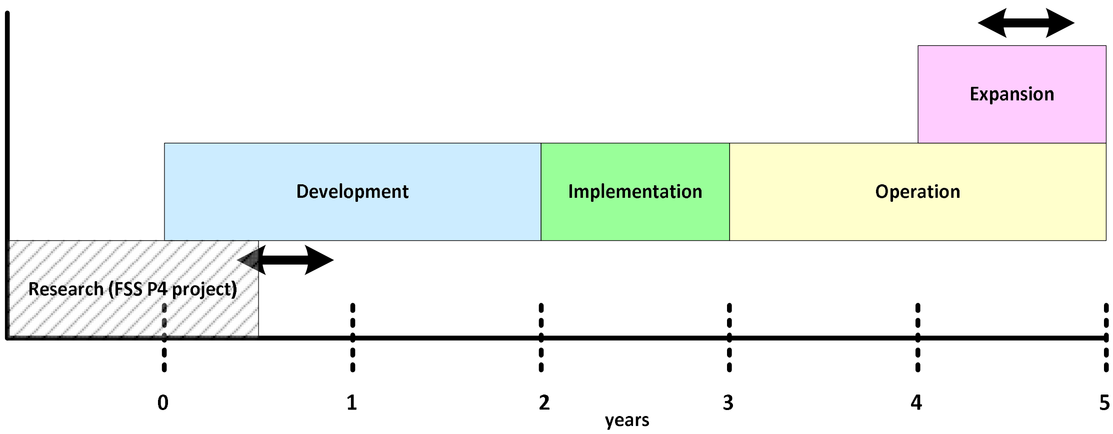

Figure 6-2 Roadmap and timeline

Research

Besides in FSS P4 "Total System Risk Assessment", which resulted in this study report, research is also being performed in SafeClouds [28]. FSS P4 develops a research prototype RO, including demonstration and evaluation of prototype technology to transform datasets into relevant safety information. The development of technical capabilities for data processing, data fusion, proactive/predictive data analysis in combination with risk modelling, and visualisation techniques are central in FSS P4. SafeClouds investigates the possible added value of data science and Machine Learning techniques.

Development

The RO will be handled by an organisation that collects, integrates, and analyses data and disseminates analysis results. This phase covers the further development of the analytical capabilities and tools.

Implementation

The RO will start small, with scalability to handle growth in stakeholders and volume and variety of data that is shared and managed. Initially, the RO will have a few "launching customers" who share data. The focus is on collecting best practices, hazards, mitigation actions, safety risk assessment reports, incident reports, etc. Collection of occurrence reports, FDM data or other data may develop over time. Open source data (such as meteorological data, ADS-B data, AIP) can be collected directly.

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Operation

In this phase the ROO is "up and running". On a regular basis data will be collected from the participating stakeholders. Data will be analysed to feed the standardised dashboards and safety studies will be initiated for specific topics of interest. Maintenance and upgrades of the technical capabilities (hardware and software) will be a continuous activity. Some training is also provided.

Expansion

Over time more organisations may be joining the ROO. With the expansion of the number of data providers, and consequently the increasing volume and variety of data, there will be a need to scale up the technical capabilities and infrastructure to process, store and analyse all data. It is also envisioned that with increasing participation, the number of safety study requests will increase and additional services (e.g. enhanced training and consultancy) will be provided. The RO shall therefore further develop knowledge, technical expertise and capabilities to remain effective and efficient.

6.5. Summary

This Section has provided an outlook on the next steps with the RO, i.e. expectations of the future and points of view on the data governance framework, scalability or ambition levels, and a roadmap.

It is recommended that there will be one operational Risk Observatory in Europe to efficiently and effectively use resources and avoid duplication of effort. The first initiative in that direction is taken by EASA with the feasibility study and proof of concept of a European big data programme for aviation safety (called Data4Safety). All the national aviation authorities should be able to connect with the RO. Important lessons can be learnt from similar initiatives such as FAA's ASIAS in the United States and mandatory occurrence reporting schemes. The main lessons learnt are [25]:

- Long-term funding strategy is essential;
- Promotional activities have to be developed and planned, and started as soon as possible;
- Added value has to be visibly demonstrated and proven as soon as possible;
- Data quality and quality control have to be ensured;
- Data governance has to ensure data protection, proper data use, dissemination of results, ...

The main challenges that are identified for the RO are:

- Development of a data governance structure in Europe will be more complex than for FAA's ASIAS, considering the number of States, different legal frameworks, different languages and cultures, and national interests. A central role for data governance should be with EASA.
- The ROO has to assure that stakeholders experience sufficient benefit and added value from sharing data compared to current practices. The RO shall be complementary to similar data sharing initiatives or analyses conducted already by the stakeholders themselves.
- The ROO needs to assure data quality to provide good quality analyses. Lack of data quality, lack of standardisation and other data processing issues (different taxonomies, corrupt data, lack of details, de-identification of data, etc.) may hamper quality and depth of the analyses.

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It is assumed that the set-up of a data governance structure for the RO is a task for the EC and EASA, and that requires addressing the first challenge mentioned above. The remaining two challenges have been considered by the research performed for development of the prototype RO of FSS P4.

It is recommended to investigate further to what extent use can be made of ICAO's integrated Safety Trend Analysis and Reporting System (iSTARS) toolset, which is based on ICAO datasets, e.g. Accident/Incident Data Reporting (ADREP) system and the Universal Safety Oversight Audit Programme (USOAP). This data is typically provided by National Aviation Authorities, key providers and users of aviation safety data. From RO viewpoint, a key element is ICAO's Safety Information Monitoring System (SIMS). This already supports States with safety oversight and the collection, analysis, and sharing of data to support their State Safety Programme (SSP). Increased collaboration with ICAO would increase efficiency.

