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European Union Aviation Safety Agency

Article 89 REPORT

MAPPING THE IMPACT OF SOCIO-ECONOMIC FACTORS ON AVIATION SAFETY FOR SAFETY-CRITICAL AIRCREW AND OCC PERSONNEL

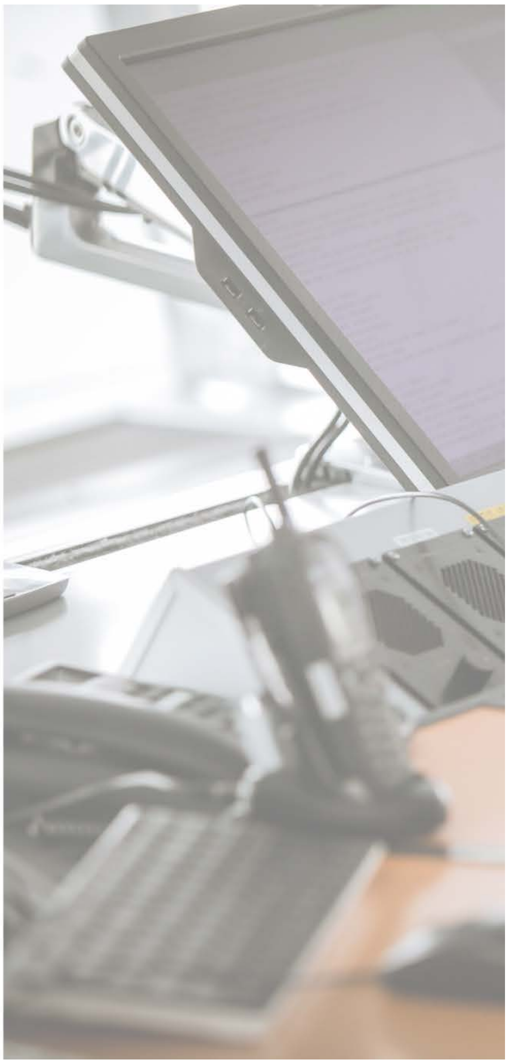

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Table of Contents

Executive summary

This executive summary outlines the purpose, analytical approach and headline findings of EASA's Article 89 evaluation on the interdependencies between aviation safety and socio-economic factors (SEFs). It summarises the scope of the assessment, the evidence base used, the main patterns observed across operator contexts and personnel groups, and the recommendations aimed at strengthening future monitoring and evidence collection.

The evaluation identifies differentiated socio-economic conditions, perspectives, and reporting patterns across operator groups and categories of safety-critical personnel, with some statistically observable associations identified between selected socio-economic factors, safety precursors, and occurrence-reporting patterns.

No major aviation safety concern or direct systemic causal relationship between socio-economic factors and adverse safety outcomes was identified within the scope of the study. However, fatigue and lack of communication emerged as the most consistently visible precursors across the combined evidence base, including literature findings, survey-based indicators, and ECR occurrence data, and these remain areas that warrant continued monitoring and attention.

The findings should be interpreted as indicative of potential enabling conditions and operational vulnerabilities rather than deterministic safety effects, noting that Key Socio-economic Indicators (KSIs) and ECR (European Central Repository) evidence is at times complementary but also partially divergent across operator contexts. The evaluation also highlights important structural limitations affecting the robustness of the analysis, particularly regarding data availability, harmonisation, and contextual richness within both ECR occurrence data and factual operator-level socio-economic data. Strengthening future monitoring capabilities will therefore require more systematic data collection approaches, continued enhancement of reporting culture and Just Culture practices, and the establishment of a more permanent and structured operator-collaboration mechanism to support evidence-based oversight and longitudinal monitoring of socio-economic factors relevant to aviation safety.

Context of Article 89

This report is prepared under Regulation (EU) 2018/1139 (the "Basic Regulation"), which establishes the common rules for civil aviation in the EU and defines the mandate of EASA. Article 89 requires EASA to address the interdependencies between civil aviation safety and SEFs through its regulatory and oversight activities, including the implementation of Just Culture principles as set out in Regulation (EU) No 376/2014 on occurrence reporting to address socioeconomic risks to aviation safety. Article 89 further requires consultation with relevant stakeholders and the publication, every three years of a review providing an objective account of actions and measures undertaken in this area. The first Article 89 report (2021) initiated this cycle by recognising that socio-economic conditions, such as employment and working conditions, health and lifestyle, and education, may influence aviation safety performance. The present report provides the updated assessment for the current cycle.

Objective and scope

Against this background, the purpose of this document is to present the findings and conclusions of the Article 89 evaluation and to consolidate the analyses and recommendations developed through the study. The study aims to deliver an evidence-based evaluation of SEFs that may influence aviation safety, assess the adequacy of current data collection processes for identifying socio-economic risks affecting safety-critical personnel (SCP), and provide actionable recommendations to support regulatory decision-making and strengthen future monitoring mechanisms. This update was commissioned under the ASSESS III Framework (EASA.2020.HVP.04) and is aligned with the objectives of the European Plan for Aviation Safety (EPAS) in supporting a proactive, data-driven approach to safety management.

The scope of the analysis is limited to scheduled commercial air transport operations within the EU. It addresses SCP categories covering flight crew (captains and first officers), cabin crew, and operational control centre staff (aircraft dispatchers, operations controllers and crew controllers). The assessment examines five SEF domains defined for the project: employment and working conditions, health and lifestyle, education, resource constraints and labour-market dynamics, and potential safety risk linked to work intensity, flexibility and uncertainty.

Key concepts

For clarity, Table 1 summarises the key concepts and terms used throughout this report. The definitions are concise and further detail is expanded in Section 2 of this document.

Table 1: Applicable key concepts for this version of the Article 89.

Concept	Definition
Socio-economic factors (SEFs)	The socio-economic conditions considered relevant to safety-critical work and assessed through the study framework.
SEF domains	The five SEF groupings applied in the study: employment and working conditions; health and lifestyle; education; resource constraints and labour-market dynamics; work intensity, flexibility and uncertainty.
Safety-critical personnel (SCP)	Personnel whose functions have a direct impact on the safety of flight operations (in scope: flight crew, cabin crew, and operational control staff).
Risk Areas (RAs)	The operational risk topics assessed in the study as the main risk through which SEFs are interpreted and analysed.
Safety Precursors (SPs)	Human and organisational mechanisms used as a “bridge” between operational conditions and safety outcomes; analysed conceptually and through occurrence data.
Key Socio-economic Indicators (KSIs)	Indicators defined in the framework to characterise dimensions of the Risk Areas using survey-based evidence (noting that data availability can limit full coverage).
Safety Performance Indicators (SPIs)	Metrics used to express safety performance and to quantify how safety precursors are reflected in reported occurrences and in reporting patterns.
Safety Outcome Indicators (SOIs) and Reporting Trend Indicators (RTIs)	A subset of SPIs focused on observed safety events/outcomes and reporting volume and patterns.

Methodology overview

The study is designed to provide a comprehensive, evidence-based evaluation of how Socio-Economic Factors (SEFs) may be associated with aviation safety for Safety-Critical Personnel (SCP) in the EU, recognising that safety margins are influenced by the operational environment in which personnel work. The scope of the study was limited to fixed-wing scheduled commercial air transport operations within the EU and to the following personnel groups: flight crew (Captains, First Officers and Cabin Crew) and Operational Control Centre (OCC) staff (Aircraft Dispatchers, Operations Controllers and Crew Controllers). The objective is to document socio-economic conditions across roles and examine their statistical associations with selected safety performance indicators, to identify recurring differences and areas for further attention in a consistent and transparent manner.

These objectives are operationalised through a structured Risk Model framework (Figure 1) that organises the analysis as a logical chain without asserting causality. The framework links SEFs to operational Risk Areas (RAs), connects these to Safety Precursors (SPs), and then to observable Safety Outcomes and Reporting Trends. It is populated through three complementary evidence sources used throughout the study: (i) surveys of over 6.000 SCP, used to construct survey-based indicators (KSIs) and informed by a qualitative review of open survey responses; (ii) occurrence-based evidence from the European Central Repository (ECR), used to derive safety performance indicators (SPIs) covering safety outcomes and reporting trends; and (iii) a literature review, which provides the conceptual basis to frame and interpret the links between SEFs, RAs and SPs within the framework.

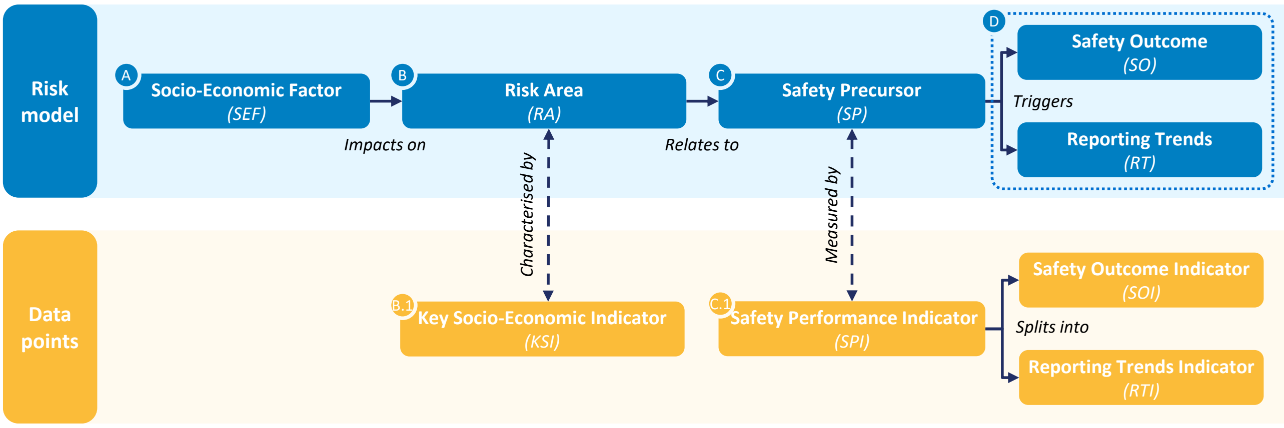


Figure 1: Conceptual framework overview

Conclusions

This study provides an evidence-based assessment of how socio-economic conditions relate to aviation safety for EU safety-critical personnel by characterising differences across roles and quantifying their associations with operational safety indicators. It applies a structured Risk Model to organise concepts and data transparently, linking Socio-Economic Factors to Risk Areas, Safety Precursors and, ultimately, Safety Outcomes and Reporting Trends, using KSIs and SPIs as measurable data points to test statistically robust relationships while explicitly not claiming causality. Aligned with the EPAS Human Factors/Human Performance priority and the Article 89 mandate, the conclusions are descriptive and bounded by the scope, definitions and limitations of the evidence assembled for this assessment.

Overall, the literature suggests that Employment and Working Conditions operate as a foundational socio-economic factor that might have implications across multiple RAs.

"While the literature and KSI patterns point to a broad set of potential HF/HP (High Frequency/High Probability) precursors linked to SEFs, available occurrence reporting data only shows clear volume signals for aircrew fatigue and lack of communication issues, with other precursors not reflected to the same extent."

Across Socio-economic factors (SEFs), the literature consistently points to a limited set of HF/HP precursors recurring across multiple Risk Areas, and Key Socio-economic Indicators (KSI) patterns indicate that the corresponding enabling conditions are present. However, this breadth is not consistently mirrored in ECR reporting: clear reporting signals are mainly observed for fatigue and lack of communication, whereas other literature-expected precursors are only weakly or inconsistently reflected in the reported sample.

This partial divergence between the three evidence sources should be interpreted in light of their different analytical roles within the framework. The literature review and KSIs primarily capture conceptual mechanisms, perceived operational conditions, and enabling factors that may influence safety-critical performance, including organisational, psychosocial, and cultural dimensions that are not always directly observable within occurrence-reporting systems. By contrast, ECR data reflects only those effects that become operationally visible, recognised by reporters, and consistently codified within occurrence taxonomies. As a result, occurrence reporting appears more sensitive to tangible and operationally explicit precursors such as fatigue and communication breakdowns, while broader precursor states such as stress, pressure, contractual insecurity, or reduced psychological safety may remain only partially reflected in reported occurrences. This does not invalidate the complementary three-source framework; rather, it highlights the importance of interpreting the evidence collectively and recognising the current limitations of occurrence-reporting data in capturing complex socio-economic and organisational influences on safety performance.

- Aircrew Fatigue provides the clearest and most internally consistent signal across the evidence base. The literature links fatigue to multiple SEF pathways, KSI patterns suggest that conditions that potentiate this precursor are present across several RAs, and Fatigue-related concerns were the most recurring theme across additional survey analysis. This is reflected in reports submitted to EASA's Confidential Safety Reporting (CSR) scheme as well as in ECR reporting as its reporting increased across 2019-2024, being in 2024 the most frequently reported precursor, present in almost 60% of SP-related occurrences. Notably, the increase in fatigue reporting is not primarily driven by high-severity occurrences; rather, fatigue is increasingly recorded in lower-severity (Tier 2) events, potentially reflecting a combination of increasing exposure along with increasing reporting sensitivity and increased awareness within the reporting system. However, this signal does not fully align with the outcomes of dedicated and independent fatigue studies conducted by EASA, suggesting that the observed association may be influenced primarily by survey responses rather than being strongly supported by more objective datasets.

- Lack of communication provides a second example of partial alignment across the evidence base. Within the context of this study, "lack of communication" is used as a broad organisational and operational precursor construct encompassing communication and coordination breakdowns, procedural ambiguity, incomplete information transfer, and interoperability-related reporting pathways reflected within occurrence-reporting taxonomies, rather than solely ATM-specific radiotelephony errors. The literature consistently identifies communication and coordination issues as cross-cutting precursors relevant to crew interoperability and complex operational environments across several SEFs considered. Correspondingly, communication-related occurrence categories remain visible within ECR reporting, where they rank as the second most frequently reported precursor grouping after fatigue. Although these issues are also present in Tier 1 occurrences, the increase is driven primarily by Tier 2 events, indicating growing visibility in lower-severity operational occurrences. However, the findings should not be interpreted as establishing a direct causal relationship between socio-economic conditions and specific ATM-related communication errors, as occurrence taxonomies capture a broad range of operational communication phenomena influenced by multiple operational and contextual factors.
- By contrast, stress, pressure and workload recur across several SEF-related mechanisms in the literature, and KSI patterns indicate that conditions compatible with these states are present across multiple RAs. However, they are comparatively less visible in ECR reporting.

The combined evidence should therefore be interpreted cautiously, distinguishing between indicative enabling conditions, as reflected in KSI patterns, conceptual expectations from the literature, and precursor visibility in ECR reporting, which may be shaped by reporter perception of relevance/exposure and by the practicality and usability of the taxonomy and the inherent limitations of the ERC reporting system.

"KSI and ECR provide complementary but sometimes divergent evidence of SEF-related effects by operator group. Joint interpretation is essential to understand how these factors are perceived in day-to-day conditions and how (and to what extent) they are translated into occurrence-level safety outcomes and reported precursors."

Across several Risk Areas, KSI indicators highlight differentiated operational and employment patterns across business models. Variations can be observed in areas such as contractual arrangements, operational practices and workforce mobility, with certain characteristics appearing more frequently in specific operational contexts. For example, atypical contractual arrangements are reported more frequently among ACMI Operators[1] and LCC operators, reflecting the higher prevalence of cross-border employment and registration models within these segments compared to Network operators[2]. Differences are also observed in perceptions related to the use of commander's discretion, perceived frequency of operations approaching applicable duty limits, and the frequency of home base changes, particularly within LCC operations, with additional nuances depending on whether results are considered from a flight crew or cabin crew perspective.

At the same time, these KSI patterns reflect survey-based input captured through a questionnaire, and do not in themselves imply the presence of latent safety problems. Rather, they point to perceived structural and operational differences in day-to-day working conditions across business models.

These findings should be interpreted at aggregated business-model level and do not necessarily apply uniformly across individual operators within each category. The LCC segment encompasses a broad range of operational, employment, network models, and operator-level practices that may differ significantly. In addition, KSI indicators primarily reflect perceived operational conditions reported through the survey sample and are not intended to constitute direct measures of

[1] An ACMI operator refers to a leasing company or airline that provides an aircraft, complete crew, maintenance, and insurance (ACMI) to another airline under a wet-lease agreement.

[2] A Network Operator refers to a traditional airline that operates under a hub-and-spoke business model. These airlines manage a complex and integrated route network in which flights are organized around one or more central airports (hubs). Network operators typically offer both short- and long-haul services.

regulatory compliance or objective operational performance. Where available, operator-level data provided during the study was considered qualitatively to support interpretation; however, differences in data availability, comparability, granularity, and methodological consistency limited its systematic integration into the comparative statistical framework.

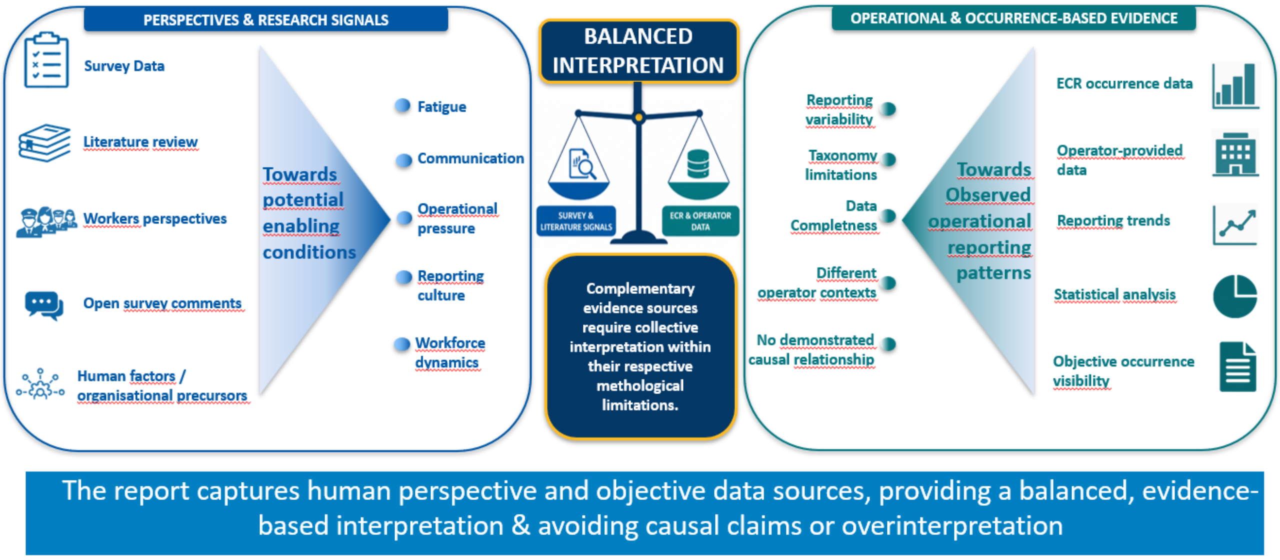
When contrasted with ECR outcomes, the inferential analysis implemented show more heterogeneous reporting patterns by operator group (keeping in mind the limitations of the ECR in terms of variability in completeness and quality of reports, reporting and coding practices, classification choices, as well as safety and reporting culture across different organisations and Member States:

- Lack of communication, knowledge and awareness reporting is more associated with LCCs than network operators, which may be more aligned with KSIs perception.
- In contrast, fatigue and workload show the opposite pattern, with higher reporting association among network operators than LCCs.
- Furthermore, complementary information is obtained from the open survey comments. Concerns about reporting confidence are raised mainly by LCC respondents, who describe hesitancy to report fatigue due to perceived negative consequences or reprimands and a perceived gap between formal Just Culture messaging and day-to-day practice.

Based on the evidence assessed, the study does not establish a demonstrable or statistically robust link between socio-economic factors and aviation safety outcomes. While variations in socio-economic conditions and perceptions are observed across personnel groups and operational contexts, these differences are not shown to translate into validated differences in accident rates, serious incidents, or other objective safety outcomes within the scope of the available data. The findings should therefore be interpreted as descriptive and exploratory rather than inferential or causal. Similarly, occurrence reporting data provides essential visibility of reported safety events and reporting patterns but is influenced by reporting culture, variations in authority application, taxonomy application, and data completeness. Variations in reporting should therefore not be interpreted as direct proxies for underlying risk levels or safety performance. Divergences observed between survey perceptions, literature-based expectations, and occurrence reporting further reinforce the need for caution in interpretation.

Overall, the study indicates that socio-economic conditions form part of the broader operational context in which aviation safety is managed, but current evidence does not support the conclusion that these factors act as direct or independent drivers of aviation safety outcomes. The primary value of the present assessment lies in identifying data gaps, highlighting methodological constraints, and informing the scope and design of future monitoring activities under Article 89.

The figure below summarises the methodology followed, and the key outputs derived.



Further action for EASA

Based on this study, the Agency has identified some potential actions that can be taken in line with the stated objective to support regulatory decision-making, inform safety promotion, strengthen future monitoring mechanisms and ensure that regulatory and oversight mechanisms remain effective. Below some of the potential actions identified:

- Include fatigue findings (recurring safety precursors) into the actions and interventions being developed under the BIS15 "Aircrew Fatigue" and other broader safety initiatives within EASA.
- Targeted actions aimed at improving reporting culture and reporting quality ensuring proper implementation of Regulation (EU) No 376/2014 on the reporting, analysis and follow-up of occurrences in civil aviation.
- Assess how risk based oversight RBO approaches cater for the specificities of various operational/business models .
- Enhance cooperation between aviation safety and Labour Authorities both at national and EU level.
- Define standardised metrics to measure markers relevant for socio economic impact enabling a continuous monitoring rather than at defined intervals.

- Safety promotion.
  - Targeted safety promotion focused on improving reporting quality and reporting and just culture.
  - Targeted safety promotion focused on enhancing the oversight effectiveness and standardisation among NAAs.
  - Targeted safety promotion on the usage of CSR (Confidential Safety Reporting), at national and EU level
- Maintain close engagement with the European aviation stakeholders, notably the European Cockpit Association (ECA) and the European Transport Workers' Federation (ETF), as well as with relevant airline industry associations (e.g. A4E, IATA), as key stakeholders that may provide valuable early indications of emerging safety-related concerns and serious occurrence trends within the sector.

1 Introduction

This section introduces the study and provides the context needed to interpret the remainder of the report. It sets out the regulatory basis under which the assessment is conducted and explains why the topic is relevant from an aviation safety oversight perspective. The section then clarifies the purpose of the document and summarises the study objectives and scope, including the domains covered and the main boundaries applied in terms of operational context and stakeholder groups. It also outlines how stakeholders were engaged throughout the work, describing the main interaction channels used to inform the framework and validate the practical relevance of the analysis. Finally, the section closes by presenting the structure of the document and guiding the reader through the organisation of the subsequent sections and annexes.

1.1 Regulatory context

The regulatory foundation for this report is established under Regulation (EU) 2018/1139 of the European Parliament and of the Council of 4 July 2018 on common rules in the field of civil aviation and establishing a European Union (EU) Aviation Safety Agency (EASA) (the "Basic Regulation"). The principal objective of this Regulation is to ensure and maintain a high, uniform level of civil aviation safety across Europe, while also contributing to the overall performance and competitiveness of the Union's aviation sector.

Within this framework, Article 89 of Regulation (EU) 2018/1139 explicitly mandates the EU Aviation Safety Agency (EASA) to address the interdependencies between civil aviation safety and SEFs. This obligation includes integrating such considerations into regulatory procedures, oversight activities, and the implementation of just culture principles as defined in Regulation (EU) No 376/2014 on the reporting, analysis and follow-up of occurrences in civil aviation. Furthermore, Article 89 requires EASA to consult relevant stakeholders and to publish, every three years, a review providing an objective account of actions and measures undertaken to address these interdependencies.

The first Article 89 report, published in 2021, marked a significant step in recognizing the influence of socio-economic conditions, such as employment and working conditions, health and lifestyle, and education, on aviation safety performance. Building on this foundation, the current update responds to EASA's continuing legal obligation and strategic commitment to enhance safety resilience by systematically assessing these factors. This update has been commissioned under the ASSESS III Framework (EASA.2020.HVP.04), which supports research and impact assessment activities aimed at improving regulatory decision-making and safety oversight.

This initiative is aligned with the objectives of the European Plan for Aviation Safety (EPAS), which promotes a proactive, data-driven approach to safety management. By incorporating socio-economic dimensions into the safety framework, EASA seeks to strengthen its capacity to anticipate emerging risks and ensure that regulatory and oversight mechanisms remain effective in a rapidly evolving operational environment.

1.2 Purpose of the document

The purpose of this document is to present the findings and conclusions of the evaluation conducted under Article 89 of Regulation (EU) 2018/1139, as part of EASA's mandate to review the interdependencies between civil aviation safety and SEFs. This final report consolidates the work performed within the framework of the ASSESS III project (EASA.2020.HVP.04) and provides a comprehensive account of the analyses, assessments, and recommendations developed throughout the study.

Specifically, the document aims to:

- Deliver an evidence-based evaluation of SEFs that may influence aviation safety, including their mapping and associated risk assessment.
- Assess the adequacy of current data collection processes in identifying and capturing socio-economic risks relevant to SCP.
- Provide actionable recommendations to support regulatory decision-making and enhance future monitoring mechanisms.
- Summarize qualitative and quantitative findings in a clear and structured manner, ensuring alignment with EASA's regulatory objectives and strategic priorities.

This report serves as a key input for EASA's ongoing efforts to strengthen safety oversight and ensure that socio-economic considerations are effectively integrated into the European aviation safety framework.

1.3 Study objectives and scope

This study, commissioned under the ASSESS III Framework (EASA.2020.HVP.04), is designed to support EASA in fulfilling its mandate under Article 89 of Regulation (EU) 2018/1139 by providing a comprehensive, evidence-based evaluation of the interdependencies between SEFs and civil aviation safety for all SCP within the EU. Specifically, the study aims to:

- Characterize socio-economic conditions across safety-critical roles and explore how these conditions are associated with variations in operational safety indicators.
- Identify statistically robust relationships between SEFs and safety-related precursors, highlighting patterns that may signal increased vulnerability or risk exposure.

- Evaluate the completeness and reliability of existing data sources for capturing socio-economic dimensions relevant to safety, and outline gaps that limit effective oversight.
- Provide evidence-based insights to inform EASA and Member States on where SEFs may influence safety performance and how monitoring frameworks can be strengthened.
- Propose a structured approach for ongoing observation and analysis, enabling early detection of emerging socio-economic risks and supporting adaptive safety management.

The scope of the study is defined by several key boundaries and focus areas. The analysis is limited to **fixed-wing scheduled commercial air transport operations** within the EU. The analysis specifically addresses the following categories of SCP:

- **Flight Crew**, including:
    - Captain
    - First Officer
- Cabin Crew
- Operational Control Centre (OCC) Staff, including:
    - Aircraft Dispatcher
    - Operations Controller
    - Crew Controller

The study examines the influence of the following SEFs on aviation safety:

- Employment and working conditions
- Health and lifestyle
- Education
- Resource constraints and dynamics within the human resources market
- Review of any potential safety risk due to the link between work intensity, flexibility and uncertainty (as referenced in Regulation (EU) No. 376/2014)

Each of these factors has been selected by EASA for its potential to affect risk exposure and SOs for the identified SCP.

This study will provide EASA and Member States with a comprehensive evaluation of the identified risks, an assessment of current data collection processes, actionable recommendations for regulatory and oversight improvements, and an evidence matrix mapping SEFs to SOs. All outputs will adhere to EASA's reporting standards and timelines.

1.4 Stakeholder engagement

Throughout the development of this study, collaboration was established with a diverse group of key stakeholders to ensure the relevance and robustness of the approach and the validity of the results. The stakeholder Focus Group included representatives from the European Cockpit Association (ECA), the European Transport Workers' Federation (ETF), Airlines for Europe (A4E, with delegation to Airlines for Dialogue (A4D)), the European Regions Airline Association (ERA), and the European Commission. Additional input was also obtained from two major European airline.

The main findings and recommendations presented in this report were shared for consulation with these stakeholders, reinforcing the legitimacy and credibility of the analysis. This collaborative approach ensured that the perspectives of principal actors in the European aviation sector are reflected throughout the study, strengthening the validity and acceptance of its conclusions.

1.5 Structure of the document

This document is structured into 5 main sections and 4 annexes:

- Section 1 – Introduction (this section): Introduces the document, outlining its scope, objectives, and overall approach, and providing the context for the Article 89 assessment.
- Section 2 – Study methodology: Describes how the study was designed and carried out. It presents the analytical framework, clarifies the key concepts used throughout the report, and summarises the data sources and the main analytical steps applied to produce the results.
- Section 3 – Analysis and results: Presents the main analytical outputs of the study. It reports the results across the study topics and groups considered and provides the evidence base needed to support the conclusions.
- Section 4 – Conclusions and recommendations: Summarises the overall conclusions of the study and proposes recommendations and next steps for potential follow-up work and future monitoring.
- Annexes A – Acronyms
- Annexes B – Extended methodological material: Provides additional methodological detail and supporting outputs to complement the main report, providing transparency on how the analyses were conducted.

- Annexes C – Background and reference material: Compiles the supporting background material used in the study, including reference information and literature underpinning the framework and the interpretation of findings.

2 Study methodology

Section 2 sets out the study methodology used to assess how socio-economic conditions may influence aviation safety and how these effects can be monitored. It explains the logic of the analytical framework, clarifies the key concepts and definitions applied throughout the report, and describes the data sources and processing steps. The section also documents the two methodological "translation layers" used in the project: the construction of survey-based KSIs to characterise RAs, and the construction of occurrence-data indicators to quantify how SPs appear in reported events and reporting patterns.

Section 2.1 introduces the conceptual architecture linking SEFs to operational RA and connecting these to SPs and measurable safety-performance signals. It explains the structure of the framework and how it is applied to organise evidence consistently across safety-critical roles and operator contexts.

Section 2.2 sets the operational definitions used throughout. It clarifies the SEF groupings, defines the scope of RA, SCP and SPs, and introduces the indicator logic: KSIs as survey-based metrics to quantify RA dimensions, and SPIs as occurrence-data metrics to capture outcomes and reporting patterns linked to precursors.

Section 2.3 describes the evidence base and how it is assembled from complementary sources. It summarises the main data streams. Surveys (with respondents classified by operator group), the European Central Repository (ECR), and case-study inputs. It also outlines how survey responses and ECR data are extracted, scoped, and processed.

Section 2.4 explains how survey information is translated into quantitative KSIs that are interpretable and comparable across groups. It summarises the principles guiding indicator construction, the aggregation approach, and the comparative analysis setup used to support interpretation.

Section 2.5 details how SPIs are derived from ECR occurrence data to support the assessment of SPs. It distinguishes indicator families, Safety Outcome Indicators (SOIs) and Reporting Trend Indicators (RTIs), and outlines the use of risk constructs, exposure normalisation, and inferential methods to examine patterns across contexts.

2.1 Conceptual framework

The study adopts a structured framework to examine how SEFs are associated with aviation SOs and reporting trends for SCP. This framework provides a systematic approach to organize concepts and data, ensuring transparency and consistency throughout the analysis. It does not aim to demonstrate causality; instead, it focuses on identifying empirically observed associations and statistically robust relationships, using available data.

The framework was designed to address four key needs: mapping the influence of socio-economic drivers on aviation safety, assessing their potential impacts, evaluating the adequacy of existing data collection processes, and defining a transparent and replicable methodology that supports evidence-based decision-making. These objectives guided the development of a framework that connects socio-economic conditions to operational safety indicators through a logical and measurable sequence.

2.1.1 Structure and components

The framework consists of two complementary elements: the Risk Model and the Data Points. The Risk Model provides the conceptual logic, while the Data Points introduce measurable indicators intended to support a consistent and evidence-informed analysis based on surveys, occurrence-reporting data, and supporting literature.

The Risk Model begins with SEFs, which represent internal and external conditions that influence organisational and personnel performance. These factors are linked to RAs, specific operational domains where socio-economic conditions may create vulnerabilities. From there, the framework considers Safety Precursors (SPs), which are human and organisational factors acting as early signals of risk. Finally, the chain leads to SOs and Reporting Trends (SO/RT), which reflect observable safety performance, such as incident rates and reporting behaviour.

To complement this qualitative logic, the framework introduces Data Points that quantify each stage. KSIs translate broad socio-economic concepts into measurable variables, allowing the characterization of RAs. Similarly, Safety Performance Indicators (SPIs) capture the link between SPs and actual outcomes, using data primarily derived from the European Central Repository (ECR) and other sources. Together, KSIs and SPIs provide the empirical backbone of the analysis, enabling systematic testing of associations across the entire chain.

2.1.2 Application of the framework

The methodology applies this structure in a stepwise manner. Each component is clearly defined to ensure a shared understanding of scope. RAs are operationalised through KSIs, while SPIs link precursors to outcomes. Observational data is then used to test associations between SEFs, RAs, SPs, and SO/RT. These findings are interpreted qualitatively and validated through literature review and expert input, reinforcing the robustness of the analysis.

Figure 2 illustrates this dual structure. The upper section represents the Risk Model, showing the logical progression from socio-economic drivers to Ss. The lower section represents the Data Points, which provide the quantitative foundation that transforms abstract concepts into measurable indicators. This combination ensures that the framework is not merely descriptive but analytical, offering a defensible link between initial hypotheses and observed results.

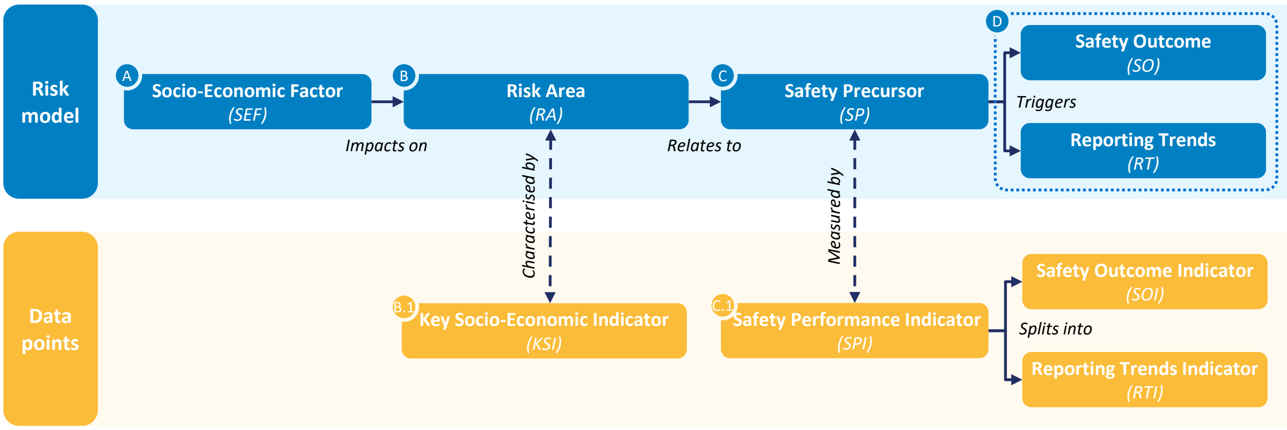


Figure 2: Conceptual framework overview.

The figure shows how SEFs influence RAs which relate to safety precursors and ultimately to SOs and reporting trends. Data Points (KSIs and SPIs) quantify these relationships, enabling systematic analysis of associations across the entire chain.

2.2 Definitions and key concepts

This section presents the definitions and key concepts that form the conceptual foundation of the study. These definitions apply exclusively within the scope of this analysis and are intended to ensure consistency and clarity throughout the work. Establishing a common understanding of these terms is essential because socio-economic and safety-related concepts can vary significantly across sources and stakeholders. Without standardization, comparisons and conclusions would lack coherence and reliability.

The need to conceptualize the framework was identified as a critical requirement during the design phase of the study. By defining these elements clearly, the methodology ensures that all participants, including analysts, stakeholders, and decision-makers, interpret the components of the framework in the same way. This approach reduces ambiguity, supports methodological rigor, and strengthens the validity of the results.

- The definitions provided in this section were derived from an extensive literature review, which is available in Annex C, and have been validated by EASA. They serve as the reference point for all subsequent analysis and provide the structure that connects SEFs to SOs. This conceptualization is necessary to maintain transparency and to ensure that the study operates within a well-defined analytical framework.

2.2.1 Socio-economic factors

- SEFs are conditions related to the social and economic environment that can influence the functioning of organisations and the performance of individuals in aviation. These include aspects such as employment stability, income levels, education, and broader economic trends that shape operational contexts and working conditions for SCPI

The set of SEFs considered in this study was provided by EASA as part of the project scope. Their definitions have been consolidated through an extensive literature review, documented in Annex C.1, to ensure clarity and consistency with established research and regulatory practices. The SEFs applicable for the study are shown in Figure 3:

Employment and working conditions
Safety Risks related to employment contracts and structure of the airline

Health and lifestyle
Mental fitness, well-being, fatigue risk management

Education
Risks related to the degradation of safety culture, safety promotion, just culture, skills and knowledge

Resource constraints and dynamics within the human resources market
Shortage of qualified personnel, shortage of ground handling staff, underrepresentation of certain societal groups, aspect of business set-ups including multiple-AOCs, outsourcing of safety-critical services, complex sub-contracting chains, permanent wet-leasing arrangements,…

Work intensity, flexibility and uncertainty
Atypical employment forms, corporate safety culture, operational/commercial pressures

Figure 3: SEFs applicable to the study.

The definition relevant to each SEF is provided in the subsequent sections.

2.2.1.1 Employment and working conditions

Working conditions define the environment and circumstances in which work takes place. They consist of various features of the job, whether individual or combined, that can be influenced and improved over time. Today, the concept of working conditions goes beyond the physical setting and includes broader factors that may affect workers' mental and physical wellbeing. This broader understanding also considers the economic aspects of work and how employment influences living standards. Because of their importance, working conditions are governed by labour law and regulated through legislation, collective agreements, workplace policies, contracts, and established practices[3].

More specifically, working conditions cover not only the physical workplace but also the terms and conditions of employment. This includes how work is organised, the availability of training and skill development, health and safety measures, overall wellbeing, working hours and the balance between professional and personal life. Compensation, as a core component, is integral to these conditions[4].

At the EU level, the social policy framework is outlined in Article 151 of the Treaty on the Functioning of the EU (TFEU), which sets the objectives for social policies, while Article 153 provides the legal tools enabling the EU to support and complement the efforts of its Member States in achieving these goals[5].

Several EU directives specifically regulate aspects of working conditions. For instance, the Working Time Directive (2003/88/EC) limits weekly working hours and establishes minimum rest periods, while the Framework Directive on Health and Safety at Work (1989/391/EEC) forms the basis for more detailed rules, including those addressing the safe use of visual display units (Directive 90/270/EEC).

The European Pillar of Social Rights elevates "fair working conditions" to a fundamental principle. It aims to guarantee robust protection of workers' health and safety, ensure employment that is both predictable and secure, promote fair remuneration, and uphold the right to clear information regarding employment terms. It also stresses the importance of work-life balance, active social dialogue, and measures to prevent precarious employment.

Key aspects emphasized by the European Pillar of Social Rights include:

- **Secure and adaptable employment**: workers should be well informed about their employment conditions, including probation periods and have the right to request more predictable and stable arrangements after a certain period.
- **Fair wages**: compensation should enable workers to maintain a decent standard of living.
- **Information about employment conditions**: essential employment details must be communicated clearly and in writing.

[3] Eurofound (2021). Working Conditions. European Foundation for the Improvement of Living and Working Conditions

[4] European Industrial Relations Dictionary

[5] Treaty on the Functioning of the European Union (TFEU)

- **Protection in case of dismissals**: workers should have access to information and safeguards concerning their rights if dismissed.
- **Social dialogue**: dialogue between employers and employees is crucial to resolving workplace challenges and improving conditions.
- **Work-Life balance**: support for parental leave and flexible work arrangements help maintain this balance.
- **Health and safety**: employees have the right to a safe, healthy, and supportive work environment.
- **Preventing precarious work**: actions are needed to curb unstable or exploitative forms of work, including misuse of atypical and zero-hour contracts.
- **Training**: mandatory, job-related training should be provided free of charge to employees.
- **Right to disconnect** with telework becoming more common, workers' ability to disconnect outside working hours is increasingly recognized and supported.

2.2.1.2 Health and lifestyle

In the EU context, health and safety at work are understood in a broad sense, extending beyond merely preventing accidents and disease to encompass all aspects of a worker's well-being. This comprehensive view is shared by both the International Labour Organization (ILO) and the World Health Organization (WHO) [6].

The World Health Organization defines health as "a state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity". This holistic definition emphasizes that health is more than the absence of illness, requiring balance across essential dimensions:

- **Physical well-being**: includes not only freedom from disease but also having the energy and ability to carry out daily activities and maintain a healthy body.
- **Mental well-being**: encompasses emotional and psychological health, it involves managing stress, regulating emotions, and sustaining a positive mental state.
- **Social well-being**: refers to effective social interaction, participation in community life, and meaningful contribution to society.

[6] World Health Organization (WHO)

The WHO's definition highlights that health is a fundamental human right and recognizes the interconnectedness of physical, mental, and social well-being as crucial components of overall health.

Moreover, the concept of well-being extends this further, describing a state where individuals, through self-awareness and self-management across physical, psychological, social, and practical domains, can work positively and productively. They can cope with workplace stressors, achieve personal goals, and contribute meaningfully[7].

This integrated understanding of health and well-being is particularly vital in high-pressure, safety-critical fields like aviation, where maintaining a sustainable balance is key to ensuring both safety and performance.

2.2.1.3 Education in the context of Just Culture

Just Culture refers to the ongoing process through which SCP are informed, trained, and empowered within an organizational framework that encourages the reporting of errors, incidents, and safety concerns without fear of punitive consequences, provided actions are not the result of gross negligence or intentional misconduct. This process helps individuals distinguish between honest human error and reckless behaviour, fostering a culture of trust, learning, and continuous safety improvement[8].

Key aspects of Just Culture education include:

- **Education is fundamental to building trust**: staff need clear training to understand their rights and responsibilities in a Just Culture. Many crew members only fully understand how Just Culture works when faced with a reportable incident. Without adequate knowledge, fear of consequences can lead to underreporting or avoidance of reporting altogether. Education helps clarify the difference between human error, at-risk behaviours, and reckless conduct.
- **Training should include real-world case studies**: scenario-based training that reflects actual safety dilemmas benefits pilots, dispatchers, and cabin crew by showing how Just Culture principles apply. These real-world cases help distinguish between acceptable errors and unacceptable behaviours.

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[7] EASA (2020) – An Aviation Professional Guide to Wellbeing

[8] EUROCONTROL HindSight Magazine Issue 35. JUST CULTURE...REVISITED PROGRESS IN JUST CULTURE: WHAT HAVE WE DONE FOR YOU?

- **Role of the organization**: proactive and transparent: organizations must educate and reassure staff on how reports will be handled. Transparent policies and procedures around investigations and accountability are crucial. Just Culture thrives only when management openly demonstrates that reports are treated fairly and constructively.
- **Education is ongoing, not one-off**: Just Culture training cannot be a one-time event during initial onboarding. Continuous reinforcement is essential through recurrent training, peer discussions, and regular safety briefings to keep the culture alive and effective.

2.2.1.4 Resource constraints and dynamics within the human resources market

Resource constraints and dynamics within the human resources market describe the complex interaction between organizational capacities and workforce conditions that influence personnel availability, skill distribution, and employment stability. This encompasses issues such as labour shortages, challenges in recruitment and retention, outsourcing and subcontracting practices, demographic changes and the evolution of employment relationships. These factors collectively affect organizational effectiveness, workforce composition, and operational safety within the aviation sector[9].

More specifically, resource constraints and dynamics refer to broader labour market trends and employment conditions that shape the availability, stability, and suitability of personnel in each industry. Structural developments such as labour shortages, an aging workforce, skill mismatches, and the increasing prevalence of atypical and flexible contracts all play a significant role[10]. Additionally, organizational practices like outsourcing and subcontracting further influence workforce dynamics. Together, these elements impact recruitment and retention efforts, modify workforce composition, and may limit employees' access to training, inclusion in safety management systems, and their willingness to report safety concerns, issues that are particularly critical in safety-sensitive industries such as aviation. While the referenced EASA COVID-19 review does not specifically assess long-term labour-market structures, it highlights how workforce disruption, reduced operational continuity, skills degradation, wellbeing concerns, and organisational strain can influence safety resilience in safety-critical environments. Within the context of this study, these observations are therefore used as supporting contextual considerations rather than as direct evidence of broader structural labour-market dynamics.

[9] Eurofound (2021). Labour market change: Trends and policy approaches towards flexibilisation

[10] European Commission (2016). Employment and Social Developments in Europe (ESDE 2016)

2.2.1.5 Work intensity, flexibility and uncertainty

Work intensity, flexibility and uncertainty are fundamental aspects of working conditions that shape job quality and employee well-being. These dimensions encompass the demands of workload, the ability to adapt to changing circumstances, and the predictability of schedules, roles, and employment stability. In the aviation sector, they manifest through operational pressures, variability in scheduling, last-minute changes, and job insecurity, all of which have important consequences for fatigue management, employee stress levels, operational decision-making, and proactive safety reporting[11].

Specifically, work intensity refers to the physical and mental demands placed on workers, often involving time pressure, high workloads, and sustained effort[12]. Flexibility denotes the extent to which working conditions can be modified, either by employees controlling their schedules or tasks, or by employers adjusting working hours, duties, or workplace locations. Uncertainty relates to unpredictability in work schedules, roles, or contract stability, which contributes to job insecurity[13]. Given the safety-critical nature of aviation, these factors play a significant role in influencing both employee well-being and overall operational safety, as acknowledged in Regulation (EU) No. 376/2014.

2.2.2 Risk areas

The identification of the RAs emerged as a key step in the early stages of the project. Initially discussed during the Kick-off Meeting, these areas were shaped through expert consultation and subsequently refined during an internal review process by EASA. Rather than being theoretical constructs, they reflect practical concerns voiced by authorities, industry stakeholders, and frontline personnel, capturing both long-standing and emerging vulnerabilities within the aviation ecosystem, as highlighted in the previous Article 89 report , in studies by the European Commission and European Cockpit Association[14] on atypical employment and home base arrangements, as well as in broader safety analyses by ICAO[15].

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11 Eurofound (2020). Working conditions in sectors

12 Eurofound (2023). Living and working in Europe 2023

13 Eurofound (2022). Platform work: Work intensity and working time quality

14 European Commission: Directorate-General for Mobility and Transport, Ricardo, Molina, C., Levin, S., Castillo, L. et al., *Study on employment and working conditions of aircrews in the EU internal aviation market – Final report*, Publications Office, 2019

15 ICAO (2 024). *State of Global Aviation Safety / Safety Report 2024*. Montréal: International Civil Aviation Organization

The RAs fulfil an essential role within the analytical framework by providing the link between the socio-economic conditions considered in the study and the operational aspects of aviation safety. They act as the point at which broad socio-economic influences are translated into concrete domains that can be examined through indicators and data sources. Within this structure, RAs help organise how SEFs relate to SPs and, ultimately, to observable SOs and reporting patterns.

Table 2 presents the list of RAs along with their respective definitions.

Table 2: Risk Areas definitions.

Risk Area	Definition
Pilot retirement age	The safety risks that may arise from extending retirement age beyond 65 without adequate provisions to address potential impacts on health, cognitive performance, and transition planning.
Homebase changes	The operational risks linked to frequent or insufficiently managed crew relocations, which may affect pilot or crew stability, performance, and decision-making.
Crew interoperability	The risks associated with deploying flight and cabin crews across different Air Operator Certificates (AOCs) within a single airline group, including safety concerns related to unclear responsibilities, inconsistent regulatory oversight, and non-standardized procedures, alongside socioeconomic implications such as atypical employment practices and wage disparities.
Atypical contracts	The risks arising from non-standard employment models in which airlines engage crew through third-party agencies usually in lower-tax jurisdictions with lower labour protections, potentially weakening regulatory compliance, oversight, and workforce stability.
Skills and training gaps	The risks linked to insufficient investment in initial or recurrent training, safety promotion, or knowledge retention, which may affect procedural consistency, particularly under conditions of high turnover or subcontracting.
Workforce shortages	The operational risks related to insufficient availability of qualified personnel or imbalances in workforce composition, which may weaken oversight, increase workload, and reduce system resilience.
ACMI operations	The risks inherent to the wet-lease business model in which airlines provide Aircraft, Crew, Maintenance, and Insurance, where features such as global

Risk Area	Definition
	fleet mobility, lean staffing, and older aircraft may influence operational resilience and safety performance.
Generational risk behaviour	The risks associated with evolving lifestyle trends and cultural shifts, such as attitudes toward substance use, risk perception, and work-life balance, which may shape operational behaviour and decision-making.
Commercial pressure	The safety risks that arise when financial or operational performance objectives influence decision-making in ways that may compromise safety priorities, including how such pressures may affect personal behaviours and contribute to substance use among personnel.
Fuel management	The risks linked to the planning, allocation, and operational handling of fuel resources, including the accuracy of calculations and adherence to established procedures.
Go-around decisions	The risks associated with reluctance or delay in initiating a go-around, which may increase the likelihood of unsafe landings during critical flight phases.
Pilot discretion use	The risks arising from recurrent reliance on pilot discretion to extend flight duty periods beyond those permissible on the day or adjust operations, which may mask systemic issues such as insufficient standby crew or inadequate scheduling buffers.
Fraud risk	The risks linked to the deliberate falsification of records, training documentation, or duty logs, particularly in contexts where oversight is weak or accountability is subcontracted.

2.2.3 Safety critical personnel

In the context of this study, Safety critical personnel (SCP) are understood as individuals whose functions have a direct and essential impact on the safety of flight operations and related activities. For the purposes of this study, three groups have been identified as SCP:

- **Flight Crew**: This group includes those crew members designated by the operator to perform essential duties during the flight duty period (FDP). It must include at least one Captain and a First Officer. All flight crew members are required to hold appropriate licenses and ratings as mandated by Commission Regulation (EU) No 1178/2011 (Part-FCL). Flight crews are responsible for the safe conduct of the flight, including navigation, aircraft control, communication, and compliance with operational procedures and regulations as outlined in Annex III (Part-ORO) and Annex IV (Part-CAT) of Regulation (EU) No 965/2012.

- **Cabin Crew** with Safety Responsibilities: These personnel are assigned by the operator to ensure passenger safety and aircraft security during all phases of flight operations. They must be properly certified and qualified according to Regulation (EU) No 965/2012, particularly Annex III (Part-ORO.CC.115 & 125, Annex V (Part-CC) to Reg 1178/2011). Their duties include managing onboard emergencies, facilitating evacuations, enforcing safety procedures and contributing to the overall safety and security environment within the cabin.
- **Operational Control Staff**: This category covers flight dispatchers, Operations Control Centre (OCC) personnel and flight operations officers. They handle pre-flight planning, dispatch, weight and balance calculations, and real-time operational support during flights. While not uniformly subject to EU-wide licensing, they are regulated under frameworks such as ORO.GEN.110 and are involved in safety-sensitive decision-making often under commercial and operational pressures.

While no formal definition of SCP exists within current European regulations, the working definition adopted in this study is informed by multiple sources. The selection of personnel categories considered as SCP was guided by an extensive review of the literature on human factors in aviation safety, complemented by expert assessments and consultation with EASA. This process ensured that the categories identified are operationally relevant while remaining proportionate to the scope of the study. The literature sources supporting this classification are listed in Annex C.2.

The scope of this study was deliberately focused on those roles with the most direct and immediate influence on flight safety. Although other categories such as maintenance personnel, ground handling staff, business avaition, rotorcraft or air traffic controllers were considered during the scoping phase, they were ultimately excluded because they fall outside the remit defined for this iteration of the analysis. Ground handling activities are already addressed under dedicated regulatory frameworks, and with Regulation (EU) 2025/24 entering into application from 27 March 2028, this area will be subject to reinforced oversight in future updates to Article 89. Air traffic controllers were also excluded due to their distinct operational context and regulatory treatment. They may, however, be considered in subsequent versions of this report should EASA determine that their inclusion is appropriate for future assessments. The same applies for Business Aviation and Rotorcraft they both were not considered due to the very specific on demand nature of this type of operation but could be considered in future assessments.

2.2.4 Safety precursors

SPs refer to underlying human and organisational factors that have the potential to influence safety outcomes. They often manifest as latent conditions or early indications of vulnerabilities within operational environments. By highlighting behavioural tendencies, organisational dynamics and systemic weaknesses, SPs provide essential insight into how safety performance may be affected before incidents occur.

To identify and define the SPs relevant to this study, an extensive literature review was conducted. This review highlighted the "Dirty Dozen" as one of the most widely recognised frameworks for understanding human error precursors across the aviation sector. Since its introduction in 1993[16], the framework has moved well beyond its original application in aircraft maintenance and is now broadly used to support safety-culture initiatives, promote awareness of human factors, and structure discussions on operational risk in safety-critical contexts.

Building on the findings of the literature review, the study incorporated targeted consultations with experienced aviation professionals who hold operational and human-factors expertise. Their feedback confirmed the suitability of the Dirty Dozen as the foundation for identifying relevant precursors. These consultations also supported the addition of Workload as a supplementary thirteenth factor, reflecting its relevance across contemporary operational environments and ensuring that the set of precursors aligns with the practical realities observed across safety-critical functions.

The final list of SPs used in this analysis, together with their associated descriptions, is presented in Table 3.

Table 3: Safety Precursors (SPs) list and descriptions

Safety precursor	Description
Lack of communication	Ineffective communication occurs when essential information is not clearly exchanged, misunderstood, or assumed rather than confirmed. This can lead to errors in coordination, missed warnings, or unsafe decisions.
Distraction	Distractions, whether external or internal, pull attention away from critical tasks. Even momentary lapses in focus can lead to incomplete work or safety oversights.

[16] Dupont, G. (1993). The Dirty Dozen [Training module]. Transport Canada.

Safety precursor	Description
Lack of resources	A shortage of time, staff, equipment, or documentation can pressure personnel to improvise or skip steps. Inadequate resources often result in increased workload, errors or reduced quality.
Stress	Stress arises from time pressure, interpersonal conflict, workload, or personal issues. While short-term stress can sharpen focus, chronic or excessive stress impairs judgment, attention, and communication.
Complacency	When tasks become repetitive or overly familiar, individuals may stop actively anticipating problems. Overconfidence or a false sense of security can lead to missed hazards or deviations from procedure.
Lack of teamwork	Poor coordination, unclear roles, or lack of mutual support can weaken team effectiveness. Without trust and open communication, tasks may be duplicated, missed, or performed inconsistently.
Pressure	External or internal pressure to meet deadlines, reduce costs, or satisfy expectations can lead individuals to rush, cut corners, or ignore protocols.
Lack of awareness	Situational awareness involves understanding what is happening around you and anticipating how things might change. A lack of awareness can lead to delayed reactions or unsafe decisions.
Lack of knowledge	Inadequate training, limited experience, or unfamiliarity with systems or procedures increases the likelihood of mistakes.
Fatigue	Mental or physical exhaustion reduces concentration, reaction time, and decision-making ability. Fatigue can be caused by long hours, shift work, or poor rest.
Lack of assertiveness	Hesitating to speak up when something seems wrong can allow unsafe situations to go unchallenged. Assertiveness means expressing concerns respectfully but clearly, regardless of hierarchy.
Norms	Informal practices that develop over time can drift from official procedures. While they may seem efficient, these habits often bypass safety steps.
Workload	An excessive or insufficient workload can both impair performance. Overload can lead to rushing, errors, or missed steps; underload can reduce alertness or engagement.

2.2.5 Key socio-economic indicators

KSIs are quantitative metrics used to characterise and assess each RA. Their function is to transform broad socio-economic aspects into measurable variables, allowing these dimensions to be examined systematically within the framework of the study. Within the existing EASA safety structure, where operational risks are already organised through defined RAs, KSIs add a complementary analytical layer by introducing a socio-economic perspective aligned with established monitoring practices. For each RA, a dedicated set of KSIs has therefore been defined to capture its associated socio-economic dimensions.

To illustrate this distribution, Figure 4 presents the number of KSIs assigned to each RA. The graph highlights how certain areas, such as "Skills and training gaps" or "Commercial pressure," require a broader set of indicators due to their multidimensional socio-economic nature, while others demand fewer but more targeted KSIs. This visual overview helps clarify the relative complexity of each RA and the corresponding depth of socio-economic analysis applied in the study.