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7 CONCLUSIONS AND RECOMMENDATIONS

7.1. Conclusions

While the RO is a support tool for safety management, it requires an actual organisation to deliver and maintain RO services. In view of this, the key elements of a business model – value proposition, customers, customer relationships, communication channels, key activities, resources, partners and cost and revenue streams – are described. The main business drivers are the following three offers:

- Providing service providers with data-driven decision support for safety management;
- Providing regulators and authorities with enhanced capabilities for safety oversight;
- Assisting individual States with establishing and managing their State Safety Programme.

An early version of the risk observatory prototype was developed on the basis of an initial set of requirements, and demonstrated to stakeholders [17]. Feedback was taken into account in the further development of the RO based on an integrated risk assessment framework. Both the early prototype and the follow-up research prototype are described in this study. Various dashboards and visualisations of risks and safety performance indicators are provided to how safety data can be translated into safety information. Different Use Cases are presented, explaining possible uses of the RO by service providers and the authorities in establishing and managing State Safety Programmes.

The work in Future Sky Safety P4 includes the development of a risk assessment framework and the associated risk models. To illustrate the approach, two types of accidents have been considered in detail: runway excursions and mid-air collision risk, and trials have been conducted [26]. Based on publicly available occurrence data on accidents and serious incidents, three total aviation system risk pictures have been created [18], [21], [23]. This enables prioritisation of safety actions.

Five possible use cases for the authorities have been presented and discussed. These are:

- Understanding of top risks in a country;
- Support for definition of safety objectives;
- Support for oversight of organizations;
- Integral Safety Assessment related to the airport growth;
- Enrichment of occurrence data from Mandatory Occurrence Reports.

An outlook is presented on future steps with the RO. This includes ideas for a data governance framework, scalability or ambition levels, and a high level roadmap covering five phases: research, development, implementation, operation, and expansion. The present RO functionalities focus on service providers, and were mainly tested by an aircraft manufacturer and airline. For future developments, more attention should be given to possible Use Cases for the national aviation authorities, including for safety oversight.

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The main identified challenges are:

- Development of a data governance structure in Europe will be more complex than for FAA's ASIAS, considering the number of States, different legal frameworks, different languages and cultures, and national interests. A central role for data governance should be with EASA.
- The RO has to assure that stakeholders experience sufficient benefit and added value from sharing data compared to current practices. The RO shall be complementary to similar data sharing initiatives or analyses conducted already by the stakeholders themselves.
- The RO needs to assure data quality to provide good quality analyses. Lack of data quality, lack of standardisation and other data processing issues (different taxonomies, corrupted data, lack of details, de-identification of data, etc.) may hamper quality and depth of the analyses.

7.2. Recommendations

It is assumed that the set-up of a data governance structure for the RO is a task for the EC and EASA, and that requires addressing the first challenge mentioned above. The remaining two challenges have been considered by the research performed for development of the prototype research RO developed in FSS.

It is recommended to investigate further to what extent use can be made of ICAO's integrated Safety Trend Analysis and Reporting System (iSTARS) toolset and Safety Information Monitoring System (SIMS). This already supports States with safety oversight and the collection, analysis, and sharing of data to support their State Safety Programmes (SSPs).

Sufficient involvement of operational stakeholders and sharing of safety data will be the key for success.

Acknowledgement

This study report relies on work performed by Joram Verstraeten, Gerben van Baren, Rombout Wever, Arjen Balk, Bas van Doorn and Graham Greene in Future Sky Safety P4 Total System Risk Assessment [17, 18, 21, 23, 25]. We would like to acknowledge their work, which was key for generating this study report.

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Appendix A REQUIREMENTS

For each requirement the following attributes have been identified:

- **Identifier**: It is defined as the label *Type_id*, wherein:
    - *Type* is a label with the following possible values:
        - BRQ for business requirements
        - USR for user requirements
        - SYS_GEN for system general requirements
        - SYS_FUN for system functional requirements
        - SYS_QUAL for system quality requirements
        - SYS_INT for system data and interfaces requirements
    - *id* is a progressive number starting from 001 to allow unique identifying and traceability
- **Short Title**: It facilitates a briefly understanding of the requirement scope
- **Description**: It represents the textual description of the requirement
- **Justification**: It provides a brief justification of the requirement itself (not applicable for user requirements)
- **References**: It is applicable only for system requirements and it provides the link to any reference which the requirement covers (e.g., to business and user requirements) to allow a quick trace of the requirement and to verify that the stakeholders' requirements are covered
- **Priority**: It provides the priority of the requirement (not applicable for user requirements) and can be high (HP), medium (MP), low (LP) or very Low (VLP); system requirements inherit the priority of the referring business requirement.

In the following sections, business, user and system requirements are reported. In detail, only HP business and system requirements are specified.