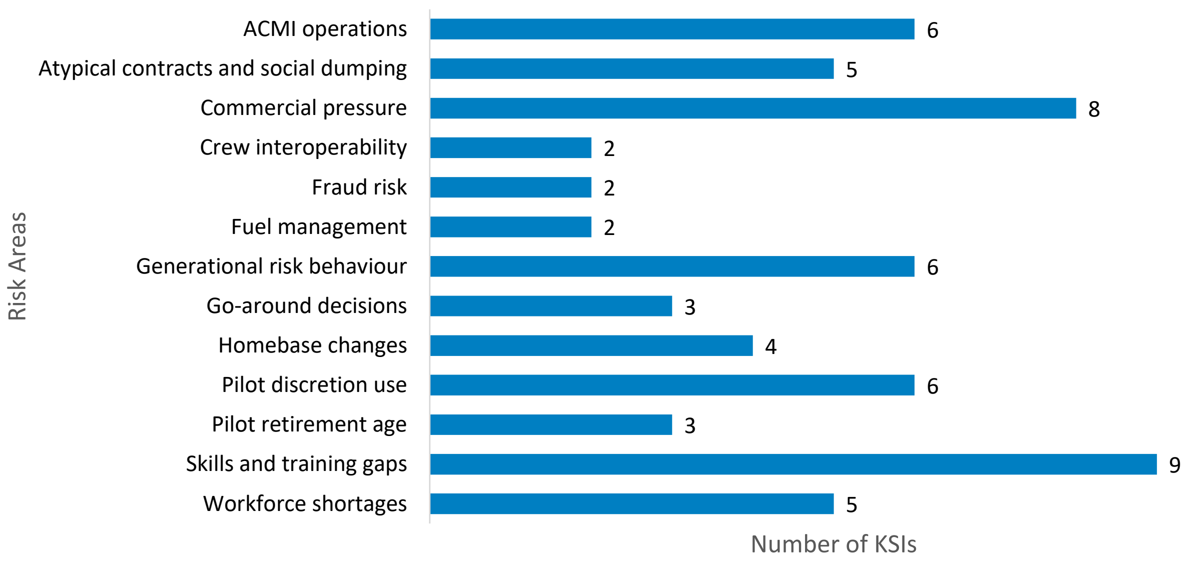

Figure 4: Number of KSIs defined for each RA.

The KSIs are constructed and populated using information obtained from the survey and relevant databases. Further details on the data collection methodology are provided in Section 2.4. For readability, the complete list of KSIs, including their definitions and source references, is provided in Annex C.4.

2.2.6 Safety performance indicators

Safety Performance Indicator (SPI) is a metric used to express the level of safety performance achieved within a system as defined by the ICAO Safety Management Manual. SPIs enable aviation authorities and operators to monitor safety, identify trends and emerging risks, and support informed decision-making to maintain and improve safety performance. They are a core element of both State Safety Programmes (SSP) and organisational Safety Management Systems (SMS), as outlined in ICAO Annex 19.

In this project, SPIs are used to quantify, in a structured and comparable way, how SPs are reflected in reported safety occurrences and how such occurrences are reported. This provides a quantitative basis for examining the safety relevance of socio-economic SPs across different contexts. To reflect these different dimensions, SPIs are organised into two complementary categories:

- **SPIs of safety outcomes (SOIs):** Indicators that measure observed safety events, such as accidents, serious incidents, or other adverse occurrences.
- **SPIs of reporting trends (RTIs):** Indicators that capture the volume and patterns of safety reporting, supporting the interpretation of reporting behaviour and the identification of weak signals.

This section describes the data collection activities carried out for the study. The objective of this phase is to gather the information required to populate the indicators defined in the conceptual framework and to document the evidence needed to analyse the relationships between SEFs, RA, SPs and SOs. These activities therefore represent the first practical application of the analytical framework, allowing the study to move from its theoretical structure to the use of real data.

Figure 5 provides an overview of how the different data sources relate to the components of the framework. The upper part of the figure represents the conceptual framework, which links SEFs to RAs, SPs and SOs. The lower part illustrates the corresponding data points, showing how each component is informed by specific sources: surveys and databases for the KSIs, ECR data for Safety SPIs, and additional qualitative inputs such as case studies where relevant. This visual summary helps clarify which data sources feed each analytical element and how these inputs align with the overall structure of the study.

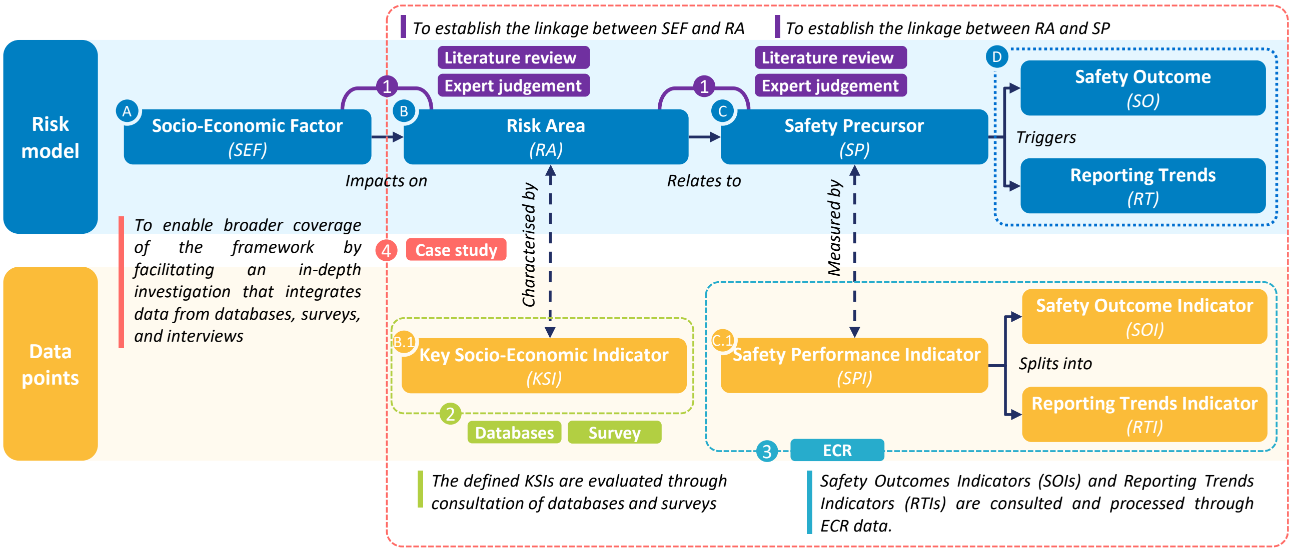

Figure 5: Data collection elements integrated within the study framework.

The results of the data collection phase not only identify the information available for the current iteration but also highlight structural gaps in existing datasets. These findings provide the basis for the recommendations on improving socio-economic data collection that are presented later in the report.

2.3 Sources of data

This study uses several complementary data sources, each contributing different information required to address the elements defined under framework described in Section 2.1.2. Because these aspects cannot be fully represented by a single dataset, multiple inputs were combined to provide both operational insight and analytical consistency. The four sources of data used in the study are shown below, together with a brief summary of their respective purpose. Further subsections provide more details about the characteristics of the source of data.

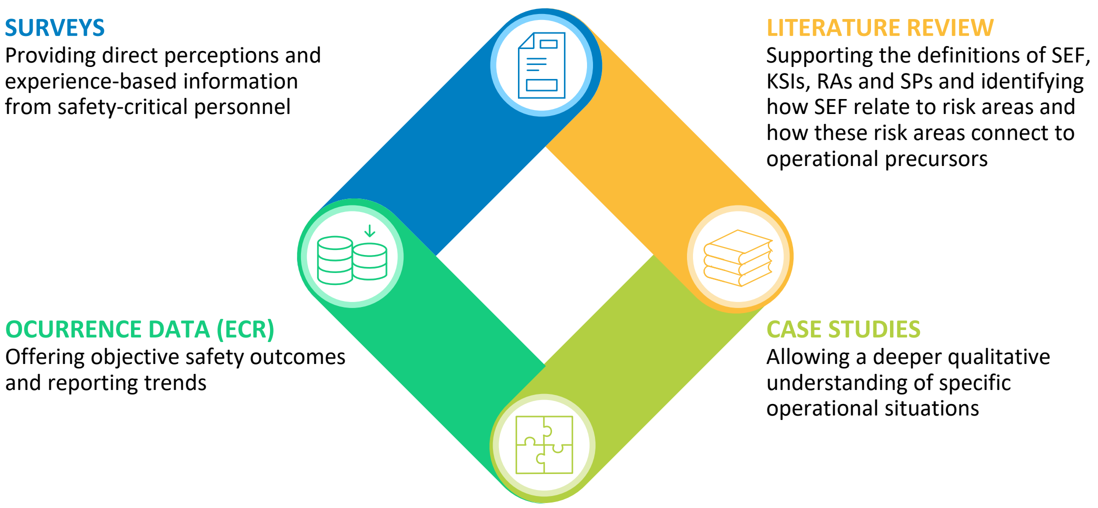

Figure 6: Overview of the four data sources.

2.3.1 Literature review

The literature review was carried out at the start of the project with the objective of establishing a clear and evidence-informed foundation for the study's analytical framework. EASA initially provided a set of high-level Socio-Economic Factors, and the aim of the literature review was not to reassess these categories but to develop formal, well-supported definitions based on existing academic, regulatory and industry sources. More than fifty references were consulted for this purpose, including sources shared by EASA and additional materials identified during the early iterations of the project.

The literature review was used in a targeted manner across the components of the framework. First, it served to formalise the definitions of the Socio-Economic Factors by identifying how similar dimensions are described and understood in existing research, ensuring that the study adopted consistent and well-established terminology. Second, although the RAs were defined separately as part of the project scope, the literature review was used to explore whether published studies described relationships between these RAs and the defined socio-economic factors. This exercise provided an initial evidence-based mapping between SEFs and RAs, with the understanding that these linkages would later be reinforced through KSIs.

Third, the literature review supported the definition of the SPs by drawing on well-recognised human-factors frameworks and documented contributors to human error. The review was also used to identify any evidence suggesting relationships between RAs and SPs, complementing these findings with expert judgement when literature was limited or indirect. Finally, regulatory and institutional sources were reviewed to support the definition of Safety-Critical Personnel and to ensure that the personnel categories considered in the study reflect established regulatory requirements.

The literature review therefore provided the conceptual starting point for the framework. Its outputs are not presented as final causal conclusions; instead, they serve as preliminary evidence positions that will be later tested through surveys, operational databases, operator-provided data or occurrence-reporting analysis. A detailed overview of all reviewed sources and the corresponding outputs is presented in Annex X (literature review on Socio-Economic Factors) and Annex Y (literature review on Safety-Critical Personnel).

2.3.2 Surveys

The surveys were designed to mainly collect operational perceptions and experience-based information from the SCP included in the scope of this study. This comprises flight crew, cabin crew and operational control personnel (OCC) as defined in Section 2.2.3. The questionnaires focus on how socio-economic factors (SEFs), operationalised for this report and aligned with the Article 89 framework, manifest in day-to-day operations and relate to the indicators developed in the study. Section 2.2.1 provides the formal definition of the SEFs used in this report.

The survey complements occurrence reporting by capturing aspects that event-based systems cannot observe, such as organisational practices, employment arrangements, safety culture attributes and perceptions of workload or predictability. These dimensions represent relevant socio-economic and operational influences that may act as precursors of safety performance.

Distribution

The questionnaire was deployed on EUSurvey[17] and remained open from 3 November 2025 to 8 December 2025. Dissemination used EASA's communication channels and the support of European aviation stakeholders, including social partners (ECA and ETF). This ensured targeted access to the SCP groups identified in Section 2.2.3. EASA also published an official communication bulletin on its website to raise awareness across the aviation community. For the accuracy of the survey, safeguards have been put in place to limit potential instrumentalization of the answers (e.g. identifying unusual reporting patterns, multiple response from the same IP address, potential use of bots).

Figure 7: Official EASA Survey communication bulletin. Accessible via: https://www.easa.europa.eu/en/newsroom-and-events/news/easa-launches-survey-effect-socio-economic-factors-aviation-safety.

[17] EUSurvey is the European Commission's official online survey management system supported by the Directorate-General for Digital Services. For further information, please visit https://ec.europa.eu/eusurvey/home/welcome

Participation volume

A total of 6,142 valid responses were collected. When compared with the size of the European workforce, participation remains modest. According to the latest figures from the SIS database[18], Europe counts approximately 80,000 licensed pilots[19], 110,000 cabin crew and 20,000 operational control personnel. The lower number of OCC responses aligns with the comparatively smaller size and limited accessibility of this group. Overall, the dataset is diverse and analytically usable, and although below the potential population it constitutes a large sample size. Figure 8 provides a visual overview of the participation levels across the three safety-critical groups.

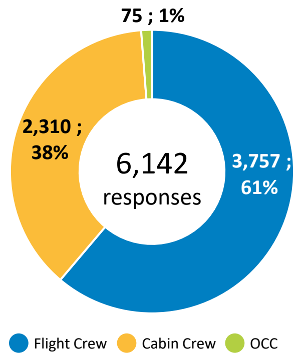

Figure 8: Survey participation overview

Survey structure and content

The questionnaire consisted of a total of 97 questions, fully listed in Annex **Error! Reference source not found.**. It combined items applicable to all safety-critical personnel groups with others specifically tailored to their respective operational contexts. Its structure comprised the following components:

- **Demographic questions**, designed to capture essential contextual information such as age, gender, home base and years of operational experience, thereby providing the background necessary to interpret the analytical results.
- **Categorical questions**, aimed at collecting discrete information on operational practices, employment conditions and qualitative aspects of the working environment that cannot be retrieved from occurrence reporting.
- **Likert-scale questions**, which constituted the core quantitative input for the statistical processing described in Section 2.3.5.1.2 and enabled the measurement of perceptions and experience-based assessments across key socio-economic and operational dimensions.
- **Open-ended question**, offering respondents the opportunity to provide additional comments or raise issues not explicitly addressed elsewhere in the questionnaire.

Operator groups represented

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[18] SIS is EASA's web-based system for collecting regulatory data from national authorities, https://sis.easa.europa.eu

[19] Airline Transport Pilot Licences – Aeroplanes (ATPL(A) licenses)

Survey respondents were classified into operator groups reflecting different employment environments and business models within the aviation sector. The following are represented in the survey:

- **ACMI operators / wet lease providers**, including operators primarily supplying aircraft, crew, maintenance and insurance services (e.g. SmartLynx Airlines, Avion Express, Hi Fly, Airhub Airlines)
- **Business aviation**, overing on-demand and fractional ownership operations (e.g. NetJets Europe, Luxaviation, GlobeAir)
- **Cargo operators**, focusing on dedicated freight operations (e.g. ASL Airlines, Cargolux, DHL, Lufthansa Cargo)
- **Charter airline**, operating predominantly leisure-oriented and seasonal services (e.g. TUI fly, Smartwings, Corendon Airlines Europe, SunExpress)
- **Low-cost carriers**, characterised by point-to-point networks and high-utilisation operating models (e.g. EasyJet, Ryanair, Vueling, Wizz Air)
- **Network carriers**, operating hub-and-spoke models with integrated short- and long-haul networks (e.g. Lufthansa, Air France, KLM, Iberia, Austrian Airlines)
- **Regional airline**, operating under capacity purchase agreements (e.g. Air Nostrum, Widerøe, Loganair, Lufthansa CityLine, Air Dolomiti).

Data protection and processing

All responses were collected anonymously and processed in compliance with EU data protection requirements[20]. No personally identifiable or operationally sensitive information was retained in the analytical dataset. The survey data were then processed through a structured workflow of extraction, cleaning, and statistical analysis, as detailed in Section 2.3.5.1.

Considerations

To ensure a precise interpretation of findings, the following methodological aspects should be noted:

- **Survey refinement**: The initial questionnaire ensured that each KSI was represented by at least one survey item. A structured refinement phase was then conducted with a Focus Group comprising social partners (ECA and ETF), airline associations (A4D and ERA), EASA and a major

[20] EU General Data Protection Regulation (Regulation (EU) 2016/679).

European airline. The group reviewed the clarity, operational relevance and coverage of all items, leading to the addition and adjustment of several questions to better reflect operational realities. As a result, the final survey contains (i) items not linked one-to-one to a specific KSI, and (ii) a few KSIs without a direct survey item.

- **Voluntary participation and self-selection**: Participation was voluntary. Results describe the surveyed population and should not be interpreted as a census of the entire workforce.
- **Nature of perception-based data**: The survey captures experiences and perceptions, which complement, but do not replace objective safety data.
- **Retrospective questions:** Some items require respondents to reflect on past practices or conditions. Though it may introduce natural variability in recall, it is mitigated by the large sample size.
- **Cross-group and cross-country heterogeneity**: Differences in business models, employment arrangements, and national practices may influence responses. Group-based comparisons are therefore interpreted with contextual controls in the statistical analysis.

2.3.3 ECR

The measurement of safety performance in civil aviation relies on the systematic collection and analysis of safety relevant occurrences and operational precursors. In the European context, this role is fulfilled by the European Central Repository (ECR), the central database of civil aviation safety occurrences reported to national competent authorities and to EASA in accordance with Regulation (EU) No 376/2014[21] on the reporting, analysis and follow-up of occurrences in civil aviation. At the same time, EASA recognises that effective Safety Management System (SMS) activities and regular oversight audits remain equally essential components of aviation safety performance monitoring and continuous improvement.

Occurrences in the ECR are reported and exchanged using ECCAIRS 2, which supports the structured recording and management of civil aviation occurrence data by competent authorities. Occurrence reporting is based on the ICAO ADREP taxonomy, providing standardised definitions of event types, contributing factors, operational contexts and outcomes, and enabling consistent aggregation and analysis of occurrence data across Member States.

The ECR includes both mandatory and voluntary occurrence reports, as defined under Regulation (EU) No 376/2014. Mandatory occurrence reporting applies to occurrences listed in the applicable

[21] Regulation (EU) No 376/2014 of the European Parliament and of the Council of 3 April 2014 on the reporting, analysis and follow-up of occurrences in civil aviation, OJ L 122, 24.4.2014, available at: https://eur-lex.europa.eu/eli/reg/2014/376/oj/eng (accessed January 2026)

implementing rules, while voluntary occurrence reporting enables the reporting of any safety-related information perceived by the reporter as an actual or potential hazard to aviation safety. Both reporting streams contribute to the identification of safety risks and support a proactive, learning-oriented safety management approach.

Considerations

To ensure an appropriate definition and interpretation of the SPIs, it is crucial to understand the characteristics and limitations inherent to the ECR:

- **Reporting structure and culture**: The ECR contains both mandatory and voluntary occurrence reports submitted under Regulation (EU) No 376/2014. As reporting practices and reporting cultures may vary across States, organisations and professional groups, analyses should consider the potential variability in reporting behaviours and interpret group-based SPIs accordingly
- **Reporting quality:** Given the nature of the reporting system, the completeness, consistency, and classification of occurrence reports may vary across reporting entities. In addition, duplicate reports may arise when the same occurrence is reported by different organisations.
- **Event-based data:**. Occurrence data stored in the ECR provide information on reported safety events and precursors but do not, on their own, include operational exposure metrics such as flight hours, movements or traffic volume. Such exposure data therefore need to be integrated from complementary operational data sources when developing risk-based analyses or SPIs.
- To mitigate this limitation, the analysis is complemented with operational exposure data from EUROCONTROL, provided under the **Data4Safety (D4S) Programme**. This traffic data covers monthly IFR flights within EASA Member States airspace (data scope available from 2019) and is used to normalise occurrence counts and to support the interpretation of SPIs in relation to changes in activity levels rather than solely in terms of absolute event counts.

2.3.4 Case studies

The case studies were originally designed as a complementary analytical component intended to provide a level of depth and contextual understanding that cannot be achieved through standard quantitative approaches alone. While the broader data-collection framework combines surveys, structured datasets and interviews to map socio-economic influences at scale, certain RAs require a more focused and qualitative examination to understand how these influences manifest within real operational environments.

In this context, the case studies were conceived with three principal objectives:

- Aimed to explore potential causal relationships between selected Key Socio-economic Indicators and specific safety-relevant precursors, enabling a deeper understanding of how socio-economic conditions may shape operational performance.
- Sought to complement and enrich the broader statistical results by providing highly contextualised, real-world evidence drawn from specific organisations or operational scenarios.
- Intended to help validate and refine the methodological framework by identifying practical lessons regarding data availability, measurement feasibility and the analytical pathways required to examine socio-economic influences at a granular level.

To achieve these objectives, the case study framework was designed to be flexible. It could combine targeted surveys, focused database queries, internal operator metrics, interviews or other tailored techniques as needed to reach the required level of detail for each selected RA. The selection of these areas was to be guided by their systemic relevance and by the added value that an in-depth qualitative assessment could provide.

During the execution of the study, however, the level of data availability and the feasibility of conducting the planned in-depth analyses were more limited than anticipated. Even so, two operators provided partial but structured operational data relevant to specific KSIs. Although this information is not sufficient to develop the originally envisioned full case study format, it nevertheless constitutes valuable factual evidence. As a result, the study approach was adapted to repurpose these contributions into a targeted cross-source comparison, illustrating how operator-provided data can support selected KSIs and offering early insight into how such data could strengthen future iterations of this study.

A detailed explanation of this adapted analytical approach and its results is provided in Section 3.3.1.

2.3.5 Data extraction and processing

Here, each source of data will be analysed.

2.3.5.1 Surveys

This section provides a high-level overview of the methodology applied to process the survey data. The workflow follows the sequence illustrated in Figure 9, moving from data collection to preprocessing, validation and the construction of analytical variables.

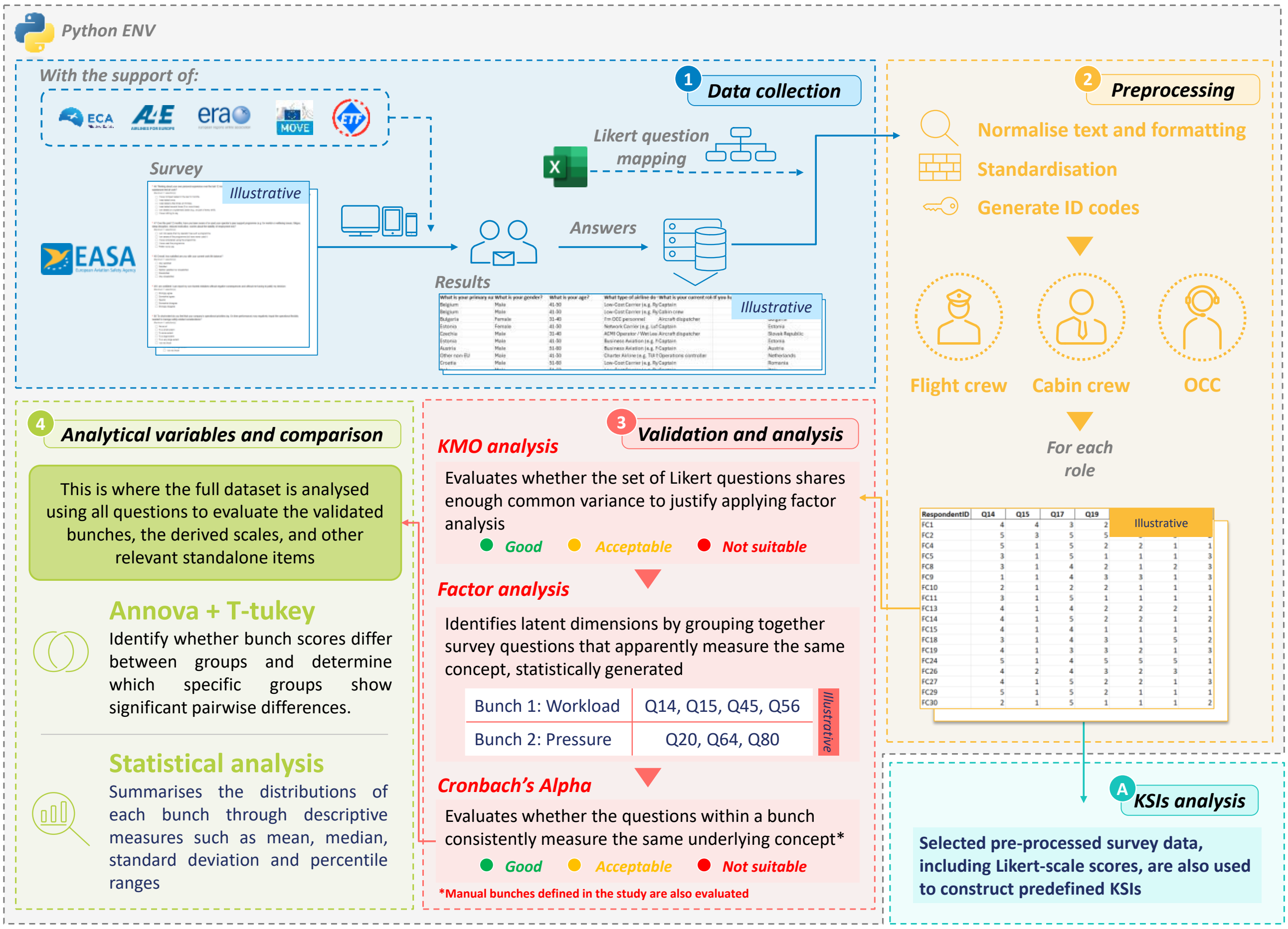

Figure 9: End-to-end workflow of the survey process.

Importantly, only the steps up to and including preprocessing are used for the construction of the survey-based KSIs, as shown in *block A – KSI analysis* of the figure. The full workflow is applied when analysing additional survey questions that are not linked to KSIs, many of which were added during the refinement phase upon recommendation of the focus group.

The following subsections outline the four stages of the workflow, moving from **data collection** through **preprocessing**, **validation and analysis**, and finally the **construction and comparison of analytical variables.**

2.3.5.1.1 Data collection

Survey responses are downloaded from the EUSurvey[22] platform together with the structural metadata of the questionnaire. These two inputs ensure that all items, formats and routing logic are preserved and that the dataset is fully traceable throughout processing.

2.3.5.1.2 Preprocessing

Preprocessing transforms the raw responses into a clean, structured and analysable dataset. At this stage, responses are standardised, coded and anonymised, and each participant is assigned to one of the three groups: flight crew, cabin crew or OCC personnel.

Likert-scale answers are converted into numerical scores using a predefined mapping to ensure consistency across roles and items.

This step marks the end of the workflow used for building KSIs. The pre-processed numerical outputs feed directly into the KSI methodology (block A), where they are used solely to construct the predefined KSIs described in Section 3.1.2.2.

2.3.5.1.3 Validation and analysis

Beyond KSI construction, the remaining steps of the workflow assess whether Likert questions form reliable and interpretable structures that can be used as analytical variables. These steps correspond to the validation block in the figure.

They include:

- **KMO analysis**, to verify that the Likert items share enough common variance to justify grouping them.
- **Factor analysis**, to identify patterns across questions and reveal coherent latent dimensions.
- **Cronbach's Alpha**, to confirm that the questions grouped into each dimension demonstrate adequate internal consistency.

These validation procedures create a set of additional perception-based dimensions that extend the analytical value of the survey.

2.3.5.1.4 Analytical variables and comparative analysis

The validated dimensions from the previous step are summarised into composite scores, representing broader concepts such as workload, pressure or organisational support. In addition,

[22] EUSurvey is the European Commission's official online survey management system supported by the Directorate-General for Digital Services. For further information, please visit https://ec.europa.eu/eusurvey/home/welcome

some individual items are retained as standalone variables when they address specific themes highlighted during the refinement phase.

These variables are then merged with demographic and contextual information to enable comparisons across business models, employment arrangements and other population segments.

This stage is not part of KSI computation. Instead, it underpins the extended analysis where the study examines broader socio-economic and operational patterns beyond the predefined KSIs.

At this step, the analytical variables are compared across groups using descriptive statistics, **ANOVA** and **Tukey tests**, as illustrated in the bottom part of the figure. This enables the study to identify significant contrasts across workforce segments and to explore perceptions that may be relevant for risk assessment or workforce policy considerations.

These analyses are presented in detail in Section 3.3.3, including specific results for the additional questions incorporated during the survey refinement process.

2.3.5.2 ECR

This section describes the data preparation applied to the ECR database for the purpose of this study. The process consists of three stages. Data collection specifies how and under which framework the database is accessed. Data scoping defines the temporal and operational boundaries of the analytical sample. Data transformation describes how SPs are identified in ECR occurrence records.

2.3.5.2.1 Data collection

Access to ECR occurrence data for analytical and research purposes is provided to ALG through the Data4Safety (D4S) programme, in accordance with the Data Governance (DaGo) framework and applicable data protection and confidentiality requirements.

2.3.5.2.2 Data scoping

Temporal coverage

Occurrence reporting is subject to delays in submission, updating, and validation following the event. To ensure data completeness and stability, the analysis is therefore restricted to occurrences up to 2024. Furthermore, as Regulation (EU) No 376/2014 entered into force at the end of 2014, the analysis is restricted to data from 2015 onwards to ensure consistency in reporting definitions and practices.

Aviation domain

The scope of this study is limited to Fixed Wing Scheduled Commercial Air Transport operations. Occurrences associated with rotary-wing operations, military aviation, maintenance activities, and other non-operational contexts are excluded.

2.3.5.2.3 Data transformation: Safety precursor identification in ECR

This subsection describes the approach used to operationalize the presence of SPs in the ECR, detailing the mapping specification and the occurrence-level classification logic applied to identify SP-related records.

Mapping specification

Human factors and human performance have previously been analysed using the ECR in the context of the Annual Safety Review (ASR) 2021 by EASA[23]. These analyses rely on generic reporting categories from the ECCAIRS 2 taxonomy, which are suitable for strategic monitoring but are not designed to assess the specific impact of SPs in safety aviation.

The present study focuses on the association between specific SPs and SOs. As SPs are not explicitly reported within the ECCAIRS 2 taxonomy, an indirect mapping approach is applied to identify them. The detailed mapping between SPs and taxonomy elements is documented in Annex B.3.1. This identification is implemented through the following steps:

1. **Taxonomy-driven identification:** The ECCAIRS 2 taxonomy is used as the primary reference to locate where information relevant to each precursor is captured. Particularly, the *Events* entity is where this information is located.
2. **Narrative-based validation:** For taxonomy values with ambiguous relevance, occurrence narratives are reviewed to assess whether they plausibly reflect the underlying precursor concept. This qualitative review is used to refine the selection and to exclude elements that do not consistently capture the intended condition or behaviour.

Note: For the precursor "lack of assertiveness", no mapping with the taxonomy values could be identified. This precursor was therefore excluded from the analysis.

ECR classification logic

The mapping is applied at the occurrence level.

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[23] Annual Safety Review 2021, EASA annual safety performance review report, available at: https://www.easa.europa.eu/en/document-library/general-publications/annual-safety-review-2021 (accessed January 2026)

"An occurrence is classified as SP-related if at least one event recorded in the ECR occurrence matches a taxonomy element included in the precursor mapping."

This classification indicates that the SP is identified as relevant to the occurrence, but it should not be interpreted as evidence of causality. Tags are not mutually exclusive and a single occurrence may therefore be linked to multiple precursors. On this basis, the analytical dataset supports:

- A binary flag distinguishing SP-related versus non-SP-related occurrences
- SP specific indicators identifying which SP(s) are recorded for each occurrence

2.4 Methodological framework for Key Socio-economic Indicators construction and analysis

This section describes the methodology followed to translate the information collected through the different data sources into quantitative KSIs. It explains the analytical steps used to identify suitable inputs, construct and quantify each indicator, and ensure their consistency and comparability across groups. The objective is to provide a transparent and reproducible approach that allows the information obtained in this study to be systematically used to respond to the defined KSIs, while acknowledging the methodological constraints and data availability limitations encountered.

2.4.1 General considerations

As described in Section 2.2.5, a set of KSIs is defined for each RAs to enable their systematic assessment within the scope of this study. These indicators function as the operational instruments through which the socio-economic dimensions associated with each RA are examined.

The complete list of KSIs, together with their detailed descriptions, is provided in Annex C.4. The annex includes a comprehensive table specifying, for each indicator, the information necessary to ensure transparency, traceability and consistency in both interpretation and calculation. Figure 10 provides a schematic overview of the KSIs construction.

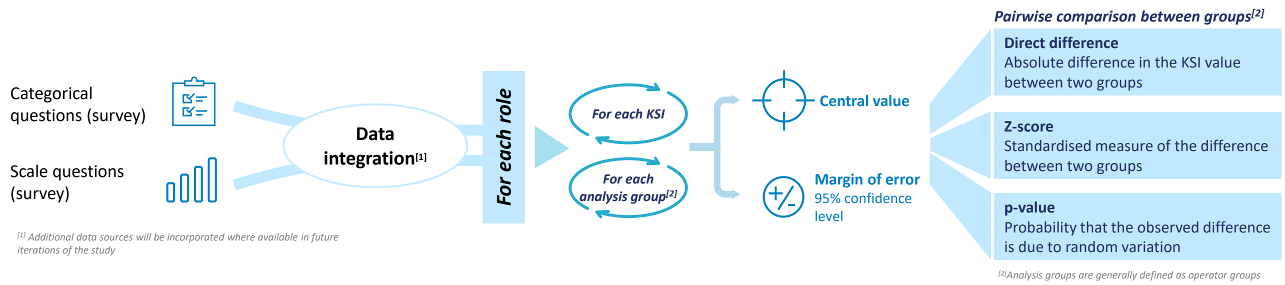


Figure 10: KSIs workflow construction.

At the initial design stage, all KSIs were intended to be addressed through an integrated use of targeted survey data and complementary data sources, depending on the characteristics of each indicator. However, following successive review and validation stages, adjustments to the survey scope and constraints in data availability resulted in a subset of KSIs not being fully populated in this iteration of the study.

Despite these limitations, the methodological framework underpinning the KSIs remains fully defined and documented. This ensures that future iterations of the study will be able to populate all KSIs in a consistent manner, without requiring structural modifications, once the necessary data sources become available.

According to the study's objectives, the primary analytical perspective applied to the KSIs is a comparison across operator groups. For a limited number of indicators, however, data availability, indicator characteristics or methodological considerations do not permit disaggregation by airline type. In such cases, the analysis is performed at an aggregated level, and the rationale for this approach is explicitly detailed in the corresponding KSI description.

Note: As a general interpretative rule, higher KSI values indicate less favourable socio-economic conditions in relation to their associated RA. Where this interpretation does not apply, the specific directionality of the indicator is clearly stated in its individual description provided in Annex C.4.

2.4.2 Methodological approach to indicator construction

The analytical framework was originally designed to integrate information from multiple data sources, including survey data, operational datasets and other complementary inputs. In this iteration of the study, constraints in data availability and alignment resulted in the exclusive use of survey-based information to set those indicators. This does not limit the flexibility of the framework, which remains fully prepared to incorporate additional sources in future editions of this study without requiring methodological restructuring.

For the construction of the indicators, two types of survey inputs are used:

- **Scale-based survey questions**: These ordinal (Likert-type) items provide a quantitative basis for indicator computation. For indicators relying on such inputs, values are derived from the proportion of respondents selecting specific scale options or ranges defined in the indicator specification. This enables perceptions and experience-based assessments to be transformed into measurable indicators.
- Categorical or combined **survey questions:** These include binary and multi-category responses, as well as cases requiring the integration of several complementary items. Indicators based on

these formats are calculated by aggregating responses across relevant categories or by combining multiple inputs in line with the respective indicator definition. This approach captures socio-economic aspects that are not appropriately represented through scale-based questions.

Using these inputs, a numerical estimate is produced for each indicator following the construction rules defined in Annex C.4. Alongside the central value, a margin of error is computed to reflect the uncertainty associated with sample size and response variability. Given the inverse relationship between sample size and uncertainty, indicators derived from smaller respondent groups carry wider margins of error, while those supported by larger samples yield more precise estimates.

The margin of error forms the basis for the indicator's confidence interval. These confidence intervals support the interpretation of results, particularly when comparing indicators across operator groups, by indicating whether observed differences are meaningful. Overlapping confidence intervals suggest that differences should be interpreted with caution, whereas non-overlapping intervals provide stronger evidence of divergence between groups.

Note: In this study, a 95% confidence level is applied, meaning that under repeated sampling the true underlying value of the indicator would be expected to lie within this interval in 95% of cases.

2.4.3 Comparative analysis across groups

- Beyond the calculation of KSI values and their associated margins of error, a comparative analysis across operators groups is conducted to assess whether observed differences between groups are meaningful and statistically supported. This step is essential to move from a descriptive reading of KSI values to an analytical interpretation of differences across operators groups. The analysis is performed at operator-group level, in line with the study objective to assess safety-relevant differences across operating models

- Given that KSIs are calculated separately for each analysis group, comparisons are performed on a pairwise basis. This approach allows differences between two operator groups at a time to be, taking into account both the magnitude of the difference and the uncertainty associated with the underlying estimates. Pairwise comparisons are particularly relevant in the presence of heterogeneous sample sizes across groups, as they enable a consistent assessment of group-level differences.

For each pairwise comparison, three complementary elements are considered:

- **Direct difference:** The absolute difference in the KSI value between two groups. This measure provides an intuitive indication of the magnitude and direction of the observed difference.
- **Z-score:** A standardised measure of the difference between two groups that accounts for sample size and variability. The z-score indicates how large the observed difference is relative to the expected variability under the assumption of no true difference.
- **p-value:** The probability that the observed difference, or a more extreme one, could arise due to random variation alone. The p-value is used to assess the statistical significance of the observed difference.

These three elements are interpreted jointly to support a comparison of KSI values across groups. Differences that are small relative to the associated margin of error or confidence intervals are interpreted with caution, even when numerical differences are observed. On the other hand, differences supported by both a substantial direct difference and statistically significant z-scores and p-values are considered more robust.

2.5 Methodological framework for Safety Performance Indicators

To support interpretation of the indicators derived from ECR data, it is useful to distinguish between lagging and leading SPIs. Lagging indicators reflect the realised outcomes of safety events, such as the number of accidents or serious incidents per unit of exposure. Leading indicators, by contrast, provide early insight into conditions, behaviours, or system states that may influence future safety performance.

In this project, SOIs and RTIs are constructed as lagging indicators, as they are based on observed and reported events associated with SPs. In the context of a Safety Management System (SMS), this reactive perspective is a necessary first step for understanding how SPs manifest in operational data and how they are reported in practice. By systematically describing and diagnosing these events, the indicators support the establishment of a baseline for monitoring, trend analysis, and the assessment of reporting capability over time.

While SOIs and RTIs provide a descriptive characterisation of safety performance, they do not by themselves reflect how safety conditions vary across operators and operational environments. Therefore, the Section 2.5.3is introduced to examine how SPs and SOs are associated with operator characteristics and operational context, providing a more complete assessment.

2.5.1 Safety outcome indicators

Safety Outcome Indicators (SOIs) quantify SOs using occurrence data. They capture what happened and what resulted from it, allowing safety performance to be assessed not only over time but also comparatively across stakeholders and operational subsystems within the aviation landscape. The following subsections outline the SOIs framework in detail, specifying the dimensions assessed and the measures used to operationalise each dimension.

2.5.1.1 SOIs analytical dimensions

To provide a comprehensive characterisation of SOs different perspectives should be analysed to understand how these SPs impact on safety aviation. For this purpose, Figure 11 introduces the three complementary dimensions defined, which together provide an integrated view by capturing evolution, outcome severity, and overall criticality to better understand the safety relevance.

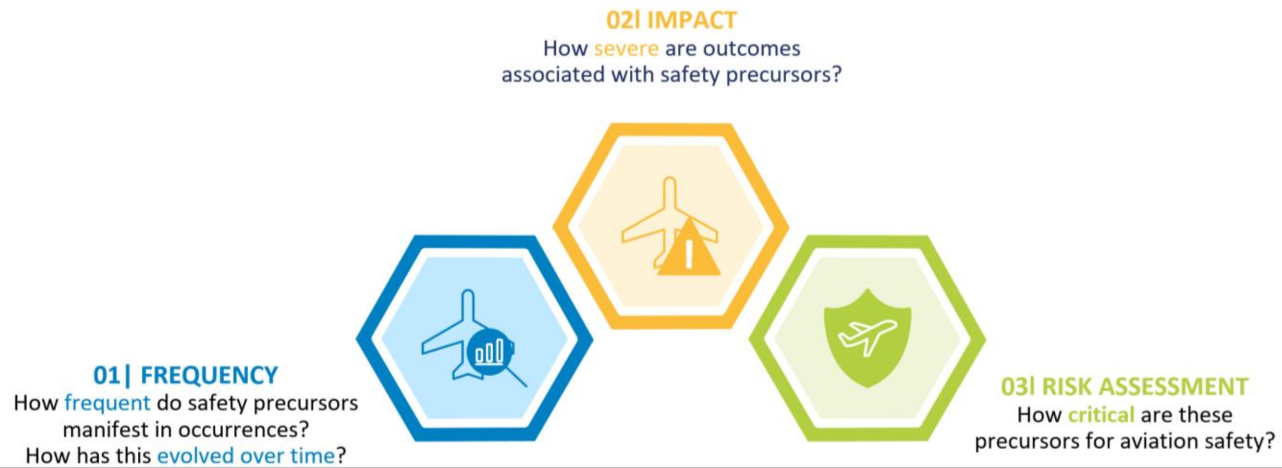


Figure 11: SOIs analytical dimensions

Building on Figure 11, each dimension is defined and operationalised as follows:

- **Frequency** describes how frequently SP-related occurrences are observed and helps identify which precursors are most commonly present. It is also implemented to understand the temporal evolution and identify potential patterns over time.
- **Impact** captures the severity profile, supporting an understanding of whether a precursor tends to be associated with comparatively more serious events. For this purpose, the attribute Occurrence Class from the ECR taxonomy is implemented. Occurrence Class values are grouped into two tiers: Tier 1 captures high-severity outcomes, including accidents and serious incidents; and Tier 2 groups all remaining classes, including incidents, observations, and occurrences with no safety effect.
- **Risk assessment** complements frequency and impact by incorporating a risk oriented perspective on how critical the associated occurrences are for safety management. This dimension is operationalised using the European Risk Classification Scheme (ERCS), which combines information on outcome severity with the potential for escalation. The ERCS is part of the common risk classification framework established under Regulation (EU) No 376/2014, through a Commission Delegated Regulation adopted in 2020 and a subsequent Commission

Implementing Regulation adopted in 2021. The application of the ERCS became mandatory as of 1 January 2023. As a result, the analysis in this section is based exclusively on occurrences classified using the ERCS in 2023 and 2024.

Taken together, these dimensions provide a strategic and comprehensive view of the safety relevance of SPs, enabling robust monitoring while laying the foundation for more proactive safety management.

2.5.1.2 SOIs measurement framework

The measurement of safety outcome indicators is subject to several important considerations arising from the nature and limitations of ECR occurrence reporting data. First, the analysis is necessarily based on reported occurrences only. This implies that observed differences may reflect not only differences in underlying safety conditions, but also differences in reporting practices and cultures across states, organisations, or operator groups. Second, occurrence data alone does not provide information on the level of operational exposure (e.g. number of flights or flight hours), which is necessary to assess whether a given number of occurrences reflects a higher underlying risk or simply a higher level of activity.

For these reasons, no single metric is sufficient to characterise SOs in a robust way. Instead, the analysis relies on a set of complementary measurement approaches that capture different aspects of the data and allow for a more balanced interpretation.

Specifically, for each analytical dimension, SOIs are quantified using three complementary metrics:

- **Occurrence counts:** Absolute counts that report the direct number of occurrences in the analytical sample that meet the criterion for a given dimension.
- **Occurrence share:** Relative proportions express the count of interest as a fraction of a defined denominator within the same analytical scope.
- **Exposure normalised rates:** Normalised rates use exposure data to scale occurrence counts per 10,000 or 1,000,000 flights, enabling comparability across groups and over time.

Together, these metrics provide a comprehensive and interpretable view of SOs and help avoid misleading conclusions that may arise when relying exclusively on a single metric.

2.5.2 Reporting trend indicators

Reporting Trend Indicators (RTIs) are designed as quantitative measures derived from safety occurrence data that describe the strength, stability, and usability of the reporting system to understand the reporting culture. They are used to characterise frequency and patterns of safety reporting, thereby providing essential context for interpreting SOIs and subsequent inferential results.

2.5.2.1 RTIs analytical dimensions

To develop a comprehensive view of ECR reporting culture, RTIs are examined along three complementary dimensions:

- **Reporting evolution** assesses how the volume of occurrence reporting changes over time and across groups, providing a baseline view of reporting intensity and potential shifts in reporting practices.
- **Severity evolution** tracks how the severity profile of reported occurrences changes over time. It helps distinguish whether trends are driven mainly by higher-severity outcomes, that are expected to be mandatorily reported, or by increased reporting of lower-severity events, which may reflect greater reporting culture.
- **Data completeness** evaluates the completeness of mandatory fields, defined under Regulation (EU) No 376/2014 as the fields required to adequately characterise an occurrence and support reliable descriptive analysis and subsequent modelling.

RTIs are examined both in the full ECR sample and within SP-related occurrences to distinguish system reporting dynamics from patterns specific to SP-related occurrences.

2.5.2.2 RTIs measurement framework

To ensure consistency with the wider analytical approach, RTIs are quantified using the same measurement framework applied to SOIs. Depending on the indicator and the analytical purpose, results are presented using the most informative combination of absolute counts, occurrence share, and exposure normalised rates.

2.5.3 Inferential analysis of safety precursors and safety outcomes

A key characteristic of aviation safety is its systemic nature. SOs rarely arise from a single isolated factor, but rather from the interaction of multiple technical, operational, organisational, and human elements. Descriptive indicators are therefore useful to characterise overall trends and patterns, but they are not sufficient to assess how different factors jointly relate to either the presence of SPs or the severity of reported outcomes.

To support a more contextual assessment, the analysis leverages information available in the ECR. Organisational context is represented by operator groups, while operational context is partially reflected in the variables recorded within occurrence reports.

Building on the frequency and impact dimensions introduced for the SOIs, two extended analyses are conducted when accounting for operational and organizational context:

- **Association between SPs and population groups:** Assesses whether occurrences are more likely to be classified as SP-related for certain operator groups once operating conditions are considered.
- **Association between severity and SPs:** Assesses whether SP-related occurrences are more likely to be high severity, conditional on operator group and operating conditions.

Given that both associations expect binary outcomes, the analyses use logistic regression. The models estimate how the probability of each outcome varies with operator group, SP-related occurrences, and key operational controls, providing adjusted associations that are more informative than simple descriptive comparisons.

The aim is not to establish causal inference, but to identify associations that remain observable once operational and organisational context are considered simultaneously. In this way, the models provide an initial step towards a more proactive SMS perspective, indicating how SP-related risk varies across conditions and organisational settings beyond reactive monitoring of past outcomes.

2.5.3.1 Analytical sample and data preparation

The inferential analysis uses the same ECR data scope defined in 2.3.5.2.2 . However, the inferential analysis requires additional data preparation compared to the descriptive analyses presented earlier. In particular, it requires the definition of operational and organisational groups and the construction of variables tailored to the multivariate specifications.

2.5.3.1.1 Analysis groups

Given the ECR nature, operators are reported at the individual airline level, through Operator attribute. For the purpose of the inferential analysis and to ensure alignment with the population categories used for the surveys analysis in Section 2.3.5.2.2, airlines are therefore grouped into operator types to provide a consistent unit for comparison and to capture organisational variation. For this purpose, Cirium data provided by EASA, is used to identify and classify the main European operators within each group.

The inferential analysis is limited to **low-cost carriers (LCC) and network carriers**, which together represent the largest segments of Fixed Wing Scheduled Commercial Air Transport and account for the majority of reported occurrences in the ECR. Other operator types, in particular ACMI operators, are not included at this stage of the inferential analysis, as the available sample is more limited in the current data.

2.5.3.1.2 Data pre-processing

Additional data preprocessing is crucial to implement the inferential analysis. This involves constructing the variables used in the subsequent analysis and ensuring their consistent definition across the dataset. Records with missing or inconsistent values in key analytical variables are excluded from the regression sample.

2.5.3.1.3 Variables and controls

This section defines the key analytical variables used to examine the associations between SPs, operator groups, operational context, and severity. The selection of variables is guided by their conceptual relevance and their availability and completeness in the ECR data.

The two analyses rely on different study variables:

- Association between SPs and operator groups
    - **Operator type (LCC vs network):** Captures organisational and business-model differences that may shape operating conditions, reporting practices, and the likelihood that precursor-related factors are recorded in occurrence data.
- Association between severity and SPs
    - **SP-related occurrence (SP present or not):** Captures whether an occurrence record contains at least one taxonomy element mapped to the SP set, indicating the presence of precursor-related information reported in association with the event.
    - **Operator type (LCC vs network):** Captures systematic differences in operational context and organisational characteristics that may influence the severity profile of reported outcomes, independent of SP tagging.

Across the two model specifications, the set of operational controls that capture baseline differences in exposure, operational complexity, and the likelihood of being exposed to certain precursors is the same:

- **Night:** This control captures differences in operating conditions and workload commonly associated with night operations.
- **Weather:** This control captures adverse environmental conditions that may influence both the manifestation and reporting of safety-related events.

- **Phase of flight:** This control captures differences in workload, task complexity and operational constraints across ground, take-off, cruise, and landing.
- **Haul length:** This control captures differences in operational profiles, including flight duration, duty patterns, and route structure, which may affect both exposure to certain precursors and the likelihood and nature of occurrence reporting.

For further detail on the specific attributes implemented for each variable and how are they implemented please refer to Annex B.3.2.1.

2.5.3.2 Model specifications

Before model estimation, two steps are undertaken to ensure that the inferential analysis is well specified and transparent. First, candidate control variables are assessed for strong pairwise correlation using Pearson coefficients and for multicollinearity using variance inflation factors (VIFs). The technical details are explained in Annex B.3.2.2.1.

Second, a bivariate analysis is conducted to establish an unadjusted reference point for interpretation. Associations between operator group and the outcomes of interest are summarised using odds ratios with 95% confidence intervals, providing an initial indication of direction and magnitude prior to introducing operational context. The bivariate approach and reporting conventions are described in Annex B.3.2.2.2. The multivariate models then assess how these relationships change once operational context is introduced, isolating the residual association with the study variable once key operational factors are accounted for, and indicating how much of the bivariate pattern is explained by operational differences.

2.5.3.2.1 Association between SPs and operator groups

For the first analysis, separate logistic regressions are estimated for each SP. The dependent variable is a binary indicator equal to one when an occurrence is tagged as related to that SP. The main explanatory variable is operator group, low-cost versus network carriers, and operational controls are included to account for differences in operating conditions and to move beyond the unadjusted bivariate baseline.

The resulting estimates indicate whether, under comparable operating conditions, occurrences tagged with a given SP are more or less associated with LCC relative to network carriers. Model specifications are documented in B.3.2.2.3.

2.5.3.2.2 Association between severity and SPs

The second analysis uses a single logistic regression to examine whether the presence of SPs is associated with higher reported severity, while accounting for operator group and operating conditions. he dependent variable is a binary severity indicator defined using the same *Occurrence*

Class attribute as in the SOI severity analysis. Model specifications and estimation details are documented in Annex B.3.2.2.3.

2.5.3.2.3 Interpretation of results

To support a clear and decision-relevant reading of the regression outputs, results are summarised using odds ratios with 95% confidence intervals. The technical details are documented in Annex B.3.2.2.3.

- **Odds ratios** summarise the direction and magnitude of the association, indicating whether the outcome is more or less likely relative to the reference category after accounting for the included controls.
- **95% confidence intervals** convey the uncertainty around the estimate and support a robustness check, indicating whether the observed association is precisely estimated and whether it is consistent with no difference relative to the reference.
- **Predicted probabilities** are also shown for selected reference profiles to express the results as an estimated likelihood of the outcome under a defined operating context. They are conditional on the controls and are intended as scenario-based summaries, not as overall incidence rates. Owing to the non-linear nature of the logit model, the implied probability change associated with a given OR depends on the baseline risk.

3 Analysis and results

Analysis and results presents the analytical results of the Article 89 assessment and translates the study framework into evidence findings. It is organised around three subsections that together connect socio-economic conditions to operational risk and, where applicable, to safety-related mechanisms and complementary streams.

Section 3.1 examines the relationship between SEFs and operational RAs through an approach that distinguishes between literature-based interpretation, empirical evidence, and analytical synthesis. It first outlines conceptually grounded linkages between selected SEFs and RAs based on a targeted review of relevant literature, providing contextual expectations rather than validated conclusions. It then presents the empirical characterisation of RAs using survey-based KSIs, which aggregate self-reported perceptions into comparable measures across operator groups and crew categories. The subsection closes with a synthesis that contrasts observed KSI patterns with the literature-based baseline, supporting an interpretation that links indicator-level results back to the underlying socio-economic conditions that motivate the study.

Section 3.2 shifts the focus from socio-economic conditions to safety-relevant mechanisms by examining how RAs relate to SPs. Building on the conceptual framing, it presents the analytical logic used to connect operational contexts and perceived risk conditions to precursor concepts and, where data allow, to measurable safety-related signals. This subsection is intended to clarify the pathways through which the risk conditions discussed in the study may manifest in operational practice, and it provides the bridge between the RA-focused assessment and the complementary safety-performance perspective.

Finally, Section 3.3 provides other relevant analyses that extend beyond the two core analytical pillars of the study. It introduces an approach for cross-source comparison between survey-based KSIs and operator-provided operational data, illustrating the method through a small set of directly comparable indicators and highlighting its scalability subject to data availability and consistency. It also examines the pilot profession outlook in Europe using dedicated survey questions on career attractiveness, working conditions, and longer-term expectations, offering contextual insight into workforce dynamics. In addition, the subsection reports the results of a statistical grouping of survey items to build higher-level dimensions and assess differences across operator groups with greater robustness than single-item analysis. The section concludes with a brief treatment of the open survey question, summarising the most frequently raised topics.

3.1 Analysis on socio-economic factors and risk areas

The relationships between SEFs and operational RAs are examined through an approach that distinguishes between literature-based interpretation, empirical evidence and analytical synthesis. The content is organised into three complementary components, each serving a specific role in supporting the overall interpretation of the results.

First, the section presents a review of relevant literature to outline conceptual linkages between selected SEFs and RAs. This initial step establishes a baseline describing how socio-economic conditions are discussed in existing research as potential drivers of risk. The literature reviewed is not exhaustive, and the associations presented reflect the authors’ interpretation of prior studies. This material is provided for contextual purposes and does not constitute validated conclusions.

Second, the section introduces the empirical characterisation of RA based on the survey data. Using the KSIs, this analysis quantifies selected dimensions of each RA, translating self-reported perceptions into indicators that allow systematic comparison across operator groups and crew categories. This step represents the core analytical component of the section and provides the data-driven basis for subsequent interpretation.

Third, the section concludes with a synthesis that contrasts the empirical patterns observed through the KSIs with the literature-based expectations described in the first step. This comparative analysis examines the degree of alignment between the literature and the results from the survey data, and supports an interpretation that links indicator-level findings back to the underlying SEFs, which constitute the primary focus of the study.

3.1.1 Relations between socio-economic factors and risk areas

This section builds on the literature review to outline conceptual linkages between selected SEFs and the identified RA. The objective is to establish a baseline describing how socio-economic conditions are discussed in the literature as potential drivers or modifiers of RAs.

The literature reviewed is not exhaustive, and the associations described reflect the authors' interpretation of existing sources. The content of this section is therefore informative and contextual in nature and does not constitute the conclusions of the analysis. These literature-based insights are subsequently contrasted with the data-driven characterisation of RA presented later in the report.

To improve transparency, the SEF–RA relationships identified in the literature review are summarised through a SEF–RA mapping matrix. This mapping is interpretative and non-exhaustive, intended as a contextual baseline, and the relationships are subsequently contrasted with the KSI-based empirical characterisation of each RA in later sections. In the mapping matrix, Fuel management and Fraud risk are not mapped, as the literature reviewed did not provide any valid prior evidence or references supporting a SEF linkage for these two risk areas.