Appendix A.1 Business Requirements

Table A-1 Business requirements

Identifier	Short Title	Description	Justification	Priority
BRQ_001	Scope	The Risk Observatory's scope shall be the EASA Member States and the operations performed by service providers within the EASA Member States.	This stems from the fact it is developed in a European context, with European partners.	HP
BRQ_005	Mission	The Risk Observatory shall be structured and marketed to be a framework for European aviation safety data analysis.	See BRQ_001.	HP
BRQ_010	Business context	The Risk Observatory shall support activities in safety management, specifically: • Safety risk management ○ Hazard identification ○ Safety risk assessment and mitigation • Safety assurance ○ Safety performance monitoring and measurement ○ The management of change	These key areas derive from a mapping between issues and needs in stakeholders' interviews and the safety management framework of ICAO. This allocation, from one side, creates a quick common understanding among stakeholders and from the other side enforces the idea of the Risk Observatory as support to safety management.	HP
BRQ_011	Stakeholders	The Risk Observatory shall target the following stakeholder domains: • Aircraft operators • ANSPs • Aircraft manufacturers • Aviation regulators • Airports	The Risk Observatory needs to provide added value to the customers in the stakeholder domains and the system needs to be tailored to the users in the stakeholder domains.	HP
BRQ_014	Safety data collection - sources	The Risk Observatory shall be able to acquire safety data from different stakeholder domains in Europe. At least from:	The Risk Observatory should provide information from all domains contributing to aviation safety. This could	HP

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Identifier	Short Title	Description	Justification	Priority
		• Aircraft operators • ANSPs • Aircraft manufacturers • Aviation regulators	improve the overall capability of safety management.	
BRQ_020	Safety data type	The Risk Observatory shall acquire safety data of different types. The following safety data shall be collected: • Occurrence data • Flight data (FDM/FOQA) • Radar data • Exposure data	The more data is collected in the Risk Observatory, the more its effectiveness increases.	HP
BRQ_035	Taxonomy	The Risk Observatory shall comply with a defined accepted taxonomy of safety information at European level (e.g., ADREP taxonomy for occurrence reporting).	Taxonomy in the safety information shall enable an automatic analysis of the information.	HP
BRQ_040	Safety Risk Management – Hazard Identification	The Risk Observatory shall support hazard identification in a combination of reactive, proactive and predictive methods. This includes hazards that overarch the hazards of an individual organization.	The combination of proactive and predictive methods is the envisaged approach to safety management according to ICAO: *Reactive approach*. It involves analysis of past outcomes or events. Hazards are identified through investigation of safety occurrences. Incidents and accidents are clear indicators of system deficiencies and therefore can be used to determine the hazards that either contributed to the event or are latent. *Proactive Approach*. It	HP

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Identifier	Short Title	Description	Justification	Priority
			involves analysis of existing or real-time situations, which is the primary job of the safety assurance function with its audits, evaluations, employee reporting, and associated analysis and assessment processes. This involves actively seeking hazards in the existing processes. *Predictive Approach*. It involves data gathering in order to identify possible negative future outcomes or events, analysing system processes and the environment to identify potential future hazards and initiating mitigating action.	
BRQ_045	Safety Risk Management - Risk Assessment	The Risk Observatory shall implement a risk framework made up of risk models for each domain, enabling quantification of accident risk and effectiveness of risk controls. The outcomes should be actionable safety information that can be used by decision makers.	The evaluation of the risks allows: • Prioritization • Quantification if possible • Identifying mitigation actions	HP
BRQ_050	Safety Assurance - Performance Monitoring	The Risk Observatory shall support Safety Performance Monitoring by : • Defining SPI, safety targets, and alerts • Monitoring SPIs against safety targets and alerts • Allowing historical trend analysis, including identification of positive	Performance monitoring shall allow to translate safety data into actionable safety information, in order to support decision making. Statistics could be used to consolidate the estimated	HP

Identifier	Short Title	Description	Justification	Priority
		trends and the causes of these trends • Allowing comparison of safety performance of different service providers • Allowing correlation analysis between indicators and safety outcomes (accidents and serious incidents) or data parameters	probability of failure conditions based on real events, their frequency and their safety impacts. This could permit to downgrade some severity levels in accordance with the airworthiness authorities. Statistics and periodic safety indicators shall be easily created and extracted • To monitor organization position in the safety space • to create reference values for safety performance comparison • to evaluate the effectiveness of mitigation actions • to guide the definition of new mitigation action and best practices (based on positive trends).	
BRQ_080	Trust	The Risk Observatory shall provide a suitable policy of data management to be agreed with stakeholders in order to facilitate framework use and data feeding.	Safety information should be collected solely for the improvement of aviation safety, and information protection is essential in ensuring the continued availability of information.	HP

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Appendix A.2 User Requirements

Table A-2 User requirements

Identifier	Short Title	Description
User Data Requirements		
URQ_001	Access to pan-European data	The RO shall have access to all relevant data from EASA member states
URQ_005	Use data	The RO shall enable use of ATC data, flight data, radar data, infrastructure data, weather data, aircraft system reliability data, atm reliability data, exposure data
URQ_010	Accommodation of occurrence types	The RO shall be able to accommodate the occurrence types that are mandatory reported according regulation 376/2014. List is available in regulation 2015/1018.
URQ_015	Access to outside data for safety investigations	The RO shall enable a user from a particular organisation to get data from other organisations to support safety investigations within that particular organisation.
URQ_020	Access to non-technical event data	The RO shall have access to information from airlines and repair stations that are not systematically recorded in technical event reports such as information on the contribution of human factors to the occurrence of the event.
URQ_030	Aircraft data harmonisation	The RO shall facilitate the harmonisation of recorded parameters across aircraft manufacturers' models and comparison or aircraft parameters managed and used by other organisations.
URQ_035	Data completeness	Data shall be complete, including contextual information for adequate analysis/understanding.
User Functional Requirements		
URQ_040	Data structure	The data shall be well structured and enable efficient querying (using appropriate keywords) and shall support safety argumentations and decision making.
URQ_045	Information linking capability	The RO shall enable linking information regarding a specific event to data from other sources to be able to understand the context of the event.
URQ_050	Identification of correlations.	The risk observatory shall enable identification of correlations between parameters/safety data, including correlations that were previously unknown.
URQ_055	Identification of recurring conditions	The RO shall enable to extract the most recurrent operating conditions of a flight for a selected failure scenario.