Table 4: Mapping of SEFs to Ras

Risk Area	Employment & working conditions	Health & lifestyle	Education	Resource constraints & HR market dynamics	Work intensity, flexibility & uncertainty
Pilot retirement age		•			
Homebase changes	•	•			
Crew interoperability	•	•	•	•	
Atypical contracts	•				
ACMI operations	•			•	•

Generational risk behaviour		•	•	•	
Commercial pressure	•	•		•	•
Fuel management					
Go-around decisions		•			•
Pilot discretion use		•			
Fraud risk					

3.1.1.1 Employment and working conditions

The literature on Employment and Working Conditions consistently highlights how structural features of the labour environment, contractual stability, remuneration models, predictability of duties and clarity of employer responsibility, directly shape aviation personnel's capacity to operate safely. The sources reviewed describe a sector where the erosion of employment quality creates conditions that undermine both reporting culture and human-performance reliability. As with the other socio-economic factors, these findings arise from a broad yet not exhaustive evidence base and therefore provide an informed starting point that will later be compared with the empirical characterisation of each RA through the KSIs.

Across the evidence, one of the most striking patterns appears in relation to **Atypical Contracts**. The literature repeatedly documents how models such as bogus self-employment, agency-mediated hiring and pay-to-fly schemes introduce profound contractual ambiguity and weaken the protective elements of the European labour framework. By exploiting cross-border legislative differences and engaging in "rule shopping", companies reduce labour costs while creating environments in which workers are reluctant to report risks, fatigue or unfitness for duty due to fear of economic repercussions. This erosion of employment stability and diluted employer responsibility is shown to compromise both psychological safety and the transparency necessary for effective oversight.

Building on this foundation, research examining **Commercial Pressure** shows how degraded employment conditions interact with financial vulnerability to amplify operational risk. Literature sources describe how precarious contracts, income-linked remuneration and unstable rosters push individuals to prioritise job retention over personal well-being. This dynamic fosters presenteeism, even when fatigued or unwell, and contributes to chronic physiological stress and circadian disruption. Several studies note the increased reliance on coping mechanisms such as stimulants to maintain alertness and alcohol or sedatives to induce sleep, indicating a deeper destabilisation of physical and mental health within high-pressure environments.

The literature further indicates that these degraded employment conditions shape the functioning of **Crew Interoperability**. Fragmented arrangements involving multiple AOCs, subcontractors or wet-lease structures create unequal employment conditions among crews performing the same tasks, while generating uncertainty regarding which organisation is responsible for training, safety reporting and welfare. This fragmentation weakens the standardisation of SOPs and the integration of Safety Management Systems, hindering consistent implementation of safety procedures. At the same time, the perceived instability and vulnerability faced by crews operating under such schemes reduce their willingness to escalate hazards, reinforcing a culture of silence incompatible with Just Culture principles.

In parallel, studies addressing **Homebase Changes** describe how employment instability extends beyond contractual terms into the geographical dimension of work. Forced mobility, temporary bases and long commuting distances complicate the application of social-security legislation and undermine rest opportunities. Literature consistently shows that crews living in temporary accommodation away from their support networks experience poorer sleep quality, increased fatigue and elevated psychosocial stress. These conditions degrade their ability to recover between duties and increase susceptibility to operational errors.

The literature also links degraded working conditions to the systemic challenges described under **Workforce Shortages**. When staffing levels are insufficient, remaining personnel face intensified workload demands and reduced access to rest, further pushing the system towards the limits of legal and physiological capacity. Under these conditions, presenteeism becomes a structural response to the lack of reserves, while chronic pressure drives turnover and accelerates the loss of experienced personnel. The erosion of institutional knowledge and supervisory depth weakens organisational resilience and compromises mentoring opportunities essential for younger crews navigating complex operational environments.

Finally, the literature on the **ACMI Operating Model** portrays how commercial structures can further degrade employment conditions. The inherent transience of wet-lease operations obliges crews to live in makeshift accommodation for extended periods, undermining psychological detachment from work and exacerbating cumulative fatigue. Moreover, regulatory fragmentation between lessor and lessee can facilitate practices that reduce labour protections, while organisational separation limits the integration of Safety Management Systems and restricts the circulation of risk-critical data such as FDM and incident reports. Taken together, these dynamics create environments where employment insecurity and diluted employer accountability discourage the reporting of operational hazards, embedding latent risks within daily operations.

Overall, the literature suggests that Employment and Working Conditions operate as a foundational socio-economic factor with far-reaching implications across multiple RAs. The narrative presented above provides a structured interpretation of these findings. In the next phase of the study, these literature-derived insights will be systematically compared with the KSI-based characterisation to evaluate the degree of alignment between conceptual expectations and data-driven evidence.

3.1.1.2 Health and lifestyle

The analysis of the literature concerning the socio-economic factor Health and Lifestyle highlights a consistent pattern across multiple RAs deteriorations in physical, mental, and social well-being act as latent drivers of operational vulnerability. Although the reviewed sources are extensive, they do not represent an exhaustive body of knowledge. For this reason, the insights presented below should be interpreted as an evidence-informed baseline that will later be contrasted with the findings derived from the quantitative characterisation of RAs through the KSIs.

Across the literature, one of the most prominent links emerges in relation to **Commercial Pressure**, where organisational prioritisation of efficiency and profitability can results in rosters that reduce opportunities for adequate recovery between duties, destabilise work–life balance and heighten chronic fatigue. These conditions interact with psychosocial stressors, such as job insecurity or fear of financial repercussions, driving patterns of presenteeism that reduce cognitive performance and increase the likelihood that degraded fitness for duty remains unreported. The cumulative effect on well-being is consistently shown to narrow safety margins.

Building on this, the literature also points to important interactions between health factors and **Generational Risk Behaviour**. Ageing crews experience natural declines in psychomotor and cognitive functions, often compensated through experience, while younger generations may struggle to assert themselves in hierarchical environments, limiting effective communication. At the same time, the literature notes coping strategies used to regulate alertness and sleep in response to fatigue, including increased consumption of stimulants such as caffeine or the use of sleep aids during rest periods, linking physiological strain with broader well-being considerations. These patterns illustrate how health and lifestyle conditions shape behaviour, communication dynamics and risk perception.

A related concern appears in contexts involving **Crew Interoperability**, particularly under atypical or mobile employment arrangements. Variable rosters, frequent changes in operating environments and limited organisational continuity hinder circadian recovery and contribute to stress, sleep disruption and social instability. The literature suggests that these conditions reduce adherence to safety practices and weaken reporting culture, particularly where employment insecurity heightens the perceived cost of refusing duties or declaring unfitness.

The **Workforce Shortages** literature similarly describes a structural erosion of well-being caused by insufficient staffing. Reduced personnel availability increases workload intensity, accelerates burnout and amplifies fatigue-related risks. Situations in which teams face high turnover, often combined with the loss of experienced staff, also weaken social cohesion and supervisory buffers. This degradation of well-being is associated with increased sickness absence and a rise in presenteeism, both of which have direct implications for operational safety.

A further dimension concerns **Pilot Discretion Use**, where the literature shows that routine or pressured use of duty-time extensions contributes to cumulative fatigue, psychological strain and rest-cycle instability. The unpredictability of extended duty periods undermines long-term recovery and personal planning, which in turn degrades mental and social well-being. These conditions create a systemic risk environment in which physiological impairment coincides with perceived organisational expectations.

Health and Lifestyle considerations also play a role in discussions around **Pilot Retirement Age**. Literature indicates a complex balance between the natural age-related decline in certain cognitive abilities and the protective effect of accumulated experience. However, studies highlight that standard medical checks may be insufficient to detect subtle declines relevant for high-complexity or high-workload situations, emphasising the need for enhanced monitoring when retirement ages extend.

Another area shaped by well-being factors is **Go-Around decision-making**. According to research, reluctance to execute a go-around is frequently rooted in accumulated fatigue, impaired executive function, stress and emotional dysregulation, all of which distort risk perception. These conditions interact with organisational influences, including commercial pressure or weak just-culture environments, to inhibit corrective action even when procedural cues are clear.

Finally, the literature shows that **Homebase Changes** can disrupt the personal stability required to maintain adequate levels of rest and mental resilience. Frequent or poorly supported geographical mobility leads to sleep quality deterioration, increased commuting times, and reduced access to social and family support networks, which together increase cumulative fatigue and psychological strain.

Taken as a whole, the literature suggests that Health and Lifestyle is a transversal socio-economic factor with influence over multiple dimensions of operational performance. The patterns summarised here provide an evidence-based narrative that supports the initial mapping of this factor to its related RAs. In the subsequent stages of the study, these literature-based insights will be systematically compared with the quantitative outputs derived from the KSIs to assess the degree to which empirical findings reinforce or challenge the relationships identified through this review.

3.1.1.3 Education in the context of Just Culture

The literature examining Education in the context of Just Culture highlights its essential role in shaping safety behaviour, communication dynamics and the willingness of aviation personnel to report conditions that may compromise fitness for duty. Across the reviewed sources, education is consistently portrayed as the mechanism that transforms Just Culture principles into operational practice, enabling crews to distinguish between acceptable human error and intentional violations while fostering trust in reporting systems. As with any literature-based assessment, the insights presented here reflect broad but not exhaustive evidence base and therefore serve as an informed foundation that will later be compared with the quantitative characterisation of RAs through the KSIs.

Within this body of research, one of the strongest patterns emerges in relation to **Crew Interoperability**. Just Culture training emphasises open communication, shared responsibility and the absence of punitive repercussions for reporting safety concerns. However, the literature shows that these principles are difficult to apply in environments characterised by fragmented organisational structures, wet-lease arrangements and atypical employment models. Contractual precariousness erodes psychological safety and discourages the reporting of fatigue, illness or operational anomalies, as individuals fear contract termination or income loss. At the same time, inconsistent SOPs and unclear lines of accountability across operators weaken the practical implementation of Just Culture teachings, as crew members may be uncertain about which organisation is responsible for processing reports or providing protection. These conditions create a structural tension between the pedagogical intent of Just Culture and the actual environment in which crews operate.

The literature also reveals a significant interaction between Just Culture education and **Generational Risk Behaviour**. Training designed within a Just Culture framework provides tools to mitigate age-related and hierarchical barriers that otherwise suppress vital safety communication. Younger crew members frequently hesitate to challenge or question senior personnel due to hierarchical norms, while more experienced crew may display overconfidence that biases their risk perception. Educational programmes help recalibrate these dynamics by normalising open dialogue, clarifying expectations around speaking up and reinforcing the distinction between involuntary human factors (such as fatigue, stress or mental health concerns) and intentional non-compliance. At the same time, the literature stresses the importance of continuous training to address maladaptive coping behaviours, such as the use of substances to manage fatigue, by embedding discussions on mental health, stress reporting and fitness to operate. This fosters psychological safety and encourages personnel to declare “unfit for duty” states without fear of stigma or reprisal.

Taken together, the literature suggests that Education in the context of Just Culture functions as both a protective and enabling socio-economic factor. Its effectiveness, however, is highly dependent on the stability of employment conditions, the clarity of organisational responsibilities and the maturity of internal reporting environments. The findings presented here therefore provide a conceptual baseline for understanding the influence of this socio-economic factor across multiple RAs. In the next stages of the study, these literature-based insights will be examined alongside the empirical evidence derived from the KSIs to assess the degree of alignment between theoretical expectations and the observed characterisation of each RA.

3.1.1.4 Resource constraints and dynamics within the human resource market

The literature addressing Resource Constraints and Dynamics within the Human Resources Market underscores a recurring pattern in the aviation sector: structural pressure on labour supply, cost-driven employment models and fragmented organisational arrangements generate conditions that weaken safety resilience by degrading the stability, availability and well-being of safety-critical personnel. These insights arise from an extensive, although not exhaustive, body of academic and regulatory sources, and therefore constitute an evidence-informed baseline that will later be compared with the quantitative characterisation of RAs through the KSIs.

A central theme across the literature relates to **Commercial Pressure**, which is consistently associated with the adoption of precarious employment models, including zero-hour contracts, pay-to-fly schemes and forms of disguised self-employment. These arrangements directly link income to flight activity, creating financial insecurity that discourages fatigue reporting and promotes persistent presenteeism. In parallel, staff shortages driven by cost containment amplify workload intensity and induce “pilot pushing”, whereby crews feel compelled to operate at the limits of their physiological capacity to protect their employment stability. Several sources also document the emergence of maladaptive coping strategies, such as reliance on stimulants or sedatives, as indicators of a degraded health environment shaped by chronic instability and irregular work patterns.

The literature also highlights how resource constraints shape the dynamics of **Crew Interoperability**. Operational flexibility requirements push airlines to rely on fragmented structures, often involving multiple operators, AOCs or cross-border employment schemes. In such environments, studies point to challenges in maintaining harmonised SOPs, standardised training pathways and integrated Safety Management Systems, as operational responsibilities and oversight may be distributed across multiple organisations. Studies describe how these conditions dilute safety oversight, complicate accountability and facilitate “rule shopping”, where operators exploit legislative and social-security asymmetries to reduce labour costs. This regulatory fragmentation undermines reporting culture and weakens the collective management of operational risk.

Within this context, the literature identifies important generational implications under **Generational Risk Behaviour**. Younger flight crews, often carrying significant training-related debt, are disproportionately exposed to precarious employment arrangements. Their economic vulnerability reinforces presenteeism and reduces their willingness to declare unfitness for duty, while chronic fatigue arising from unstable rostering increases dependency on coping mechanisms that degrade long-term well-being. At the same time, the departure of experienced personnel—linked to market volatility and insecure career prospects—reduces opportunities for mentorship, impeding the development of robust risk perception and decision-making among newer generations.

A further dimension concerns **Workforce Shortages**, which are recurrently described in the literature as a structural threat to operational safety. Staff deficits lead to the normalisation of minimum-crew models, increasing workload intensity, compressing rest opportunities and reducing organisational resilience to disruptions. High turnover erodes institutional memory and tacit knowledge, weakening the supervisory function essential for early detection of safety risks. These shortages also extend to regulatory bodies, where reduced capacity limits effective oversight and degrades the system's ability to monitor compliance, particularly in environments characterised by outsourcing and fragmented employment structures.

Finally, literature discussing the **ACMI Operating Model** reveals how resource constraints and demand volatility catalyse reliance on wet-leasing as a mechanism to maintain operational continuity. While commercially advantageous, the ACMI model can introduce additional coordination complexity, as operations may involve multiple operators and interactions with different national regulatory authorities, even though primary oversight remains with the State of the Operator. Multiple studies highlight the difficulty of integrating Safety Management Systems across lessor and lessee organisations, with restricted sharing of FDM data, incident reports and operational feedback. This lack of integration impedes a unified understanding of risk and creates opportunities for cost-driven labour practices that weaken employment stability. Operationally, crews assigned to temporary bases often experience cumulative fatigue due to transient living arrangements and limited access to stable routines or support networks, further compromising their physiological and psychological resilience.

Taken together, the literature demonstrates that resource constraints and labour-market dynamics exert a pervasive influence on operational safety by shaping staffing levels, employment stability, reporting culture and organisational cohesion. The findings outlined here provide an evidence-based perspective supporting the initial relational mapping between this socio-economic factor and its associated RAs. In the following phases of the study, these insights will be systematically compared with the empirical outcomes derived from KSIs to assess the degree of concordance between literature-based expectations and data-driven characterisations of each RA.

3.1.1.5 Work intensity, flexibility and uncertainty

The literature examining the socio-economic factor Work Intensity, Flexibility and Uncertainty highlights a consistent pattern across aviation operations: heightened workload demands, unpredictable scheduling and employment instability create conditions that degrade personnel well-being and weaken the cognitive and behavioural foundations required for safe performance. As with all findings derived from literature, the insights summarised here reflect an extensive, though not exhaustive, evidence base and should therefore be interpreted as an informed starting point that will later be contrasted with the empirical characterisation of RAs through the KSIs.

A prominent theme in the literature relates to the effect of **Commercial Pressure**, which is shown to significantly intensify work demands and amplify uncertainty in roster planning. Studies describe how aggressive productivity targets and the prioritisation of operational efficiency systematically erode planning buffers, contributing to chronic haste, elevated fatigue and an overreliance on regulatory flexibility. Such conditions foster what is frequently described as “pilot pushing,” in which implicit expectations discourage personnel from declining duties even when unfit. This environment not only increases physiological strain but also reduces the capacity and willingness to report fatigue, illness or overload, particularly among individuals employed under atypical or insecure contract models. In parallel, several sources document compensatory behaviours, including reliance on stimulants or sedatives to manage disrupted sleep–wake cycles, an indicator of maladaptive coping linked to deteriorating work–life balance.

Flowing from these pressures, the literature also identifies a strong relationship between work intensity and the dynamics underpinning **Go-Around Decisions**. Tight schedules, narrow operational buffers and elevated situational tempo increase susceptibility to hurrying and reduce the vigilance required to identify unstable approach conditions. In this context, job insecurity and perceived organisational intolerance for operational deviations can transform go-around execution, from a safety safeguard into a perceived professional risk. This perception is further exacerbated by cumulative fatigue, which impairs the executive functions involved in revising mental models, reassessing risk and initiating corrective action. As a result, high work intensity and uncertainty are recurrently associated with an increased tendency toward “press-on-itis,” whereby crews continue an unstable approach in an effort to complete the duty period.

The literature also indicates that these same conditions underpin the systemic misuse of **Pilot Discretion Use**. Although commander discretion is designed as an exceptional provision, demanding rosters, unpredictable changes and staffing constraints have normalised its recurrent application. Research suggests that personnel frequently experience implicit organisational pressure to accept duty-time extensions in order to maintain schedule integrity. Such use of discretion carries cumulative effects on fatigue and psychological strain, particularly when refusal is perceived as a potential threat to employment continuity. This pattern effectively weakens the protective value of flight time limitations by masking underlying organisational gaps in scheduling, capacity planning or resource allocation.

Taken together, the evidence demonstrates that work intensity, flexibility and uncertainty operate as cross-cutting drivers of operational vulnerability, shaping both the physiological condition of aviation personnel and the behavioural responses that influence SOs. The findings summarised here provide an evidence-informed narrative supporting the initial relational mapping of this socio-economic factor to its associated RAs. In subsequent stages of the study, these literature-based observations will be examined alongside the quantitative findings produced through the KSIs to assess the degree of alignment between conceptual expectations and data-driven characterisation of the RAs.

3.1.2 Characterisation of risk areas

This section presents the core survey-based analysis of the study and provides a characterisation of the identified RA. It begins with an overview of the distribution of survey responses, including key demographic and characteristics of the respondents.

The section then focuses on the characterisation of each RA through the KSIs. The KSIs are specifically constructed to operationalise and quantify relevant dimensions of each RA by aggregating responses from selected survey questions influencing safety-related behaviour. In this way, the KSIs translate qualitative perceptions reported by respondents into structured indicators that allow systematic comparison across operator groups and crew categories.

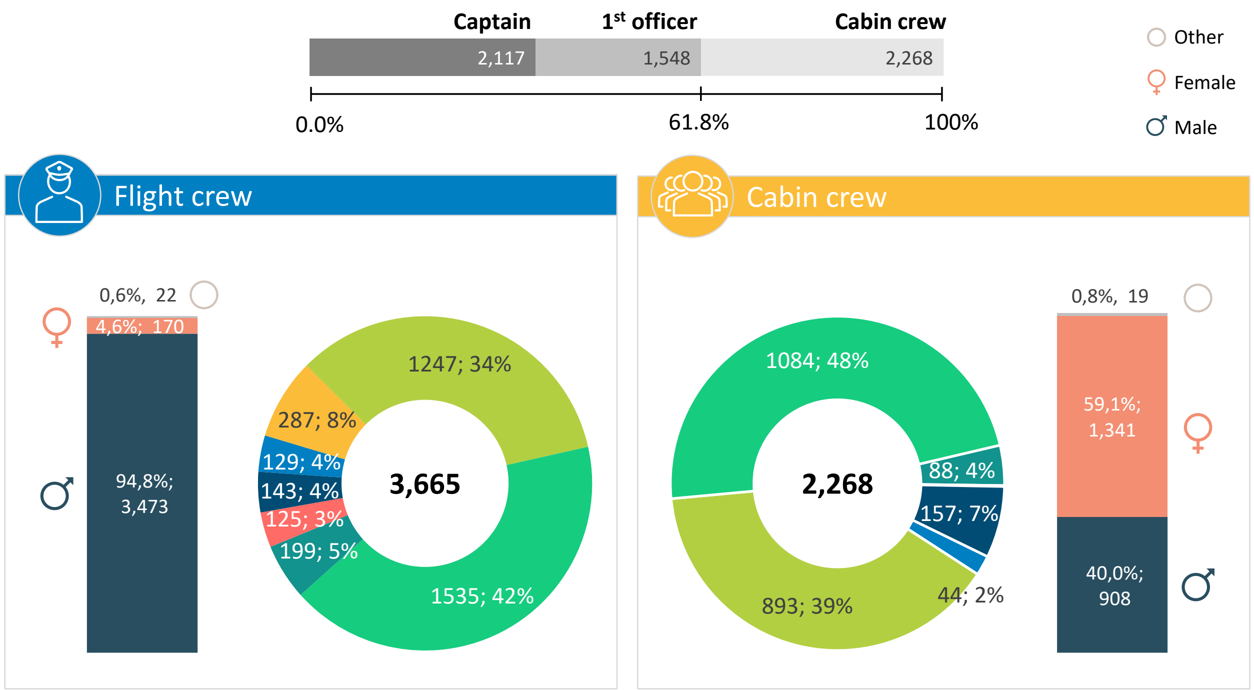
For each RA, the results are summarised separately for flight crew and cabin crew, providing an overview of observed patterns and differences. More detailed numerical results, extended breakdowns and supporting tables are presented in Section B.2, while the main body of this section focuses on the high-level interpretation of the findings.

3.1.2.1 Surveys demographic analysis

The distribution of survey responses across the main categories of safety-critical personnel provides an initial overview of the composition of the sample. Building on this, the present section offers a more detailed demographic characterisation of the populations retained for analysis. Due to the very limited number of valid responses received from OCC staff[24], this group was not

[24] Only 47 valid responses were received from OCC staff.

included in the subsequent analytical phases of the study. Accordingly, the demographic analysis presented here focuses exclusively on flight crew and cabin crew respondents, who together form the analytical basis for the results discussed in the following sections.



[1]OCC data were not included in the analysis as only 47 valid responses were available.

Figure 12: Overview of flight crew and cabin crew respondents.

For both flight crew and cabin crew, the distribution of respondents is examined by airline type, which represents the primary segmentation dimension of interest in this study and is illustrated in Figure 12. Business aviation and charter operators fall outside the analytical scope but are displayed in the figure for completeness. Low-cost and network carriers constitute the two most prominent categories in the sample and shaping the main demographic patterns observed.

Cargo airlines do not appear in the cabin-crew distribution, as cabin crew roles do not exist in cargo-only operations. Respondents working for ACMI operators are not represented at levels sufficient for robust inference; consequently, results concerning ACMI operations should be interpreted with caution[25].

[25] ACMI respondents: 129 flight crew and 44 cabin crew.

Regarding gender distribution, among flight crew respondents the proportion of males dominate the sample, whereas cabin crew respondents display a more balanced composition, with neither gender showing dominance.

3.1.2.1.1 Age distribution

Although age-related aspects are not analysed in this demographic section in terms of safety implications, the age distribution of respondents is presented here to provide contextual information on the composition of the survey sample. Age is treated as a specific RA, which is examined separately in Section 3.2.1.7.

Figure 13 presents the age distribution of flight crew and cabin crew respondents. For both groups, the majority of respondents are concentrated between 31 and 50 years of age, with lower representation in the youngest and oldest categories.

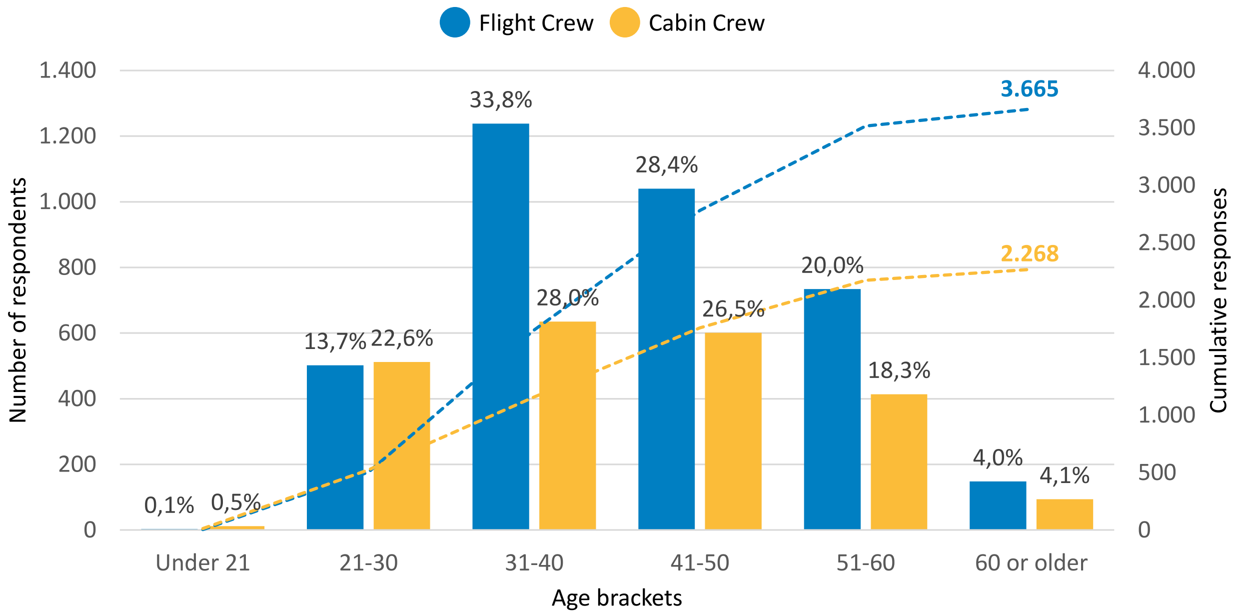


Figure 13: Age distribution of flight crew and cabin crew respondents.

3.1.2.1.2 Geographic distribution of home bases

The geographic distribution of respondents is assessed based on the reported location of their assigned home base. As shown in Figure 14, flight crew respondents are primarily concentrated in France (615), Germany (365) and Spain (343), which together account for the largest share of the sample. Among cabin crew respondents, the most represented home base countries are Germany (520), Spain (503) and Italy (457), reflecting the main clusters of operational activity captured in the survey.

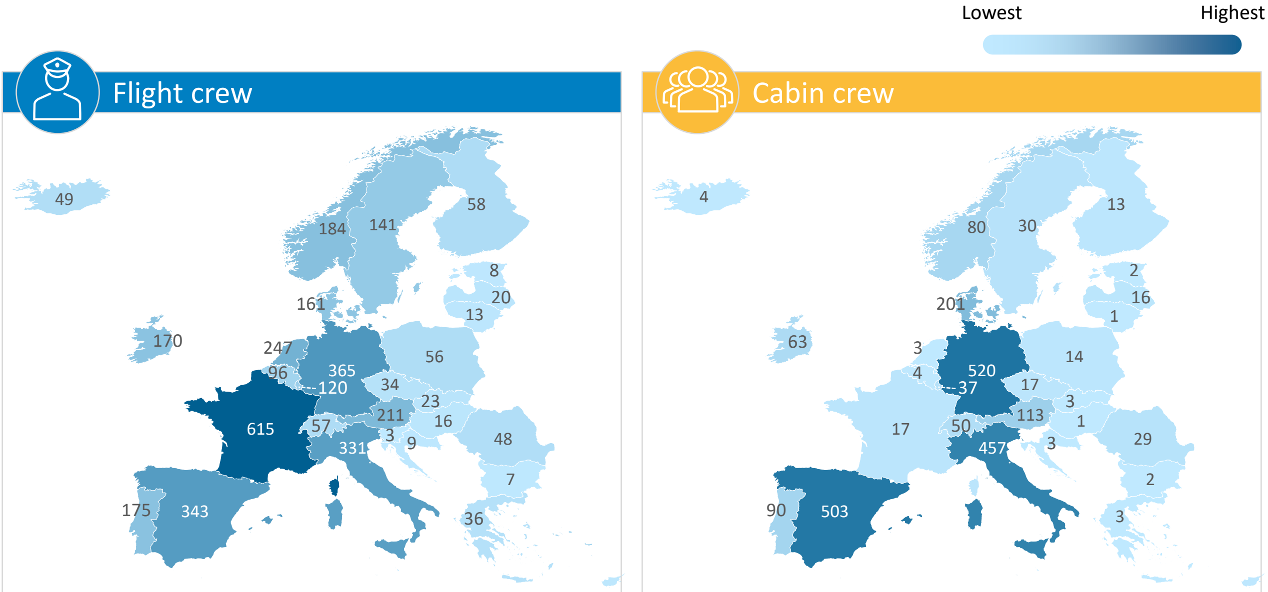


Figure 14: Home base distribution of flight crew and cabin crew respondents.