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Identifier	Short Title	Description
URQ_060	Classification of input into type of operation	The RO shall allow classification of input data into type of operation. Multiple ways of classification shall be possible.
URQ_065	Accident event sequences	The RO shall represent accidents as a sequence of events
URQ_070	EASp accident rates	The RO shall show (national) accident rates (number of accidents per flight) for the accident categories described in the EASp: • Runway excursion • Mid-air collision • Controlled flight into terrain • Loss of control in flight • Runway incursion • Fire/smoke/fumes.
URQ_075	Combination of data.	The RO shall be able to combine data from a single source and combination of sources to quantify event occurrence.
URQ_080	Automatic update of top risks	The RO shall enable automatic extraction of an up-to-data periodic (e.g. weekly) list of top risks.
URQ_085	Show origin of risk	RO shall show the origin/causes of the risk.
URQ_090	Show risk level	RO shall calculate the (level of) risk.
URQ_095	Low risk events information	The RO shall enable extraction of low probability events as well as events with low severity, i.e. 'minor' or 'major' as per CS25.1309 definitions.
URQ_100	Accident risk	The RO shall determine risks specific types of accident scenarios as well as overall risk.
URQ_105	Effectiveness risk control measures	The RO shall allow the evaluation of effectiveness of control measures
URQ_110	Support prioritisation of safety actions	The RO shall support prioritization of risk mitigation actions.
URQ_115	Predictive risk modelling	The RO shall apply predictive/pro-active risk modelling.
URQ_120	Effect on risk	The RO shall enable to determine the effect on risk of a great number of parameters.
URQ_125	Standardised cause detection process	The RO shall propose a standardized data analysis for determining causes of reported in-service events.
URQ_130	Unusual pattern alert	The RO shall alert the user to unusual patterns in data to identify hazards.

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Identifier	Short Title	Description
URQ_135	Hazard identification	The RO shall facilitate the identification of hazards that may have a wide impact on a fleet of aircraft.
URQ_145	Provide statistics of failure conditions	The RO shall provide statistics that can be used to consolidate the estimated probability and safety effects of failure conditions based on real events.
URQ_150	Quantification of SPIs	The RO shall combine data to quantify Safety Performance Indicators.
URQ_155	Safety barrier effectiveness	The RO shall calculate the effectiveness of safety barriers.
URQ_160	Safety performance alert	The RO shall alert if safety performance (expressed as risk, overall and per accident category) is not as expected.
URQ_165	Event frequency alert	The RO shall alert if event frequency (expressed as rate or absolute value) is not as expected.
URQ_170	Calculate safety performance	The RO shall calculate (based on past performance, desired performance as defined by the user, sample size, etc). expected performance and associated uncertainty.
URQ_175	Dashboard	The RO shall produce a safety dashboard that includes safety assurance information.
URQ_180	Useable for continued airworthiness	The RO shall be usable for continued airworthiness activities.
URQ_185	Indicators of safety effect of new aircraft functionalities	The RO shall provide indicators that can be used to express the safety effect of new functionalities implemented in aircraft.
URQ_190	User selection of type of result	User shall have the ability to select which type of result is displayed/produced by the RO. The following is at least required: • Trend (trend is variation of level over time) of SPI. For individual organisation and at State level. • Trend of risk (overall and per accident scenario). For individual organisation and at State level. • Combination plot of trends (e.g. runway excursion risk and mid-air collision risk in one plot). For individual organisation and at State level. • Compare own performance (trend) with that of other aircraft operators and/or (European) average trend.

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Identifier	Short Title	Description
User Quality Requirements		
URQ_195	Data timeliness	The RO shall assure timeliness of the data.
URQ_200	User selection of time span	The user shall be able to set the time span for trend and the granularity (per year/month/week/day/hour etc.).
URQ_205	Drill down capability	The RO shall allow drill down from trend to individual occurrences.
URQ_210	Dashboard configuration	The user shall be able to configure the safety dashboard.
URQ_215	User defined SPIs	The user shall be able to define SPIs in addition or in place of SPIs predefined by the system.
URQ_220	Safety analysis credibility	The RO shall assure the credibility of the safety analysis performed by it.
URQ_225	Desk-top computer	The RO shall run on desk-top computer.
URQ_230	Protection against unauthorised access	The RO shall be protected against unauthorised access.
URQ_235	De-identified access	The RO shall enable access to data stored in the European common repository but in an anonymous and di-identified manner.

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Appendix A.3 System Requirements

Table A-3 System requirements

Identifier	Short Title	Description	Justification	References
SYS_GEN_001	Representation of European aviation safety processes	RO shall support the safety management processes of European aircraft operators, ANSPs, aircraft manufacturers, aviation authorities and airports. It shall implement tasks to support the following safety management activities: • Safety Risk Management • Safety Assurance	RO has to become a complementing part to the safety management system of stakeholders. It should provide a common database and at the same time a unique approach to data management and analysis. The ICAO Safety Management Manual can represent the referencing guide for RO, both for terminology and functions.	BRQ_001 BRQ_005 BRQ_010 BRQ_011 URQ_001
SYS_GEN_005	RO General Inputs	RO shall allow user to access to the following: • accident investigation data • mandatory reporting data • voluntary reporting data • continuing airworthiness reporting data • operational data (procedures, flight data, radar data, exposure data, weather data, airport infrastructure data) • safety oversight data • data from audit findings/reports • data from regional accident and incident investigation	According to ICAO, effective safety management is data driven. Sound management of the organization's databases is fundamental to ensuring effective and reliable safety analysis of consolidated sources of data. RO should be able to accommodate the occurrence types which are mandatory reported according to regulation 376/2014. A list is available in regulation 2015/1018. Safety occurrences mean the outcomes of operations which are considered safety related by the person inserting it.	BRQ_014 BRQ_020 BRQ_021 BRQ_022 URQ_005 URQ_015 URQ_020 URQ_030 URQ_035

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Identifier	Short Title	Description	Justification	References
SYS_GEN_006	RO Import	RO shall allow to: • download input data as an ad-hoc or batch process on a regular basis • perform the data transfer by optionally using decompression and decryption • inform the data provider about the download	The listed actions are for the import of input data. The import may occurr by means of an ad-hoc process or by menas of a regular batch process. The import may require also a decompression or a decryption.	BRQ_014 BRQ_020 BRQ_021 BRQ_022 URQ_005 URQ_015 URQ_020 URQ_030 URQ_035
SYS_GEN_007	RO Import Management	RO shall allow to: • view the available data to export from each data provider • add new download areas • remove download areas • set the password and decompression/decryption actions	The listed actions are required in order to manage the available files from providers and to download them with the associated treatment (decompression/decryption)	BRQ_014 BRQ_020 BRQ_021 BRQ_022 URQ_005 URQ_015 URQ_020 URQ_030 URQ_035
SYS_GEN_008	RO Inputs Management	RO shall allow to: • move, copy or rename imported data to selected databases • remove imported data • archive imported data • recovery imported data • convert imported data into the required formats for RO tools • manage the access rights to imported data and converted data • create datasets for the analysis • delete datasets • archive datasets • manage the access rights	The RO shall enable to move, copy and rename external data. Moreover, it shall be possible to delete (with confirm) and to archive and recover selected data. The RO shall allow also the conversion of external data in other formats that may be required for further operations and that are different from the original raw format. The RO shall enable the management of access permissions to input data (both imported and	BRQ_014 BRQ_020 BRQ_021 BRQ_022 URQ_005 URQ_015 URQ_020 URQ_030 URQ_035

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Identifier	Short Title	Description	Justification	References
		to datasets	converted). Data may be confidential, thus, a clear control of the data visibility shall be possible. Datasets are sets of references to input data that are used for the analysis.	
SYS_FUN_001	RO Occurrences Management	RO shall allow a privileged user (cf. SYS_QUAL_015) to manage RO occurrences with following sw (software) operations: • insert • updating • deleting	RO occurrences represent everything users want to identify as lower level information in every scenario. RO occurrences can be causes of accidents, can be quantitatively related to accident risk, can be quantified by available data, are of sufficient detail to allow early observation of safety trends, are of sufficient detail to allow identification of safety measures. "RO occurrences" need to be clearly defined. They might be (but not limited to) Risk contributing factors (basic causes of barrier inefficiency in AIM) or Precursors (in AIM). That would involve possibility to edit (modify) the risk models (e.g. both adding/removing elements	BRQ_010 URQ_065

Identifier	Short Title	Description	Justification	References
			in the Contributing factors excel file or modifying quantitative data).	
SYS_FUN_006	Access to mandatory occurrence reports	RO shall have access to a dataset of European occurrence reports originating from the mandatory reporting scheme.	Such information can provide the context on an occurrence to be analysed and pushes for a unique environment where collect data	BRQ_005 URQ_010
SYS_FUN_055	Safety Issues attributes	RO shall manage at least the following Safety Issues attributes: • Title • description • applicable domain (aircraft, ANSPs, airlines, aircraft manufacturers) • source (who inputs the info) • location/flight phase (where it is applicable) • priority		BRQ_040 BRQ_041
SYS_FUN_056	Linking Safety Issues and RO Occurrences	RO shall allow the user to link a set of RO occurrences with a Safety Issue, whose owner is the given user.	For any given Safety Issue, the owner shall be able to associate a set of RO occurrences as examples of the issue.	BRQ_040 BRQ_041
SYS_FUN_060	Risk Computation	RO shall allow computation of risks based on the risk models and on the input data	Risks are the main part of Safety Risk Management module	BRQ_045

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Identifier	Short Title	Description	Justification	References
SYS_FUN_070	Risk Attributes	RO shall manage at least the following attributes for risks • Description of the event (e.g., Unstable approach to Airport X, RWY Y) • Accident/Backbone model to which the event contributes • Likelihood • Severity • Criteria (Timeframe, location, type of operations e.g. IMC vs VMC etc.)	Risks are the main part of Safety Risk Management module	BRQ_045
SYS_FUN_080	Risk probability	RO shall evaluate the risk likelihood using the risk assessment.	The determination of risk likelihood is one of the key functionalities of the risk models that make up the risk assessment framework.	BRQ_045 URQ_090
SYS_FUN_085	Risk severity evaluation	RO shall evaluate the risk severity (severity of hazard consequences).	Once the probability assessment has been completed, the next step is to assess the safety risk severity, taking into account the potential consequences related to the hazard. The severity assessment should consider all possible consequences related to an unsafe condition or object, taking into account the worst foreseeable situation. In literature and regulations many severity tables are available (e.g. ARP4761 used as standard in aircraft	BRQ_045 URQ_090 URQ_095