3.1.2.2 Key socio-economic indicators scoring and analysis

Following the methodology established in Section 2.4, each RA is assessed by evaluating its associated KSIs. The corresponding KSI score obtained in this study is presented utilizing the available data streams. This approach is intended to convert qualitative socio-economic dimensions into comparable quantitative outputs.

In the following sub-sections, the formal definitions of the KSIs are not provided, since the details are already provided in Annex C.4. Instead, a brief explanation is included here only to support the understanding of how each KSI is used within the analysis.

3.1.2.2.1 Reading guide

For each Risk Area, the associated KSIs are presented using graphical outputs that reflect the most relevant breakdown for the indicator under analysis. Depending on data availability and analytical relevance, results may be shown by airline business model, age group, or other contextual variables. The figure below illustrates the key elements that define the characterization of the KSIs, accompanied by a concise guide on how to interpret the data.

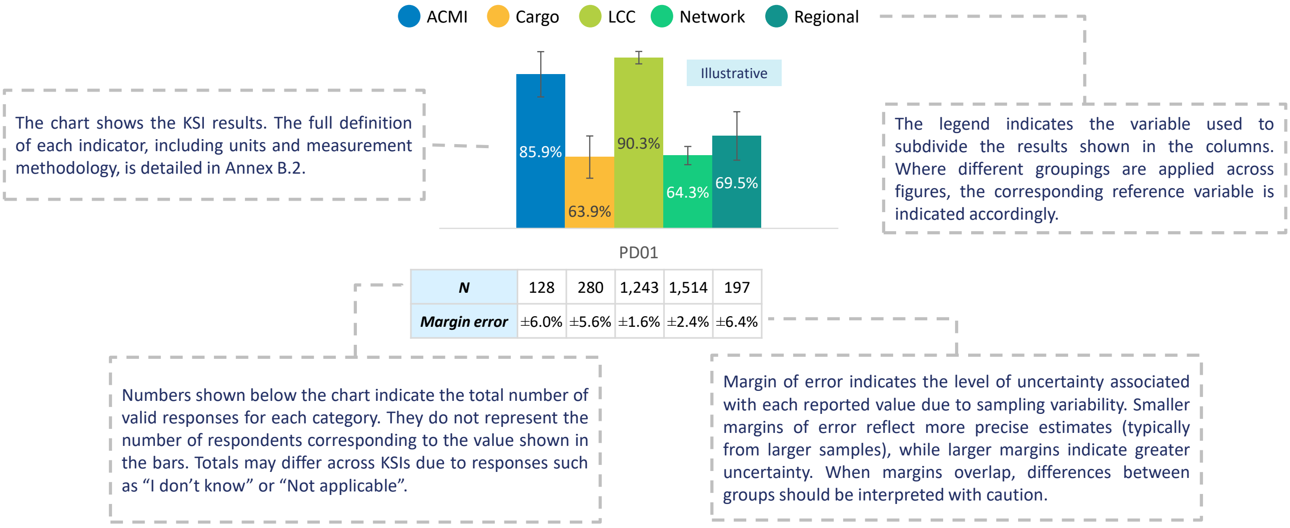


Figure 15: Illustrative example of KSI graphical presentation and reading guidance.

Note: It should be noted that KSIs cannot always be computed for all RAs. In some cases, the available data do not provide any measurable input for the KSI under consideration. This occurs when no survey questions, databases, or other data sources address the specific indicator.

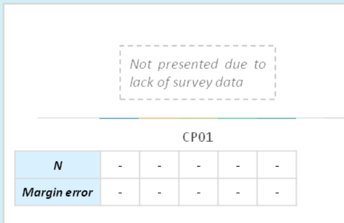


Figure 16: Message displayed when the KSI cannot be

When this situation happens, the corresponding KSI results are not presented in the graphs. Instead, a placeholder message is displayed to indicate the absence of data. An example of this notation is shown in the Figure 16.

3.1.2.2.2 Atypical contracts

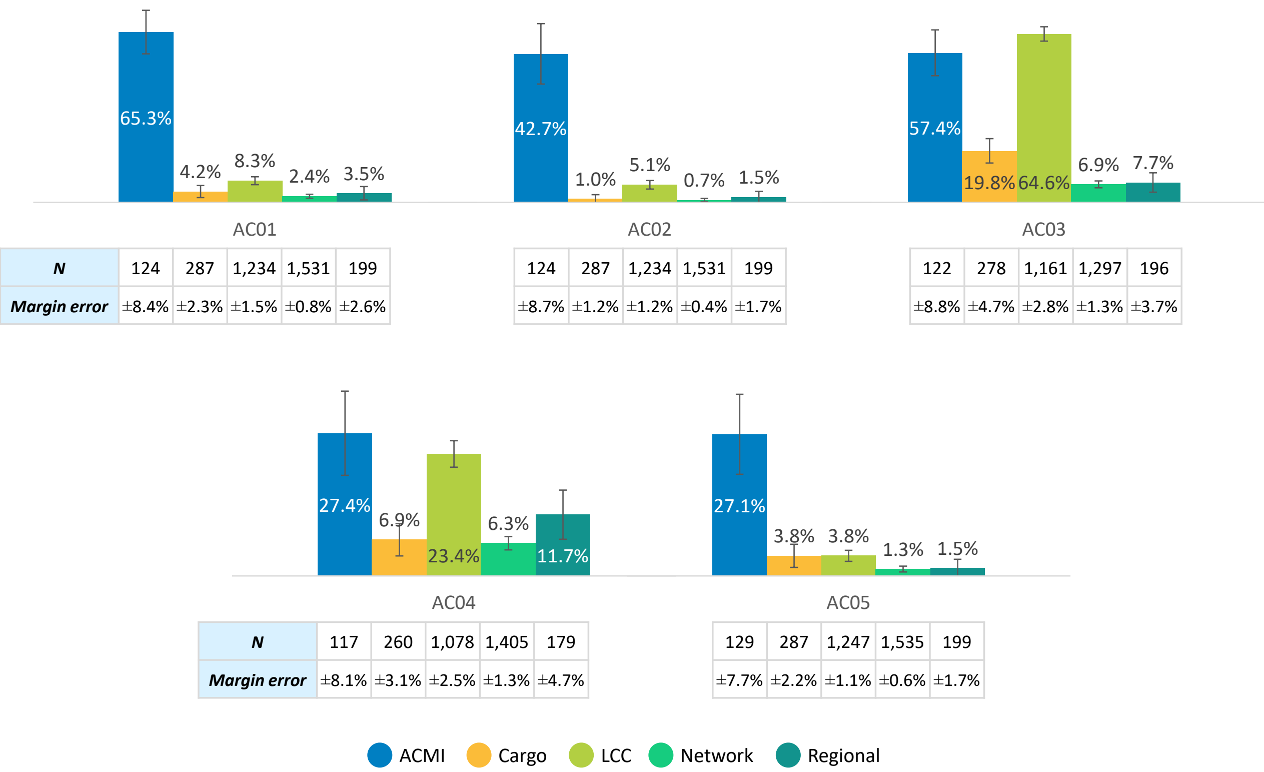
Focuses on the use of non-standard employment arrangements, including agency work, self-employment, fixed-term or zero-hour contracts, pay-to-fly schemes, and cross-border contractual setups. These employment models describe how SCP are contractually engaged and how employment and payroll arrangements are structured across jurisdictions. This RA examines the prevalence and characteristics of atypical and cross-border employment arrangements, as well as the degree of alignment between operational activity, contractual status, and payroll jurisdiction. The KSIs that characterise the atypical contracts RA are listed below:

- **AC01 – Direct employment ratio:** Percentage of respondents not directly employed by the airline on permanent contracts.
- **AC02 – Temporary contract index:** Percentage of respondents self-employed, zero-hour, fixed-term, or pay-to-fly contracts.

- **AC03 – Cross-border registration index:** Share of crew contracts registered outside the airline's primary AOC country, reflecting operational and labour market realities within cross-border aviation models, where aircrew are commonly registered in the country of employment or home base rather than in the principal place of business of the airline, including in line with individual employment choices and applicable contractual frameworks.
- **AC04 – Departure intention rate:** Percentage of respondents considering very likely to leave their airline in the next 12 months.
- **AC05 – Base-payroll jurisdiction mismatch rate:** Percentage of respondents whose payroll jurisdiction differs from their operational base.

Flight crew

Figure 17 summarises the atypical contracts KSIs for flight crew.



AC01

N	124	287	1,234	1,531	199
Margin error	±8.4%	±2.3%	±1.5%	±0.8%	±2.6%

AC02

N	124	287	1,234	1,531	199
Margin error	±8.7%	±1.2%	±1.2%	±0.4%	±1.7%

AC03

N	122	278	1,161	1,297	196
Margin error	±8.8%	±4.7%	±2.8%	±1.3%	±3.7%

AC04

N	117	260	1,078	1,405	179
Margin error	±8.1%	±3.1%	±2.5%	±1.3%	±4.7%

AC05

N	129	287	1,247	1,535	199
Margin error	±7.7%	±2.2%	±1.1%	±0.6%	±1.7%

Figure 17: Atypical contracts - Flight crew KSIs results

Non-standard and cross-border employment arrangements are present across all operational models, but their prevalence differs by business model. ACMI, and to a lesser extent Low Cost Carrier (LCC), report higher levels of atypical contracting and cross-border arrangements, whereas cargo, network, and regional operators show lower and similar levels.

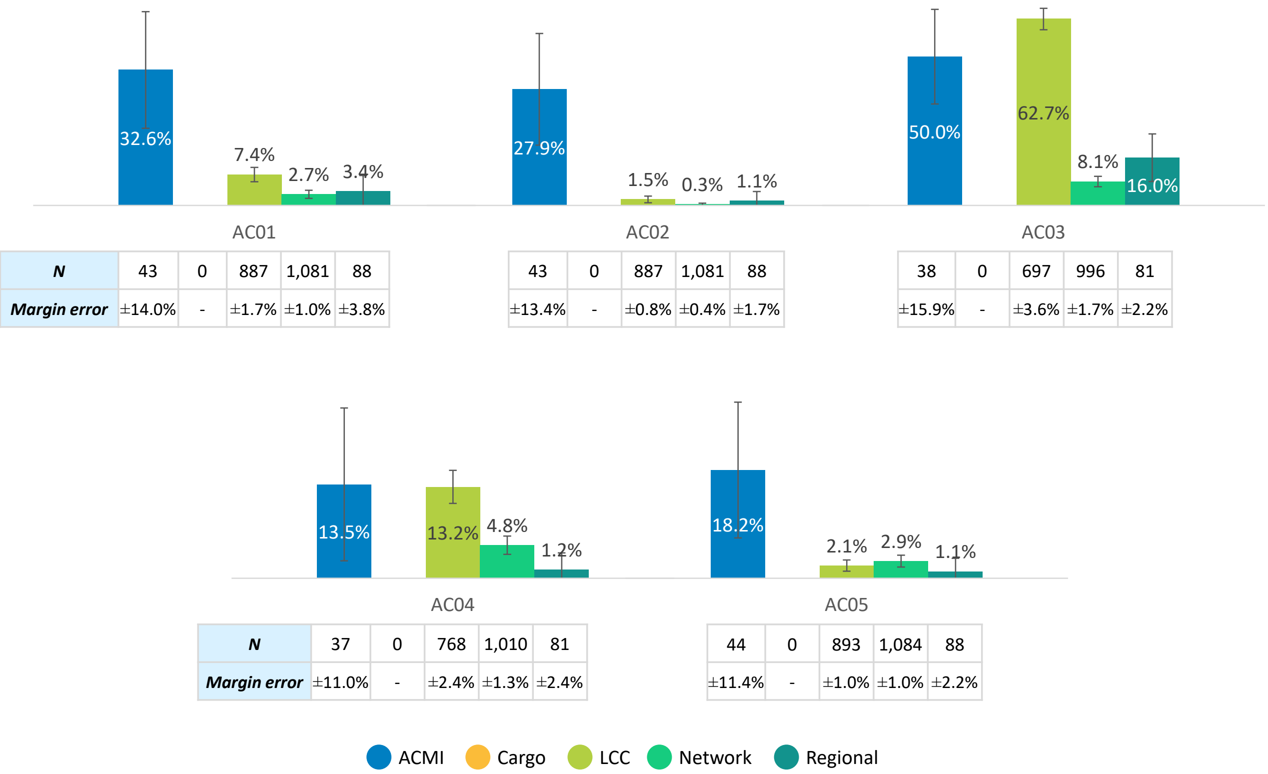
In operational environments where these arrangements are more prevalent, notably ACMI and LCC operations, KSI indicators show higher levels of cross-border contractual arrangements and payroll–base mismatches, together with comparatively higher reported departure intention. By contrast, cargo, network and regional operations generally display lower prevalence of such arrangements. These patterns should be interpreted in the context of the operational and organisational characteristics of different business models, including the use of cross-border employment structures and the mobility requirements inherent to aviation operations.

In this regard, the findings should not be interpreted as indicating non-compliance or inherently less favourable employment conditions. They reflect the application of EU labour and jurisdictional principles.

Overall, the findings suggest that atypical and cross-border employment arrangements remain limited in cargo, network, and regional operations, but represent a more structural feature of workforce organisation in ACMI and partly in LCC environments.

Cabin crew

Figure 18 summarises the atypical contracts KSIs for cabin crew.



AC01

N	43	0	887	1,081	88
Margin error	±14.0%	-	±1.7%	±1.0%	±3.8%

AC02

N	43	0	887	1,081	88
Margin error	±13.4%	-	±0.8%	±0.4%	±1.7%

AC03

N	38	0	697	996	81
Margin error	±15.9%	-	±3.6%	±1.7%	±2.2%

AC04

N	37	0	768	1,010	81
Margin error	±11.0%	-	±2.4%	±1.3%	±2.4%

AC05

N	44	0	893	1,084	88
Margin error	±11.4%	-	±1.0%	±1.0%	±2.2%

Figure 18: Atypical contracts - Cabin crew KSIs results

Non-standard and cross-border employment arrangements for cabin crew are present across operational models, but their configuration differs by operator group. ACMI operations stand out with consistently higher levels across indicators capturing atypical contracting, contractual uncertainty and structural misalignment. However, these results should be interpreted with caution due to the limited number of responses and the associated higher margin of error. By contrast, network and regional operations report uniformly low levels, indicating more stable and nationally aligned employment arrangements.

A distinct pattern emerges for LCC, where cross-border contractual arrangements and departure intention are comparatively elevated, despite lower prevalence of other atypical employment features than in ACMI environments. This suggests that, for cabin crew, cross-border registration constitutes a particularly salient dimension of employment arrangements in LCC operations.

Overall, the results indicate that atypical employment arrangements for cabin crew are most structurally embedded in ACMI operations, while LCC environments are characterised by selective exposure to cross-border arrangements. In contrast, network and regional operations display limited prevalence of atypical features.

3.1.2.2.3 Commercial pressure

Focuses on the extent to which commercial objectives influence operational planning, scheduling, and day-to-day decision-making in flight operations. Commercial pressure can manifest through tight schedules, high asset utilisation, roster constraints, and strong emphasis on on-time performance, potentially shaping how crews experience workload, fatigue margins, and operational priorities. This RA examines both objective operational indicators and crew perceptions in order to capture how commercial demands translate into operational pressure across different roles and environments. The KSIs that characterise the commercial pressure RA are listed below:

- **CP01 – Turnaround median time:** Median time aircraft spend on the ground between arrival at gate and departure for the next flight.
- **CP02 – Fleet utilization rate:** Average number of flight hours per aircraft per day.
- **CP03 – Roster capacity utilization:** Percentage of respondents who almost always operate at or near their regulatory flight and duty time limits.
- **CP04 – Short-notice roster change frequency:** Percentage of crew reporting having had more than six roster changes within 24 hours of planned duty.
- **CP05 – OTP pressure performance:** Percentage of crew reporting that pressure to maintain on-time performance almost always compromises priority over safety considerations.

- **CP06 – Share of off-duty substance use among high-pressure personnel:** Percentage of staff reporting both high perceived commercial pressure and off-duty substance use as a coping mechanism.
- **CP07 – Share of wellbeing issues among high-pressure personnel:** Percentage of staff reporting both high perceived commercial pressure and wellbeing issues such as stress or anxiety.
- **CP08 – Commander's discretion usage rate:** Percentage of respondents who do not agree that commander's discretion is used appropriately.

Flight crew

Figure 19 summarises the commercial pressure KSIs for flight crew.

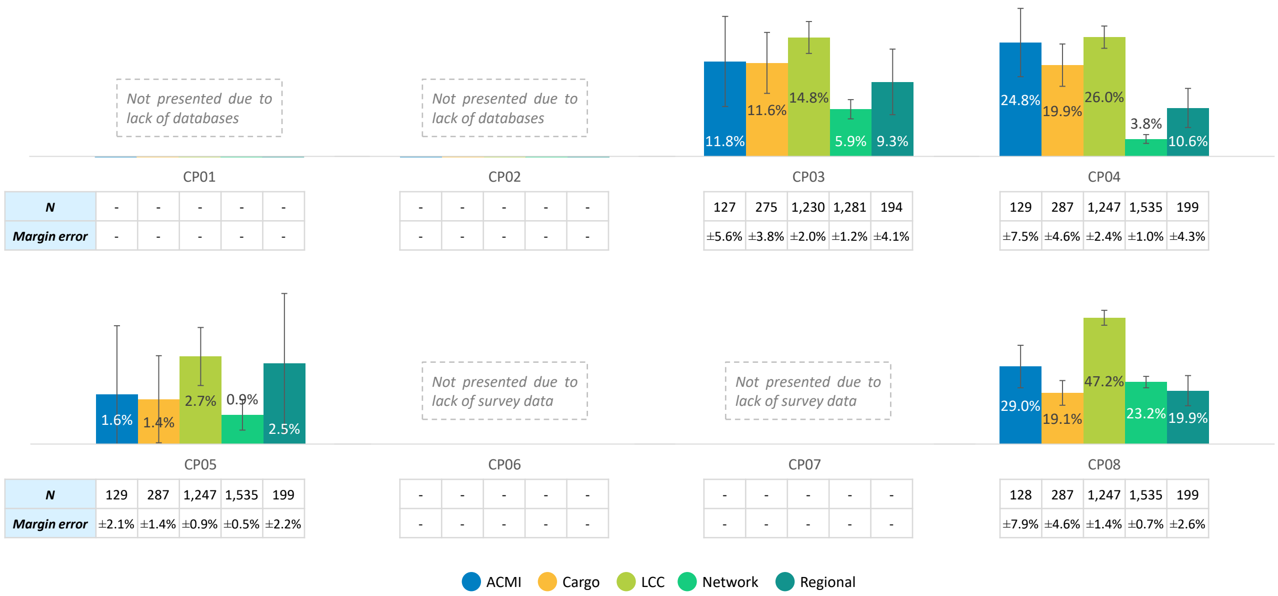
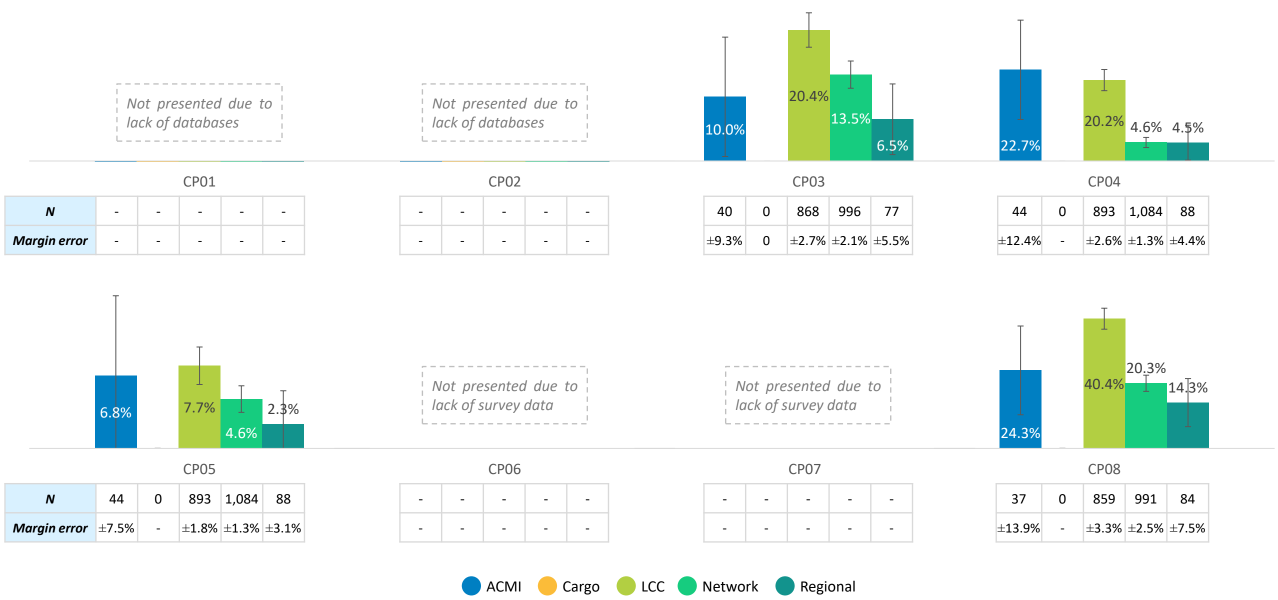


Figure 19: Commercial pressure - Flight crew KSIs results

Commercial pressure indicators vary systematically across business models. ACMI and LCC operations report higher levels across indicators related to roster capacity utilisation, short-notice roster changes, and operational flexibility, reflecting tighter scheduling. Network operations consistently show lower levels, indicating more stable planning and wider operational buffers, while cargo and regional operations generally occupy intermediate positions. Perceived pressure related to on-time performance follows a broadly similar pattern across business models, although this indicator is associated with relatively high margins of error and should therefore be interpreted with appropriate caution.

Cabin crew

Figure 20 summarises the commercial pressure KSIs for cabin crew.



KSI		ACMI	Cargo	LCC	Network	Regional
CP01	N	-	-	-	-	-
CP01	Margin error	-	-	-	-	-
CP02	N	-	-	-	-	-
CP02	Margin error	-	-	-	-	-
CP03	N	40	0	868	996	77
CP03	Margin error	±9.3%	0	±2.7%	±2.1%	±5.5%
CP04	N	44	0	893	1,084	88
CP04	Margin error	±12.4%	-	±2.6%	±1.3%	±4.4%
CP05	N	44	0	893	1,084	88
CP05	Margin error	±7.5%	-	±1.8%	±1.3%	±3.1%
CP06	N	-	-	-	-	-
CP06	Margin error	-	-	-	-	-
CP07	N	-	-	-	-	-
CP07	Margin error	-	-	-	-	-
CP08	N	37	0	859	991	84
CP08	Margin error	±13.9%	-	±3.3%	±2.5%	±7.5%

Figure 20: Commercial pressure - Cabin crew KSIs results

Commercial pressure indicators for cabin crew vary by business model with an uneven distribution. LCC operations consistently report higher levels across several indicators related to roster instability and perceived operational pressure, including frequent short-notice roster changes and higher reported constraints during duty periods. ACMI results tend to show relatively elevated values for some indicators, but these should be interpreted cautiously given the smaller sample size and higher variability of the margin error.

Network operations display lower and more stable levels across most commercial pressure indicators, suggesting more predictable rostering practices and wider operational margins. Regional operations generally align closer to network carriers, although with slightly higher variability in certain indicators. Perceived pressure related to on-time performance follows a similar pattern, with higher values reported in LCC environments.

Overall, the findings suggest that commercial pressure for cabin crew is most pronounced in LCC operations, while remaining more limited and stable in network and regional environments.

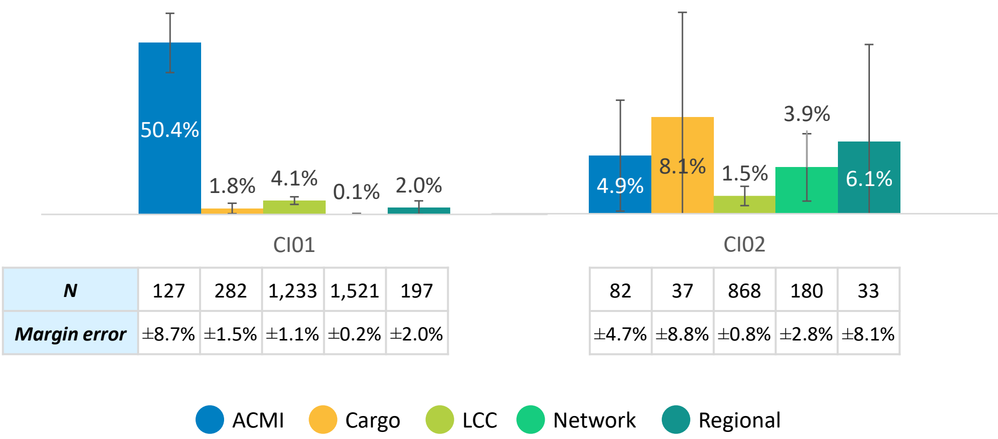
3.1.2.2.4 Crew interoperability

Focuses on the extent to which crew interoperability is applied across different Air Operator Certificates (AOCs) within operator groups or operational arrangements. Crew interoperability allows operators to deploy flight and cabin crew across multiple AOCs, potentially increasing operational flexibility. This RA examines where frequent cross-AOC operations may introduce additional complexity related to procedural (SOPs) consistency, role clarity, and situational awareness. The KSIs that characterise the crew interoperability RA are listed below:

- **CI01 – Cross-AOC flight ratio**: Percentage of respondents reporting that they frequently operate under an AOC different from their primary one.
- **CI02 – Perception of lack of SOP clarity**: Percentage of respondents reporting that roles and procedures are very unclear when operating under a different AOC.

Flight crew

Figure 21 summarises the crew interoperability KSIs for Flight crew.



	CI01					CI02				
N	127	282	1,233	1,521	197	82	37	868	180	33
Margin error	±8.7%	±1.5%	±1.1%	±0.2%	±2.0%	±4.7%	±8.8%	±0.8%	±2.8%	±8.1%

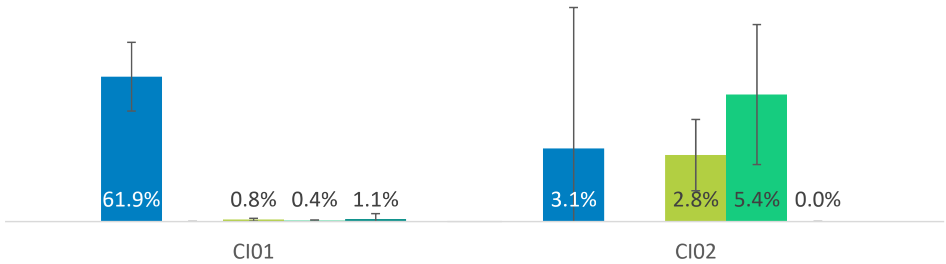
Figure 21: Crew interoperability - Flight crew KSI results

Crew interoperability is applied unevenly across operational models. ACMI operations show higher levels of cross-AOC flying, while cargo, network, regional, and LCC operations report very limited exposure. However, this pattern may partly reflect how respondents interpreted the survey question, as ACMI operations inherently involve flying on behalf of another operator (lessee), which may have been understood by some respondents as cross-AOC flying. In environments where cross-AOC operations are more widespread, reported levels of procedural and role clarity remain relatively high. By contrast, in operational models where cross-AOC flying is infrequent (others than ACMI), a slightly higher share reports unclear roles or procedures when operating under a different AOC. However, given the low values, these results are associated with a high margin of error.

Overall, the findings suggest that crew interoperability functions as a structurally embedded operating mode in ACMI environments, whereas in cargo, network, regional, and LCC operations it remains limited and more occasional, with clarity concerns emerging primarily when cross-AOC operations are less familiar.

Cabin crew

Figure 22 summarises the crew interoperability KSIs for cabin crew.