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Identifier	Short Title	Description	Justification	References
			safety assessments) The severity assessment can be based upon evaluating answers from a questionnaire relating to the consequences (in literature and regulations many severity tables are available, e.g. ARP4761 used as standard in aircraft safety assessments) or on damage and injury profiles calculated from accident data. In both cases the following is considered: a) Fatalities/injury. How many lives may be lost (employees, passengers, bystanders and the general public)? b) Damage. What is the likely extent of aircraft, property or equipment damage?	
SYS_FUN_090	Risk Severity Classification	It shall allow user to insert, delete, update its own severity classification different from ARP4761	In literature and regulations many severity tables are available. RO might propose the Severity backed by AIM (as the common risk framework model) and rules for conversion between those AIM Severity rules and various Severity tables available in the Aviation domain	BRQ_045 URQ_090

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Identifier	Short Title	Description	Justification	References
SYS_FUN_105	Risk Classification	RO shall allow users to classify risks according to an classification: acceptable, tolerable or intolerable	A possible classification to use is the ICAO classification.	BRQ_045
SYS_FUN_110	Mitigation Actions management	RO shall allow user to manage mitigation Actions by at least the following sw operations: • Insert a new mitigation action • Searching among existing mitigation actions • Updating mitigation actions • Associating mitigation actions to Safety Issues • Referring operations • Delete • Declare out-of-date	Mitigation Actions can be classified by means their association to the operations Nominal sw operations allow the user to manage such entity No, only qualitative information (list of Mitigation Actions) will be shared, without obligation for linking it to the Risk models The Mitigation Actions shall be connected to the Safety Issues (each Mitigation Action shall respond to at least one Safety Concern)	BRQ_045 URQ_105

Identifier	Short Title	Description	Justification	References
SYS_FUN_115	Effectiveness of mitigation actions	RO shall assess the effectiveness of mitigation actions by considering all the associated risks and deriving statistics on their occurrences among accidents/incidents and safety occurrences. This can be further detailed as follows: - Functionality (within Occurrences dashboard) allowing to compare occurrence rate Before and After a Mitigation action has been implemented - Functionality (within What-if dashboard) allowing to assess the predicted impact on Risk, via What-if applied to the Risk Model (change quantification, or change structure)	Assessing the effectiveness of mitigation actions can support organization to decide if it has to undertake further actions in place or in addition.	BRQ_045 URQ_105

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Identifier	Short Title	Description	Justification	References
SYS_FUN_130	Mitigation actions attributes	RO shall manage at least the following attributes on mitigation actions/best practices: • Title • Description • Applicable Domain (aircraft, ANSPs, airlines, aircraft manufacturers) • Priority according to risk • source (who inputs the info) • location/flight phase (where it is applicable) • Referring Safety Issue • Cost (optional) • effect mitigation weight (Mitigation on risk effect based on What-if or expert opinion) • actor in charge of implementing it & deadline (optional, if intended for internal safety management process) • Start and end date of application of that mitigation action	The start and end date of application of that mitigation action, together with the location/flight phase will allow to call&manage the Functionality (within Occurrences dashboard) allowing to compare occurrence rate Before and After a Mitigation action has been implemented (see SYS_FUN_115)	BRQ_045
SYS_FUN_135	Risk Sensitivity Analysis	The RO shall enable to determine the effect on risk of a great number of parameters, e.g. traffic growth, changes in traffic mix, changes in operation. More specifically, the Sensitivity Analysis	Sensitivity analysis can be implemented through What-if functionality; up to the User to specify&launch a sensitivity analysis. Possibility should be provided to select a full list of various parameters,	BRQ_045 URQ_120

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Identifier	Short Title	Description	Justification	References
		functionality shall allow the User to specify the list of values to be assigned to a parameter (or set of parameters) and the graphical representation of the sensitivity analysis results	including frequency of contributors, influences, etc and the wanted parameter variation (e.g. divided by 10, multiplied by 10 etc) Sensitivity analysis applies to Risk but also to any computed SPI/frequency NOTE: sensitivity analysis wrt the inclusion/removal of a (set of) Contributor(s) or Influencing factor(s)can be performed manually by User through the Model modification and What-if functionality	
SYS_FUN_140	What-If Analysis	RO shall enable the prediction the impacts of changes to risks using risk models. The change scenarios shall be defined by considering the following changes with respect to the baseline model: • change to contributing factors • change to influence factors • changes to parameters of the external models	The RO user shall be able to creates a scenario with a set of changes to controlling elements in selected backbone risk models. The user shall also be able to predict changes resulting from changes in parameters to related external models (which will have default values). The backbone risk models have baseline quantifications (one or more). Changes to the related contributing factors or influences can be modeled as either new absolute values or as modification factors from the chosen baseline.	BRQ_045 URQ_120

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Identifier	Short Title	Description	Justification	References
SYS_FUN_145	What-If Analysis Results	RO shall display the results of What-If Analysis by showing the baseline and the predicted risk impacts for one ore more change scenarios. Results shall be reported in tables and charts.		BRQ_045 URQ_120
SYS_FUN_200	SPI management	RO shall manage SPIs by allowing the following sw operations: • Insert a new SPI • Update • Delete • search • Calculate SPIs	According to ICAO, as part of Safety Assurance process any organization has to define its own safety performance indicators (SPIs) and their associated targets and alerts	BRQ_050
SYS_FUN_205	SPIs attributes	RO shall manage at least the following attributes for each SPI: • Title • Description • Alert threshold • Target threshold • Evaluation Frequency • Severity class • Related potential accident(s) • Formula (cf. SYS_FUN_215) • Status (active, outdated)	According to ICAO, as part of Safety Assurance process any organization has to define its own safety performance indicators (SPIs) and their associated targets and alerts	BRQ_050

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Identifier	Short Title	Description	Justification	References
SYS_FUN_210	Default SPIs	RO shall implement default SPIs that monitor the risk associated with the following occurrence categories: • Runway excursion • Mid-air collision • Controlled flight into terrain • Loss of control in flight • Runway incursion • Fire/smoke/fumes.	EASp focuses on the listed occurrence categories and many users during their interviews cited these categories.	BRQ_050 URQ_070
SYS_FUN_215	SPIs definition formula	RO shall allow the user to define new SPIs (different from proposed ones) with the related formula in a “metalanguage” that RO shall be able to execute	Any organization can be allowed to define new SPIs and the related calculation procedure that RO shall execute. Such requirement would require a metalanguage to define the formula	BRQ_050 URQ_215
SYS_FUN_216	SPIs Evaluation Types	RO shall allow to perform: • occurrence-based SPI analysis (the analysis is on a dataset from RO occurrences) • risk-based SPI analysis (the analysis is on a backbone risk model)	The generation of SPI results shall involve a dataset from RO occurrences derived from converted safety data (using a user defined SPI catalogue) or a sets of risk estimates from backbone risk models.	BRQ_050 URQ_215
SYS_FUN_220	SPIs Evaluation	RO shall implement evaluation of SPIs according to the defined formula and on the defined dataset and assessing: • if the target values have	SPIs assessment is important for the organization to understand how it is going on that specific safety aspect	BRQ_050 BRQ_055 URQ_150 URQ_170

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Identifier	Short Title	Description	Justification	References
		been reached • If the alert values have been overcome		
SYS_FUN_300	Historical Statistical Analysis	RO shall provide the user a set of statistical functions to apply to a predefined set of data with related plots (if selected by the user)	Statistical analysis are useful to understand trends	BRQ_055 URQ_145
SYS_FUN_310	SPIs Comparison	RO shall execute a comparison by SPIs on a predefined set of data with related plots (if selected by the user)	SPIs comparison is a user request. It allows organization to have external references to which compare their own safety performances	BRQ_055
SYS_FUN_315	SPI Trend Analysis	RO shall execute a SPI trend analysis on a predefined set of data with related plots (if selected by the user)	Risk trend analysis help user to understand in their safety actions are effective Regarding the Trend graphics, Risk graphics and more generally any graphics dealing with rare events- it would be more relevant to display evolution in relative terms (i.e. percentage wrt a baseline) instead of absolute figures (e.g. for Runway excursion frequency, the evolution from 7.2E-08 to 7.4E-08 per movement is not as relevant as showing an increase of 2.7%)	BRQ_055

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Identifier	Short Title	Description	Justification	References
SYS_FUN_320	Predefined datasets	RO shall allow the user to identify the datasets to which to apply analysis according to different level of aggregations which refer to temporal and geographic criteria. At least the following geographic criteria should be selectable: • Local (on data relative to the organization itself) • State domain (organizations in the same domain and state) • European domain (European organizations in the same domain • State (all organizations in the state) • Europe (all organizations in Europe)	Possibility of aggregating data in different ways is a must for the RO, as well as its usability depends on the data management and the view that it can offer	BRQ_080 URQ_200
SYS_FUN_340	RO warning function	RO shall implement a warning function triggered by the scheduler if any defined alert threshold has been exceeded. Recording warning shall be dispatched at user login and shall be always active until they are deactivated by the user.	Warning functions help users to analyze the most critical results after analysis batch execution	BRQ_075 URQ_080 URQ_160 URQ_165
SYS_FUN_350	RO query	RO shall allow the user: • to define and save queries for the search of data (RO occurrences, Safety Issues, Mitigation	Data retrieval is one of the main functions for the user. Through such tool he/she is allowed to investigate for any kind of unforeseen	BRQ_075 URQ_040 URQ_055

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Identifier	Short Title	Description	Justification	References
		Actions)	correlation among data.	
SYS_FUN_355	Reporting	RO shall provide at least the following default reports (in terms of output file textual/graphical content e.g. pdf): • Trends of SPI • Trends of risks • Contributors and Influencing factors • Risks		BRQ_075 URQ_190
SYS_FUN_356	Dashboards	RO shall attach the reports to user dashboards.	The dashboard function shall permit sets of results to be combined and manipulated and put onto a visualisation area with maximum flexibility. Dashboards represents the users way of presenting the results in one or more desired forms.	BRQ_075 URQ_190
SYS_FUN_360	Reporting Configuration	RO shall allow the user to define its own report with existing information in RO data base.		URQ_210
SYS_FUN_361	Dashboards Configuration	RO shall allow the user to edit a dashboard.	The editing of a dashboard shall consider its layout. Moreover, some attributes shall be set (e.g., sampling rates and alert levels).	BRQ_075 URQ_190

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Identifier	Short Title	Description	Justification	References
SYS_FUN_501	Risk backbone models	Risk Observatory shall provide a catalogue of different backbone models for the risk assessment and the engine for their solution	Backbone models are the instantiated models for specific risks, encompassing the contribution to the risk of each domain (airline, airports, ANSPs) if applicable. The requirement underpins a business model requiring a workgroup aggregating different domain whose main objective is to develop a unified model for the specific risk under study. The challenge to have a unique model (for each risk) for all the involved stakeholders is one the main objctives of Risk Observatory Such model takes as an example the experience done in the P4 RO development in which backbone models have been defined for RunWay excursion and Mid-Air Collision.	BRQ_045
SYS_FUN_502	Domain Specific Models	Risk Observatory shall enable the user to link domain specific models to an element of a backbone model in order to quantify it and to feed them with the needed data	Specific elements included in the backbone models can be quantified by means of user specific models that use RO data to quantify the related probability of occurrence. The RO shan't include the engine to solve the domain	BRQ_045