	CI01					CI02				
N	42	0	869	1,037	87	32	0	457	221	15
Margin error	±14.7%	-	±1.5%	±0.4%	±2.2%	±6.0%	-	±1.5%	±3.0%	±0.0%

Figure 22: Crew interoperability - Cabin crew KSI results

Crew interoperability for cabin crew is strongly concentrated in ACMI operations, where cross-AOC deployment is a structurally embedded practice. In contrast, LCC, network, and regional operations show negligible exposure, indicating that interoperability remains limited in these environments. Where cross-AOC operations are applied, reported levels of procedural and role clarity remain high. However, given the low values, these results are associated with a high margin of error.

Overall, crew interoperability for cabin crew is embedded in ACMI environments and limited elsewhere, with no indication of widespread clarity concerns.

3.1.2.2.5 Fraud risk

Focuses on the perceived robustness of the aviation system in preventing and detecting fraud-related behaviours within licensing, certification, and medical oversight processes. Fraud risk in this context relates not only to intentional misconduct, such as falsified documentation or withheld medical information, but also to systemic vulnerabilities arising from uneven implementation or enforcement across Member States. This RA examines stakeholder confidence in existing safeguards and perceptions of regulatory arbitrage, which may undermine trust in the integrity and consistency of the system. The KSIs that characterise fraud risk RA are listed below:

- **FR01 – Fraud detection confidence index:** Percentage of respondents who are very unconfident in the current system ability to detect and prevent fraud.

- **FR02 – Perceived forum shopping prevalence:** Percentage of respondents who strongly agree that some national authorities have a reputation for being 'easier' on overseeing their operators than authorities in other countries.

Flight crew

Figure 23 summarises the fraud risk KSIs for flight crew.

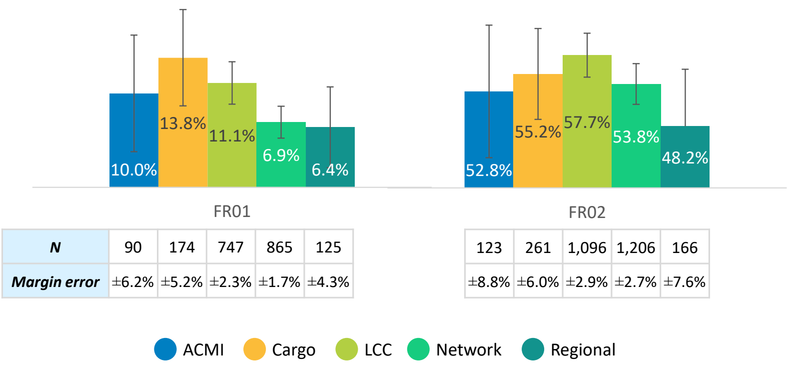


Figure 23: Fraud risk - Flight crew KSI results

Confidence in fraud detection mechanisms is generally maintained across operational models, with only moderate variation between business environments showing the cargo segment higher values than other operational environments. There is no indication of a systemic lack of trust in the system's ability to detect and prevent fraud due to the low percentages expressed in Figure 23. At the same time, perceptions of forum shopping are widespread across the sector, with limited differentiation between operational models. Results for ACMI operators display greater variability and should be interpreted with caution, as they are based on a very limited number of responses.

Overall, the findings suggest that perceived regulatory inconsistencies coexist with a good enough fraud detection framework.

Cabin crew

For cabin crew, only the fraud detection confidence indicator is considered relevant within this RA. However, this aspect was not addressed through the survey questions targeting cabin crew.

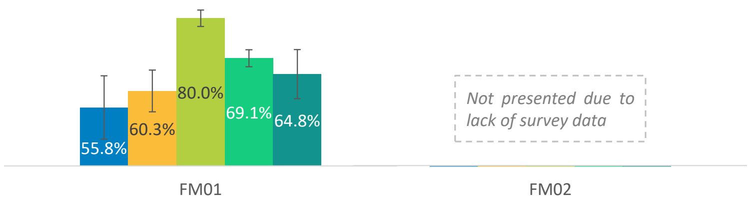
3.1.2.2.6 Fuel management

Focuses on how fuel-related decisions are made in operational practice and how economic, organisational, or commercial considerations may influence fuel planning and in-flight fuel management where discretionary decisions by flight crew can either mitigate or amplify exposure to low-fuel situations. This RA examines both the use of pilot discretion to uplift additional fuel and the occurrence of operations under critically low fuel conditions. The KSIs that characterise the fuel management area are listed below:

- **FM01 – Commander fuel discretion:** Percentage of respondents very likely to use discretion to uplift fuel beyond standard operational requirements.
- **FM02 – Fuel management:** Measures how frequently aircraft operate below minimum fuel reserves.

<u>Flight crew</u>

Figure 24 summarises the fuel management KSIs for flight crew.



	FM01					FM02				
N	129	287	1,247	1,535	199	-	-	-	-	-
Margin error	±8.6%	±5.7%	±2.2%	±2.3%	±6.6%	-	-	-	-	-

Figure 24: Fuel management - Flight crew KSI results

Uplift of discretionary fuel is widely reported across all operational models, indicating that commander fuel discretion is a common element of operational practice. Reported use is highest in LCC operations, with lower but still at substantial levels in network, cargo, regional, and ACMI environments. Notably, the dataset contains no data/reports indicating operations below minimum fuel levels. While this represents an absence of reported events rather than proof of their non-occurrence, it suggests that respondents do not perceive fuel planning practices in their operations as generating systemic safety concerns

<u>Cabin crew</u>

This RA was not addressed through the survey questions targeting cabin crew.

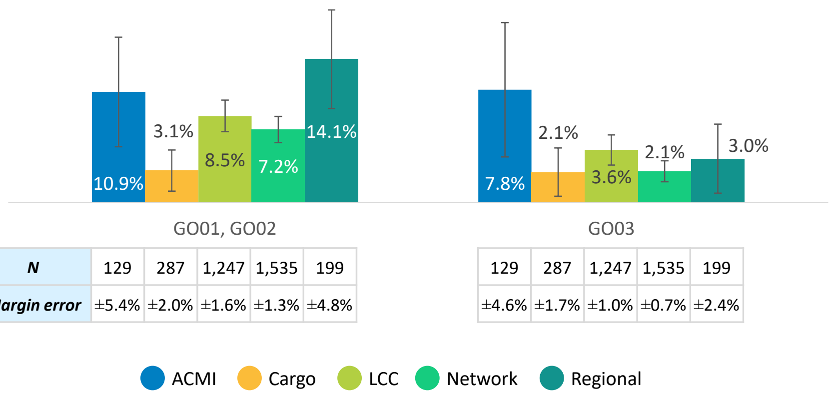
3.1.2.2.7 Go-around decisions

Focuses on pilots' perceived pressure to avoid executing go-arounds during approach and landing. Go-arounds are a normal and safety-critical manoeuvre, and any perceived disincentive to initiate them may indicate the presence of commercial, operational, or cultural pressures influencing decision-making at a critical phase of flight. This RA examines whether pilots feel undue pressure to continue an approach rather than initiate a go-around. The KSIs that characterise the go-around decisions area are listed below:

- **GO01, GO02 – Pilot go-around:** Percentage of respondents reporting undue pressure to avoid go-arounds.
- **GO03 – Go-around pressure differential:** Percentage of respondents who strongly agree that they are concerned about potential negative consequences or reprimands after performing a go-around.

Flight crew

Figure 25 summarises the go-around decisions KSIs for flight crew.



	GO01, GO02					GO03				
N	129	287	1,247	1,535	199	129	287	1,247	1,535	199
Margin error	±5.4%	±2.0%	±1.6%	±1.3%	±4.8%	±4.6%	±1.7%	±1.0%	±0.7%	±2.4%

Figure 25: Go-around decisions - Flight crew KSI results

Perceived pressure to avoid go-arounds is reported across all operational models, but at generally moderate levels. Cargo operations consistently report the lowest levels, while higher values are observed in regional and ACMI environments. Strong concern about negative consequences or reprimands after performing a go-around remains limited overall and is most pronounced in ACMI operations, with other business models reporting low and broadly similar levels. Results for ACMI operators display greater variability and should be interpreted with caution, as they are based on a very limited number of responses.

Overall, the findings suggest that while perceptions of go-around-related pressure exist, they are unevenly distributed and generally moderate.

Cabin crew

This RA was not addressed through the survey questions targeting cabin crew.

3.1.2.2.8 Generational risk behaviour

Focuses on how age-related and generational factors shape employment conditions, perceptions, and behaviours within the aviation workforce. Different age cohorts may experience distinct levels of job security, work–life balance, and exposure to operational or commercial pressures, which in turn can influence attitudes toward safety, reporting, and personal coping strategies. This RA examines whether specific generational patterns are associated with increased vulnerability, dissatisfaction, or risk-related behaviour across the workforce. Under 21 years old respondents are not shown in the analysis due to an insufficient number of observations (26*). The KSIs that characterise the generational risk behaviour area are listed below:

- **GR01, GR02 – Pilot age distribution:** Percentage breakdown of crew across age brackets.
- **GR03 – Contract type vs age distribution:** Percentage of respondents without permanent direct employment contract.
- **GR04 – Generational work-life balance:** Percentage of respondents very dissatisfied with their work life balance.
- **GR05 – Generational safety culture perception:** Percentage of respondents who strongly disagree that they can report their own mistakes without negative consequences.
- **GR06 – Age-induced substance use:** Share of staff within each age group reporting off-duty substance use in conjunction with high perceived commercial pressure.

Flight crew

Error! Reference source not found. summarises the generational risk behaviour KSIs for flight crew.

30*Under 21 years old respondents: 3 flight crew and 12 cabin crew.

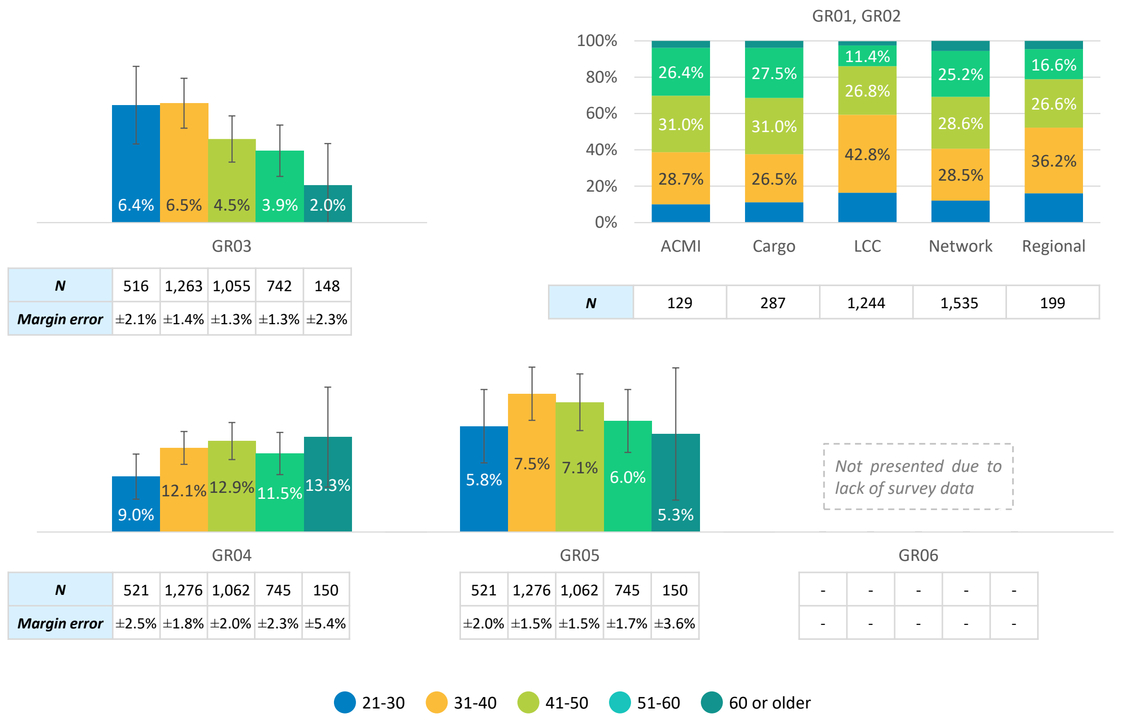


Figure 26: Generational risk behaviour - Flight crew KSI results

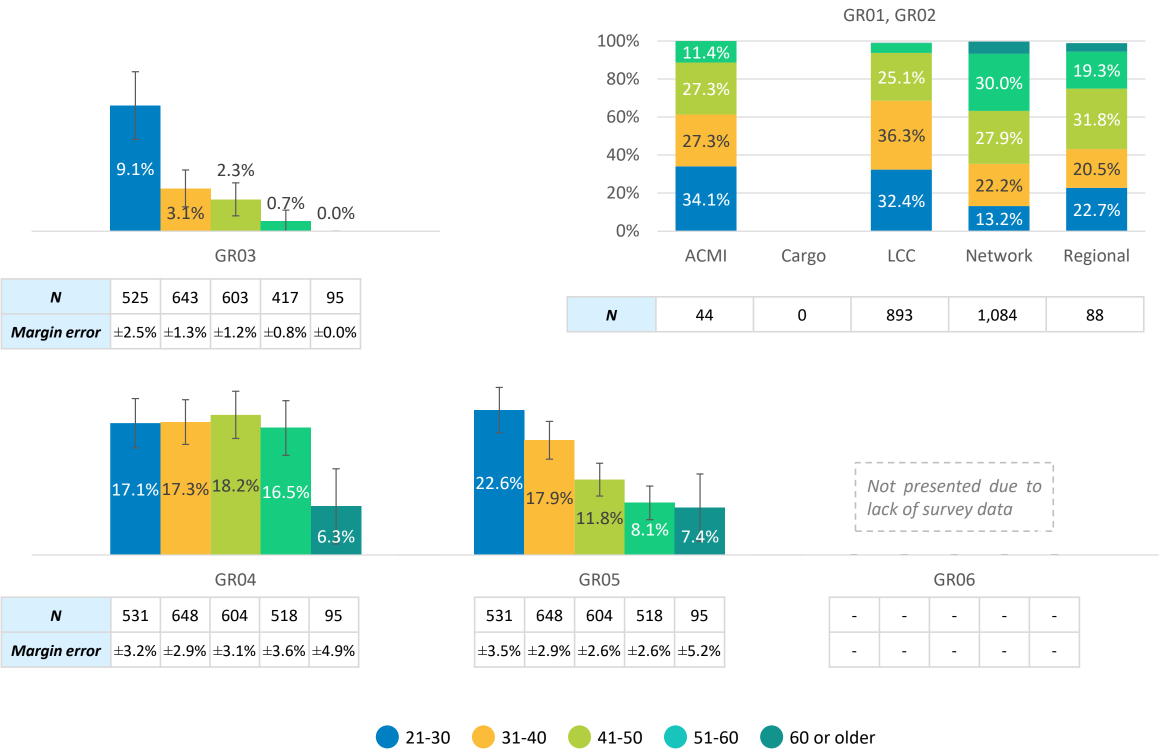
Age-related factors are associated with differences in employment conditions, wellbeing and safety-related perceptions within the flight crew population, with comparable patterns across age cohorts. LCC and regional operations concentrate a higher share of younger cabin crew profiles, while network and regional environments display a more balanced age distribution. Contractual arrangements tend to improve progressively with age, as younger cohorts are more frequently employed under non-permanent or non-direct contracts, while older cohorts show higher levels of contractual stability. Perceived dissatisfaction with work–life balance follows an opposite gradient, evolving from more favourable perceptions in younger age groups towards higher dissatisfaction later in the career. This pattern may be associated with the cumulative effect of ageing, changing personal and family responsibilities, career progression requirements and potential health-related constraints, which can increase the perceived burden of otherwise comparable working conditions across the career span.

Perceptions related to safety culture and reporting remain broadly similar across age cohorts, with no marked generational differentiation observed. Results for respondents aged 60 or older should be interpreted with caution due to the limited number of observations and the associated high margin of error, which also reflects the small number of individuals remaining operationally active in this age group.

Overall, observed differences across age cohorts remain moderate and follow gradual patterns rather than abrupt generational shifts.

Cabin crew

Figure 27 summarises the generational risk behaviour KSIs for cabin crew.



GR03

N	525	643	603	417	95
Margin error	±2.5%	±1.3%	±1.2%	±0.8%	±0.0%

GR01, GR02

	ACMI	Cargo	LCC	Network	Regional
N	44	0	893	1,084	88

GR04

N	531	648	604	518	95
Margin error	±3.2%	±2.9%	±3.1%	±3.6%	±4.9%

GR05

N	531	648	604	518	95
Margin error	±3.5%	±2.9%	±2.6%	±2.6%	±5.2%

GR06

N	-	-	-	-	-
Margin error	-	-	-	-	-

Figure 27: Generational risk behaviour - Cabin crew KSI results

Age-related patterns among cabin crew highlight both compositional and experiential differences across operational contexts. ACMI and LCC operations concentrate a higher share of younger cabin crew profiles, while network and regional environments display a more balanced age distribution.

In terms of employment conditions, contractual stability improves markedly with age. Non-permanent or non-direct employment is more prevalent at career entry, but transitions rapidly towards stable and predominantly direct contractual arrangements across all operational models, with high levels of permanent employment observed from mid-career onwards. Dissatisfaction levels related with work-life balance are relatively similar from entry through mid- and late-career stages, with a more pronounced improvement only observed in the oldest age group. Perceptions related to safety culture and reporting show a clear age gradient, with fear of reporting decreasing progressively across older cohorts, suggesting increased confidence in reporting mechanisms over time. Results for respondents aged 60 or older should be interpreted with caution due to the limited number of observations and the associated high margin of error, which also reflects the small number of individuals remaining operationally active in this age group.

Overall, generational patterns among cabin crew reflect a progression towards greater contractual stability and reporting confidence, while work–life balance perceptions remain largely stable until the final career stage.

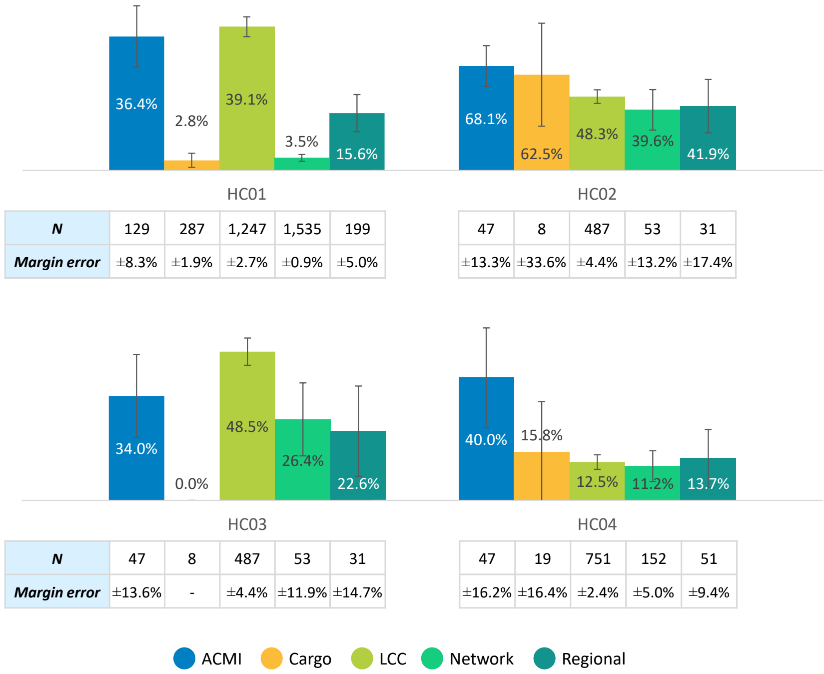
3.1.2.2.9 Homebase changes

Focuses on the frequency, intensity, and management of home base relocations affecting flight and cabin crew. From a socio-economic perspective, homebase changes can have significant implications for personnel, influencing commuting patterns, work–life balance, and job stability. This RA examines both the scale of workforce mobility and how relocation processes are perceived and experienced by affected crew. The KSIs that characterise the homebase change area are listed below:

- **HC01 – Homebase change rate:** Percentage of respondents who experienced one or more relocations within the last 12 months.
- **HC02 – Average frequency of homebase changes per affected crew:** Percentage of relocated crew who experience more than one homebase change within the last 12 months.
- **HC03 – Voluntary report rate for relocated crew:** Percentage of relocated crew reporting who do not feel at all comfortable to submit voluntary safety reports.
- **HC04 – Relocation notice period compliance:** Percentage of relocated crew reporting that they received less than 14 days' notice before a mandatory homebase change.

Flight crew

Figure 28 summarises the homebase changes KSIs for flight crew.



HC01 / HC02

	HC01					HC02				
N	129	287	1,247	1,535	199	47	8	487	53	31
Margin error	±8.3%	±1.9%	±2.7%	±0.9%	±5.0%	±13.3%	±33.6%	±4.4%	±13.2%	±17.4%

HC03 / HC04

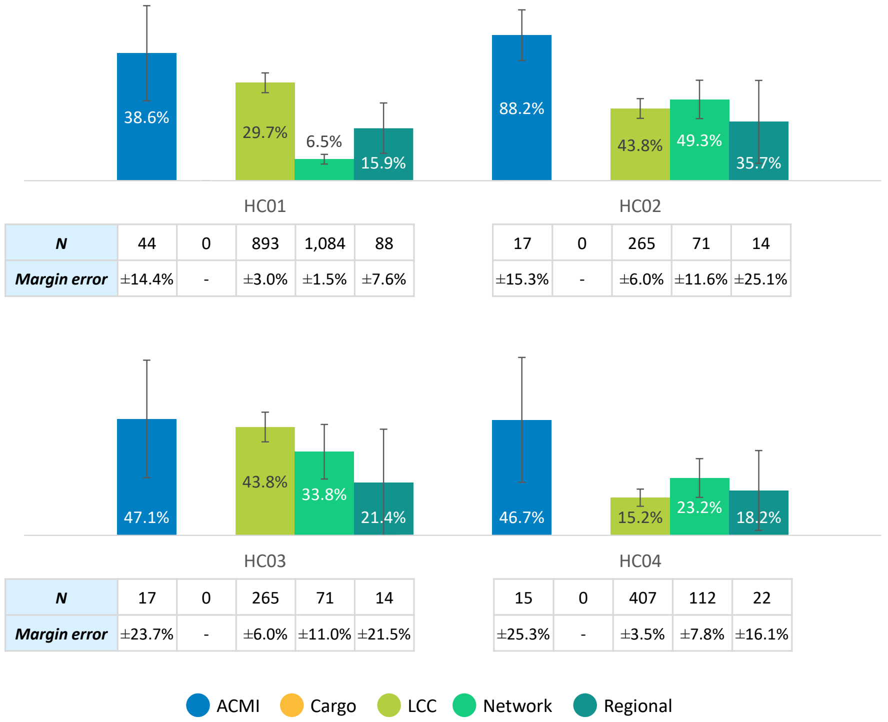
	HC03					HC04				
N	47	8	487	53	31	47	19	751	152	51
Margin error	±13.6%	-	±4.4%	±11.9%	±14.7%	±16.2%	±16.4%	±2.4%	±5.0%	±9.4%

Figure 28: Homebase change - Flight crew KSI results

Homebase changes show strong variation across operational models. ACMI and LCC report the highest exposure to relocations, while cargo and network operations remain largely stable, with regional in an intermediate position. Beyond prevalence, ACMI stands out for combining frequent relocations with a higher incidence of repeated moves, shorter notice periods, and lower reported willingness to raise safety issues among respondents, although these latter indicators are based on smaller sub-samples and should be interpreted with caution. Overall, the results indicate that workforce mobility is concentrated in specific business models and is associated with differing relocation practices and perceptions across the sector. These patterns should also be considered in light of the relative market presence and scale of operation of certain business models within the EEA aviation market, which may naturally result in a greater concentration of mobile and cross-border workforce arrangements.

<u>Cabin crew</u>

Figure 29 summarises the homebase changes KSIs for flight crew.



HC01

	ACMI	Cargo	LCC	Network	Regional
N	44	0	893	1,084	88
Margin error	±14.4%	-	±3.0%	±1.5%	±7.6%

HC02

	ACMI	Cargo	LCC	Network	Regional
N	17	0	265	71	14
Margin error	±15.3%	-	±6.0%	±11.6%	±25.1%

HC03

	ACMI	Cargo	LCC	Network	Regional
N	17	0	265	71	14
Margin error	±23.7%	-	±6.0%	±11.0%	±21.5%

HC04

	ACMI	Cargo	LCC	Network	Regional
N	15	0	407	112	22
Margin error	±25.3%	-	±3.5%	±7.8%	±16.1%

Figure 29: Homebase change - Cabin crew KSI results

Homebase changes among cabin crew are concentrated in specific operational models rather than being widespread across the sector. Relocations are most prevalent in ACMI and LCC operations, while remaining comparatively rare in network and regional operations. Beyond prevalence, the structure of relocations differs markedly: ACMI combines high exposure with frequent repeated moves and a higher incidence of short-notice relocations, whereas relocations in LCC operations tend to be less recurrent and better anticipated. Network and regional operations show lower overall exposure, with relocations appearing more occasional.

3.1.2.2.10 Use of commander's discretion to extend the planned FDP

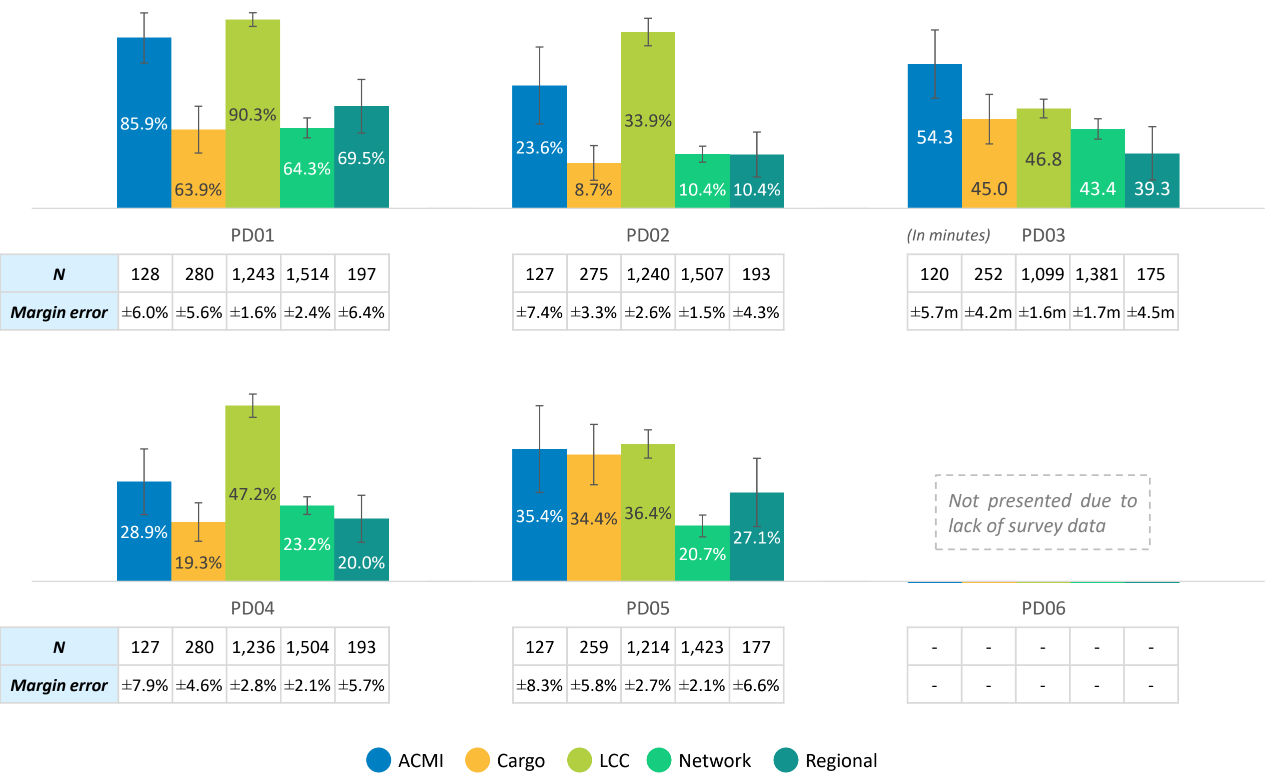
Focuses on the use of Commander's Discretion to extend FDPs beyond planned limits. While such flexibility is intended as an exceptional tool to complete a flight in unforeseen circumstances, its frequent or routine use may indicate underlying operational, organisational, or commercial pressures. This RA examines whether discretion remains an occasional relief or if it is embedded into normal operational planning. The KSIs that characterise the pilot discretion use RA are listed below:

- **PD01 – Prevalence of discretion use:** Percentage of respondents reporting that they have been affected by the use of commander's discretion.