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Identifier	Short Title	Description	Justification	References
			specific models but it has to provide the domain needed input data. The elaboration of the domain model is outside the RO. Its oucome be means of the created link feed the element of the RO backbone model	
SYS_FUN_503	Backbone models Management	Risk Observatory shall allow the administrator to: - insert new backbone models - insert a new version of an existing backbone model		BRQ_045
SYS_FUN_504	Risk Assessment models management	Risk Observatory shall allow the user to define its own risk model starting from an existing backbone model.	RO will allow a user to open the “official” model, to edit it and to save a new instance of the model according to its own needs. Such model will be saved in the list of Users Model in order to differentiate between those official and those recognized by the others For the backbone models only, a user can insert into the Users Model new mitigation actions, or new contributing factors, or delete some elements from the model, or modify probabilistic data or severities However, upon agreement	BRQ_045

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Identifier	Short Title	Description	Justification	References
			amongst all concerned Users, modifications to the "official" model shall be possible (performed through specific User rights)	
SYS_FUN_505	Contributing Factors Linking	Risk Observatory shall allow the user to define the linking of contributing factors to backbone models.	The user shall be able to add new contributing factors to a backbone model. In the prototype, all the supported backbone models whill have these links available.	BRQ_045
SYS_FUN_506	Influence Factors Linking	Risk Observatory shall allow the user to define the linking of influence factors to contributing factors.	A quantifying relation between the influence factor and the contributing factor is needed in order to define the amount of risk of a contributing factor that is related to a given influence factor.	BRQ_045
SYS_QUAL_001	User id and Pswd	RO shall allow the access to its functionalities by user id and password		BRQ_080 BRQ_075 URQ_235
SYS_QUAL_005	User and Pswd Management	RO shall manage the user with at least the following attributes: • Id • Pswd • Domain • Profile • Status		BRQ_080 BRQ_075

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Identifier	Short Title	Description	Justification	References
SYS_QUAL_010	Pswd Management	RO shall implement mechanisms to manage passwords	Passwords management is a delicate matter. Secure mechanism shall be implemented to guarantee that RO is accessed only by authorized user	BRQ_080 BRQ_075
SYS_QUAL_015	User Profiling	RO shall manage the user profiling by allowing the user to define profile, selecting the level of data access and the kind of functionalities (analysis, reporting, entities, …)	It shall be possible that different type of users can access to RO within the same organization	BRQ_080 BRQ_075
SYS_QUAL_020	User Profile	RO has to manage user profiles to access data and functionalities. Profiles can be defined: • Local Level: accessing only to its own data • State Domain Level: accessing to data relative to state organizations in the same domain without knowing the organization source • European domain level: accessing to data relative to European organizations in the same domain without knowing the organization source • State level: accessing to data relative to state organizations also in different domains without knowing the organization source	It shall be possible that different type of users can access to RO within the same organization	BRQ_080 BRQ_075 URQ_235

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Identifier	Short Title	Description	Justification	References
		• European level: accessing to data relative to European organizations also in different domains without knowing the organization source • State Aviation authorities level: accessing to overall data for the belonging state • European Aviation authorities level: accessing to overall data in Europe		
SYS_QUAL_050	Safety Database	RO Architecture shall be designed to provide a web server application with at least these three kind of databases to query: • Local database with user local settings (configuration, internal security). • Server databases with main RO data entities • External databases (with accidents, incidents, FDM data, radar track data, weather data, traffic data, data on airport and airspace infrastructure)	Large numbers of safety databases have been developed independently by many different organizations with very specific areas of responsibility and analysis needs. In order to provide aviation safety analysts with expanded views of safety issues, it is necessary to build safety information integration facilities that can extract information from multiple sources, apply common data standards, consolidate metadata and load the information onto a common platform housed in centralized data storage architecture. Big limitations are expected	BRQ_016 BRQ_030 URQ_040 URQ_225

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Identifier	Short Title	Description	Justification	References
			with regards to the accessibility of existing safety-related databases (due to confidentiality issues) ADREP seems insufficient to cover the ATC needs. ADREP is the taxonomy used for incident reporting A wider taxonomy needs to be agreed or developed (based on existing ones, E.g. augmenting ADREP with ATC-specific bits)	
SYS_QUAL_055	Architecture	RO Architecture shall be designed thinking of the following main aspects: • Extensive modularity to facilitate maintenance • A weak coupling with user interfaces by defining format for importing and uploading information (by considering existing taxonomies like ADREP) • An accurate management of software errors • Local changes to the RO should not require extensive redevelopment of underlying models, data query structure, etc. • An error management in I/O sw operation on DB preserving the data integrity	ADREP seems insufficient to cover the ATC needs. ADREP is the taxonomy used for incident reporting A wider taxonomy needs to be agreed or developed (based on existing ones, E.g. augmenting ADREP with ATC-specific bits)	BRQ_017 BRQ_035 URQ_030

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Identifier	Short Title	Description	Justification	References
SYS_QUAL_065	Performance	RO shall guarantee response to user no later than 5 minutes. Anyway in procedures like analysis on a great set of data, RO shall warn user of the response time and as it progresses of the remaining time	RO is not a real time application. It can guarantee response time up to a certain size of dataset. If such size is overcome it shall inform user.	BRQ_080 BRQ_075

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