- **PD02 – Frequency of discretion use:** Percentage of respondents perceiving that commander's discretion is used regularly rather than as an exceptional measure.
- **PD03 – Perceived average duration of discretion:** Typical self-reported length of duty period extensions (in minutes) when commander's discretion is applied.
- **PD04 – Perception of appropriate use:** Percentage of respondents who do not agree that commander's discretion is used appropriately.
- **PD05 – Crew consultation rate:** Percentage of respondents reporting that they are not consulted about their level of alertness every time a FDP extension is decided.
- **PD06 – Reporting confidence index:** Pilots confidence in the reporting environment after using discretion.

Flight crew

Figure 30 summarises the pilot discretion use KSIs for flight crew.



	PD01					PD02					PD03				
N	128	280	1,243	1,514	197	127	275	1,240	1,507	193	120	252	1,099	1,381	175
Margin error	±6.0%	±5.6%	±1.6%	±2.4%	±6.4%	±7.4%	±3.3%	±2.6%	±1.5%	±4.3%	±5.7m	±4.2m	±1.6m	±1.7m	±4.5m

	PD04					PD05					PD06				
N	127	280	1,236	1,504	193	127	259	1,214	1,423	177	-	-	-	-	-
Margin error	±7.9%	±4.6%	±2.8%	±2.1%	±5.7%	±8.3%	±5.8%	±2.7%	±2.1%	±6.6%	-	-	-	-	-

Figure 30: Pilot discretion use - Flight crew KSIs results

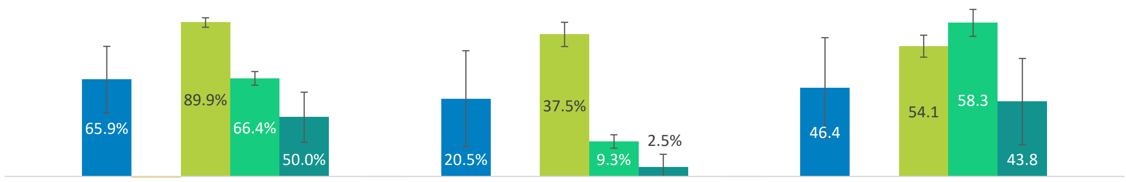
Commander's Discretion is reported across all operational models, reflecting its common purpose of providing operational flexibility when unforeseen circumstances affect the planned operation. However, reported frequency varies by business model: LCC operators, and to a lesser extent ACMI, indicate higher exposure and a stronger perception that discretion is used more frequently rather than exceptionally. Cargo, network and regional operations report lower and broadly similar level.

Where discretion is more frequent, it is associated with longer perceived duty extensions, greater scepticism regarding appropriate use, and weaker perceived crew consultation. By contrast, cargo, network and regional operations tend to show shorter extensions, lower dissatisfaction, and more consistent consultation practices, indicating that discretion largely retains its intended role as an exceptional safeguard.

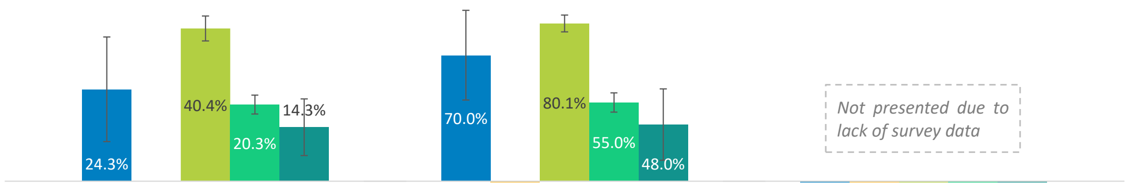
Overall, the findings suggest that discretion is generally perceived as an exceptional tool in cargo, network and regional operations. In LCC and, to a lesser extent, ACMI operations, respondents report somewhat more frequent use, although the available data do not indicate that this exceeds established monitoring thresholds or regulatory safeguards.

<u>Cabin crew</u>

Figure 31 summarises the pilot discretion use KSIs for cabin crew.



	ACMI	Cargo	LCC	Network	Regional
PD01 ***N***	44	0	874	1,030	68
PD01 ***Margin error***	±14.0%	-	±2.0%	±2.9%	±10.6%
PD02 ***N***	39	0	881	1,027	81
PD02 ***Margin error***	±12.7%	-	±3.2%	±1.8%	±3.4%
PD03 ***N***	33	0	762	850	63
PD03 ***Margin error***	±9.3m	-	±2.0m	±2.5m	±8.0m



	ACMI	Cargo	LCC	Network	Regional
PD04 ***N***	37	0	859	991	84
PD04 ***Margin error***	±13.8%	-	±3.3%	±2.5%	±7.5%
PD05 ***N***	40	0	873	1,009	75
PD05 ***Margin error***	±14.2%	-	±2.7%	±3.1%	±11.3%
PD06 ***N***	-	-	-	-	-
PD06 ***Margin error***	-	-	-	-	-

ACMI   Cargo   LCC   Network   Regional

Figure 31: Pilot discretion use - Cabin crew KSIs results

Commander's Discretion is widely experienced by cabin crew, though its prevalence and perceived use vary by business model. LCC operations report the highest exposure to discretion and the strongest perception that it is used frequently rather than exceptionally. ACMI also shows elevated exposure levels, although results should be interpreted with caution given the smaller number of responses, also in terms of regional operator. Network and regional operations report lower and more moderate levels across these indicators.

In operational environments where discretion is more prevalent, it is also associated with longer perceived duty extensions, higher levels of dissatisfaction regarding appropriate use, and weaker reported crew consultation.

By contrast, network and regional operations tend to show shorter extensions, lower dissatisfaction with discretion use, and more consistent consultation of cabin crew, indicating a more exceptional use of discretion.

Overall, the findings suggest that for cabin crew, commander's discretion retains its role as an exceptional tool in network and regional operations, while showing clear signals of potential normalisation in LCC environments and, to a lesser extent, in ACMI.

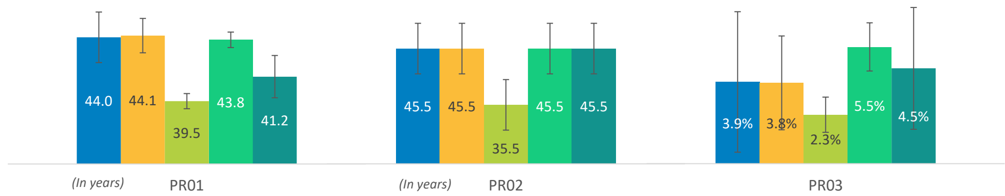
3.1.2.2.11 Pilot retirement age

Focuses on the age structure of the pilot workforce and the implications of upcoming retirements for workforce sustainability, capacity planning, and long-term system resilience. An ageing pilot population can create structural pressures on recruitment, training pipelines, and operational continuity, particularly if retirements are concentrated within a short time horizon. This RA examines both the current demographic profile of pilots and the expected scale of near-term retirements. The KSIs that characterise the pilot retirement RA are listed below:

- **PR01 – Pilot age distribution:** Demographic breakdown of the pilot workforce across predefined age bands, calculated as a weighted average using the midpoint of each age band.
- **PR02 – Pilot median age distribution:** Median age of the pilot workforce, defined as the age-band midpoint at which the cumulative frequency exceeds 50% of pilots.
- **PR03 – Retirement wave projection:** Percentage of respondents that is above 60 years of age.

<u>Flight crew</u>

Figure 32 summarises the pilot retirement age KSIs for flight crew.



	PR01					PR02					PR03				
N	129	287	1,247	1,535	199	129	287	1,247	1,535	199	129	287	1,247	1,535	199
Margin error	±1.8y	±1.2y	±0.5y	±0.6y	±1.5y	±4.5y	±4.5y	±4.5y	±4.5y	±4.5y	±3.3%	±2.2%	±0.8%	±1.1%	±2.9%

Figure 32: Pilot retirement age - Flight crew KSI results

Pilot age profiles are broadly similar across ACMI, cargo, network, and regional operations, with weighted average ages clustered around the mid-forties, while LCC operations display a consistently younger workforce. This difference is also reflected in the median age, which is lower in LCC than in other operational models. The share of pilots already beyond retirement age remains limited across all segments, although it is relatively higher in network and regional operations and lowest in LCC.

Overall, the results indicate moderate ageing across most business models, with demographic differences driven primarily by younger age structures in LCC rather than by an immediate, sector-wide retirement wave. These findings should be interpreted with some caution, as the underlying survey data are based on age bands rather than exact respondent ages, which limits the precision of the derived age metrics.

Cabin crew

This RA was not addressed through the survey questions targeting cabin crew.

3.1.2.2.12 Workforce shortages

Focuses on structural and perceived pressures affecting workforce availability, workload, and retention across the aviation system. Staffing shortages, high utilisation rates, and pronounced seasonal demand peaks can place sustained pressure on operational personnel and organisational resilience. This RA examines both objective indicators of workforce capacity and survey-based perceptions of workload and staffing adequacy, capturing potential mismatches between operational demand and available human resources. The KSIs that characterise the workforce shortages RA are listed below:

- **WS01 – National pilot availability index:** Ratio of active ATPL licences issued by the national aviation authority to total annual flight hours operated in the country.
- **WS02 – Perceived high utilisation rate:** Percentage of respondents who strongly agree that they operate consistently near their legal duty limits.

- **WS03 – Perceived staffing shortage:** Percentage of respondents who strongly agree that staffing levels are insufficient to manage daily workload safely and effectively.
- **WS04 – Average crew tenure:** Average length of time, in years, that crew members have been employed.
- **WS05 – Peak season demand ratio:** Ratio between flight hours in the busiest operational month and the average monthly flight hours for the year.

<u>Flight crew</u>

Figure 33 summarises the workforce shortages KSIs for flight crew.

	WS01					WS02					WS03				
N	-	-	-	-	-	125	283	1,236	1,516	197	117	253	1,159	1,403	187
Margin error	-	-	-	-	-	±8.1%	±4.6%	±2.7%	±1.9%	±6.0%	±7.6%	±5.2%	±2.7%	±1.6%	±5.9%

	WS04					WS05				
N	129	287	1,247	1,535	199	-	-	-	-	-
Margin error	±1.9y	±1.2y	±0.5y	±0.5y	±1.4y	-	-	-	-	-

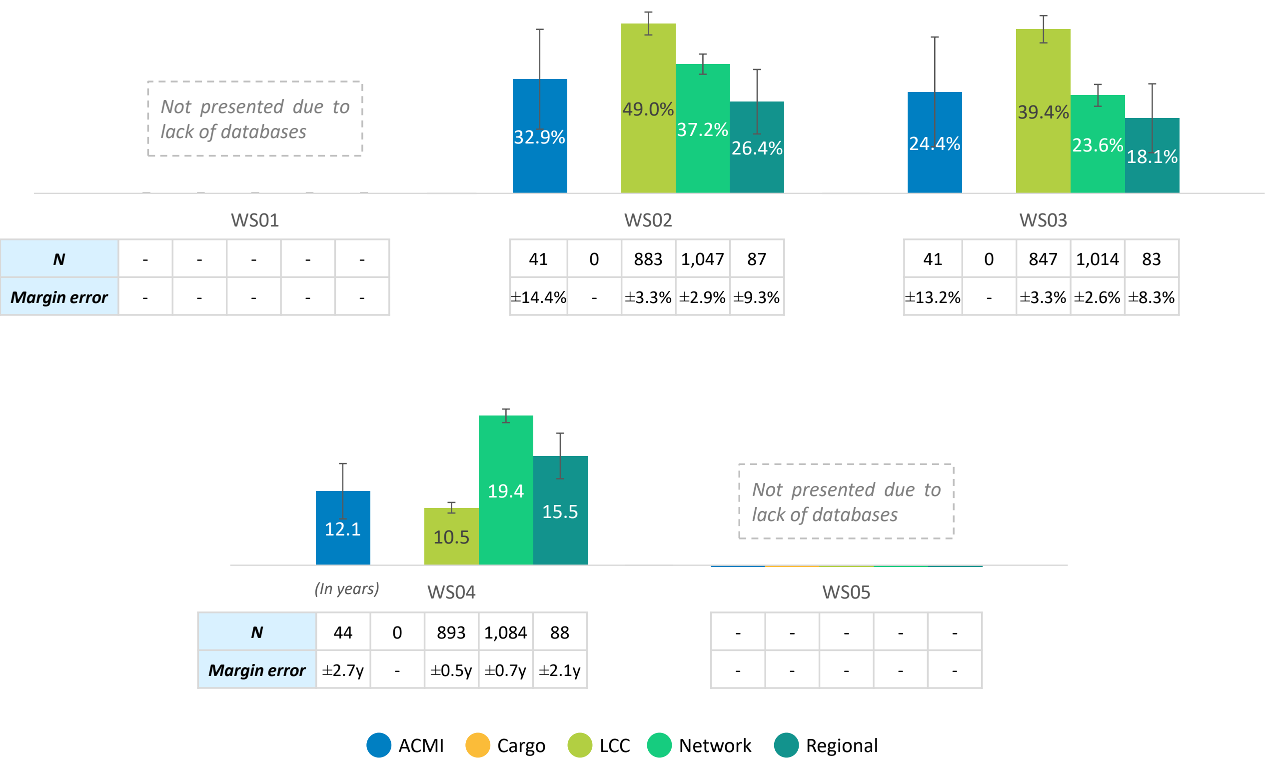
Figure 33: Workforce shortages - Flight crew KSI results

Workforce strain varies clearly across operational models. LCC and ACMI report the highest levels of perceived high utilisation and staffing shortages, while network operations consistently report lower workload pressure. Several of these differences are statistically significant, particularly between LCC and network, indicating that perceived workforce pressure is concentrated in specific business models rather than evenly spread across the sector.

Structural indicators support this pattern. LCC reports the lowest average crew tenure, while cargo and network combine longer tenure with lower perceived strain. ACMI occupies an intermediate position, with elevated pressure indicators but wider uncertainty. Overall, the findings point to a concentration of workforce strain in LCC and, to a lesser extent, ACMI operations.

Cabin crew

Figure 34 summarises the workforce shortages KSIs for cabin crew.



WS01

	ACMI	Cargo	LCC	Network	Regional
N	-	-	-	-	-
Margin error	-	-	-	-	-

WS02

	ACMI	Cargo	LCC	Network	Regional
N	41	0	883	1,047	87
Margin error	±14.4%	-	±3.3%	±2.9%	±9.3%

WS03

	ACMI	Cargo	LCC	Network	Regional
N	41	0	847	1,014	83
Margin error	±13.2%	-	±3.3%	±2.6%	±8.3%

WS04

	ACMI	Cargo	LCC	Network	Regional
N	44	0	893	1,084	88
Margin error	±2.7y	-	±0.5y	±0.7y	±2.1y

WS05

	ACMI	Cargo	LCC	Network	Regional
N	-	-	-	-	-
Margin error	-	-	-	-	-

Figure 34: Workforce shortages - Cabin crew KSI results

Workforce strain and staffing shortages among cabin crew are not evenly distributed across operational models. LCC operations consistently report the highest levels of sustained workload pressure and perceived understaffing, while also exhibiting the lowest average crew tenure, indicating a structurally more strained workforce environment. Network operations report relatively elevated utilisation pressure but combine this with substantially higher tenure and lower perceived staffing shortages, pointing to a more stable workforce structure despite high demand. ACMI and regional operations occupy intermediate positions, with more mixed signals and wider uncertainty associated with the margin of error.

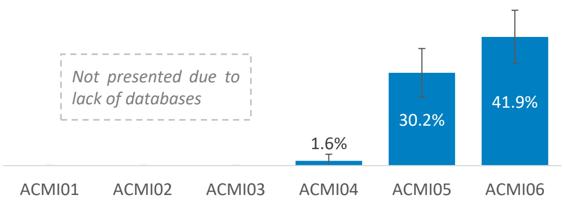
3.1.2.2.13 ACMI operations

Focuses on ACMI operations as a flexible operational model within the European aviation system. Its activity is characterised by high levels of operational variability, cross-border deployment and specific organisational and employment structures. This RA examines how ACMI-related operational pressure, reporting culture and employment arrangements may affect workforce wellbeing, stability and safety-related behaviours. The KSIs that characterise the ACMI operations RA are listed below:

- **ACMI01 – ACMI exposure ratio:** Percentage of flights operated under ACMI agreements.
- **ACMI02 – Fleet age exposure:** Average age of aircraft used in ACMI operations.
- **ACMI03 – Fleet mobility rate:** Percentage of aircraft in ACMI operations deployed across multiple regions or operators.
- **ACMI04 – ACMI wellbeing pressure index:** Percentage of ACMI respondents reporting that their workload has almost always exceeded their capacity to manage it effectively.
- **ACMI05 – ACMI reporting willingness ratio:** Percentage of ACMI respondents who strongly agree that they are not confident to report their own honest mistakes without fear of negative consequences.
- **ACMI06 – ACMI employment precarity index:** Percentage of ACMI respondents working under short-term, self-employed or pay-to-fly contracts.

Flight crew

Figure 35 summarises the ACMI KSIs for flight crew.



	ACMI01	ACMI02	ACMI03	ACMI04	ACMI05	ACMI06
N	-	-	-	129	129	124
Margin error	-	-	-	±2.13%	±7.9%	±8.7%

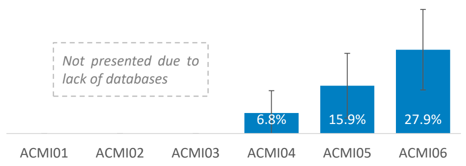
ACMI

Figure 35: ACMI operations - Flight crew KSIs results

Within ACMI operations, the survey results point to a specific workforce profile characterised by limited reporting of persistent workload pressure, alongside a substantial share of respondents reporting reduced confidence in safety reporting and operating under non-standard employment arrangements. However, the limited number of ACMI responses implies a high margin of error.

Cabin crew

Figure 36 summarises the ACMI KSIs for cabin crew.



N	-	-	-	44	44	43
Margin error	-	-	-	±7.5%	±10.8%	±13.4%

ACMI

Figure 36: ACMI operations - Cabin crew KSIs results

For cabin crew operating in ACMI environments, the results indicate moderate levels of reported workload pressure, alongside lower but still relevant levels of reduced confidence in safety reporting and employment precarity. Compared to flight crew, cabin crew report higher workload pressure but lower levels of reporting reluctance and non-standard employment arrangements. However, the limited number of ACMI responses implies a high margin of error.

3.1.3 Conclusions on the analysis of socio-economic factors and risk areas

The empirical characterisation of the Risk Areas provides a structured way to compare the survey results with the expectations set out in the literature review, by examining how the KSIs manifest across different operational environments. Because these quantitative indicators do not capture underlying socioeconomic mechanisms directly, they are used as proxies for the operational and organisational conditions through which those mechanisms may be reflected in safety relevant vulnerabilities. On this basis, the section contrasts the empirical patterns observed for each Risk Area with the mechanisms described in the literature for the corresponding Socioeconomic Factors, in order to identify where the quantitative evidence supports the initial mapping, where it adds context, and where it helps clarify the operational configurations in which socioeconomic pressures are most visible.

The overview that follows summarises the observed relationships between the literature mapping of Socioeconomic Factors to RAs and the survey based characterisation derived from the KSIs. The content is descriptive and should be interpreted within the scope and limitations of the sources used in the study. Overall, the KSI patterns tend to reinforce or contextualise the literature pathways by showing how socioeconomic conditions are reflected in measurable differences in operational and organisational arrangements across operator contexts, without implying causality. The summary is supported by, and should be read in conjunction with, the detailed findings presented in the sections below.

Across the five SEFs, the KSI-based patterns largely reinforce or contextualise the literature pathways by showing how socio-economic conditions are reflected in observable operational and organisational configurations.

- **Health and lifestyle** is most consistently mirrored through KSI signals linked to roster design and duty-time management, mobility and base stability, staffing buffers, and the operational use of flexibility tools, aligning with literature mechanisms that connect commercial and organisational pressures to fatigue, recovery capacity and day-to-day resilience.
- **Education in the context of Just Culture** is reflected primarily through differences in reporting-related perceptions across age/early-career groups and through variations in role clarity under fragmented or cross-operator settings, matching the literature emphasis on how Just Culture education is mediated by organisational boundaries and career-stage confidence in speaking up.
- **Work intensity, flexibility and uncertainty** is supported by KSI patterns indicating tighter planning margins and recurrent reliance on flexibility, which aligns with the literature framing of sustained tempo and reduced buffers as structural conditions that shape behavioural responses and fatigue management.
- **Resource constraints and labour-market dynamics** appear as multi-pathway influences, mainly driven by operational pressure, fragmented operational arrangements, early-career vulnerability, and staffing limitations, consistent with literature expectations that market and resourcing conditions embed pressure into routine operations rather than isolated events.
- **Employment and working conditions** are reflected through the distribution of non-standard contractual arrangements, geographic mobility, and organisational fragmentation, and their overlap with operational pressure and staffing buffers, which refines the literature mapping by indicating where contractual and organisational features coincide with the KSI-based exposure patterns.

3.1.3.1 Health and lifestyle

The empirical characterisation of health and lifestyle examines how the mechanisms identified in the literature manifest across the associated RAs.

In the domain of **Commercial Pressure**, quantitative data confirm the physiological strain described in theory. Scheduling management indicators reveal that a significant portion of the workforce, particularly within LCC and ACMI operators, operate closer to the regulatory flight and duty time limits. These findings support the premise that the pursuit of organizational efficiency may affect rest cycles, consolidating chronic fatigue as a measurable operational reality.

Consequently, these operational demands intersect with **Generational Risk Behaviour**, where workforce indicators highlight an experience gap that further stresses individual well-being capacity. Data suggest that in rapidly expanding regional and low-cost operators, the dilution of experience hinders the effective transmission of safety culture. Younger crews, though physically resilient, report higher levels of cognitive strain when operating in high-pressure environments. This lack of a protective structure shifts the safety burden onto the individual's psychological resilience, a burden often compounded by the instability of the employment itself.

This instability is further evidenced in **Crew Interoperability**, where Operational structures and business models play an important role in shaping these conditions. Business models characterised by higher workforce mobility, particularly in ACMI environments show greater exposure to relocation practices, temporary basing, and transient living arrangements, reflecting the operational flexibility inherent to this type of operation. Such arrangements may influence the continuity of personal routines and social support structures for some crew members, depending on individual circumstances and duration of deployment. In contrast, cargo and network operations generally report more stable employment patterns and lower exposure to relocation-related arrangements.

The strain of interoperability is often exacerbated by market dynamics, as observed in **Workforce Shortages** indicators, which reflect a structural erosion of well-being across the industry. Survey responses show perceived insufficient staffing levels and professional burnout, especially among LCC and ACMI operator groups. This tension translates into an increase in presentism, where crews feel driven to fill operational gaps despite compromised health, validating that labour market shortages not only affect availability but degrade individual safety margins by normalizing operations under suboptimal health conditions.

This culture is also captured in data regarding **Commander's Discretion Use**, which manifests as a routine tool for managing unexpected operational constraints. Records across various operator groups show that the commander's discretion to extend duty times is frequently used to compensate for staffing deficits or flight delays and knock-on disruptions, especially in ACMI and LCC. The unpredictability of these extensions may degrade long-term mental and social well-being, creating a systemic environment where physiological deterioration is accepted as a necessity for mission completion, effectively eroding the safety margins that discretion was intended to protect.

Regarding **Pilot Retirement Age**, workforce indicators primarily reveal the average age distribution across network and regional operators rather than specific health outcomes. While the available data does not allow for a direct cross-analysis between age and physiological decline, it confirms a structural reality: a significant portion of the workforce is approaching retirement while operating under high-productivity rosters.

Regarding **Go-Around Decisions**, the indicators highlight that some crews report direct pressure to avoid these manoeuvres. The data show that a significant portion of the workforce is concerned about the potential negative consequences or management scrutiny following a go-around. This empirical finding suggests that SEFs and organizational culture may distort risk perception, potentially inhibiting this critical safety action when personnel feel that commercial or operational expectations outweigh stabilized approach criteria.

Finally, the disruption of the personal life cycle is most clearly observed in **Homebase Changes**, confirmed as a potent disruptor of personal stability and health. Geographical mobility indicators show that a substantial majority of affected personnel, particularly in LCC and ACMI, where forced mobility may increase cumulative fatigue and psychological strain, establishing residential stability as a fundamental pillar of health and, consequently, of the overall resilience of the European aviation system.

In summary, the indicators confirm that current socio-economic trends are measurable pressure on Health and Lifestyle across the industry. Data shows that patterns such as roster instability, forced mobility, and systemic presenteeism may worsen crew health. Improving this SEF and safeguarding safety margins will therefore require a targeted reduction of these negative trends to ensure that commercial and organizational demands do not compromise the physiological and mental fitness required for safe operations.

3.1.3.2 Education in the context of Just Culture

The empirical characterisation of education in the context of Just Culture examines how the mechanisms identified in the literature manifest across the associated RAs.

In relation to **Crew Interoperability**, the survey results show to some extent that fragmented organisational environments challenge the practical application of Just Culture principles, particularly where crews lack routine exposure to cross-operator operations. Indicators related to operational clarity and reporting-related perceptions suggest that environments in which personnel are not accustomed to working across different organisational structures exhibit lower role clarity. This aligns with the literature's emphasis on the importance of clear accountability and stable organisational boundaries for education in Just Culture to translate into effective reporting behaviour.

A complementary alignment is observed for **Generational Risk Behaviour**, where the data reveal systematic differences in reporting-related perceptions across age cohorts. Younger personnel, particularly among cabin crew, report higher levels of perceived constraints when reporting their own mistakes, while these perceptions diminish progressively with age. This pattern is consistent with the literature-based argument that Just Culture education plays a critical role in mitigating hierarchical barriers and encouraging speaking up at early career stages.

Taken together, the empirical evidence points to generational dynamics as the clearest channel through which Education in the context of Just Culture manifests in practice. The quantitative results show that age, early career status and employment stability shape reporting confidence and safety communication.

3.1.3.3 Work intensity, flexibility, and uncertainty

The empirical characterisation of work intensity, flexibility, and uncertainty examines how the mechanisms identified in the literature manifest across the associated RAs.

In relation to **Commercial Pressure**, the quantitative results align with the literature-based depiction of intensified work demands and reduced planning buffers. Operational environments characterised by tighter scheduling margins and higher reliance on flexibility display patterns consistent with sustained work intensity and greater uncertainty in duty planning, especially in ACMI and LCC operator groups. These conditions suggest that flexibility is frequently used as a structural feature of operations rather than as an exception, reinforcing the literature's concern that commercial imperatives normalise high workload exposure.

Flowing from these pressures, a complementary alignment emerges in relation to **Go-Around Decisions**. While the empirical layer does not observe decision-making processes directly, the concentration of workload- and tempo-related signals in specific operational contexts supports the literature-based argument that elevated work intensity and uncertainty influence risk perception under time pressure.

A further alignment is observed for **Commander's Discretion Use**, where the quantitative results reflect the normalisation of flexibility mechanisms described in the literature. In operational contexts marked by demanding rosters and limited slack, discretion appears as a recurrent tool to absorb scheduling variability rather than an exceptional safeguard, especially in LCC and ACMI operator groups. This pattern supports the literature-based concern that persistent work intensity and uncertainty can weaken the protective intent of regulatory limits, shifting the management of fatigue and operational risk from organisational systems to individual crews.

Taken together, the empirical evidence suggests that work intensity, flexibility and uncertainty operate as structural conditions that shape both physiological strain and behavioural responses across operational contexts. The quantitative patterns do not contradict the theoretical pathways identified in the literature and instead provide contextual support for the relevance of Commercial Pressure, Go-Around Decisions and Pilot Discretion Use as key channels through which this SEF influences operational vulnerability.

3.1.3.4 Resource constraints and dynamics within the human resource market

The empirical characterisation of resource constraints and dynamics within the human resource market examines how the mechanisms identified in the literature manifest across the associated RAs.

In relation to **Commercial Pressure**, the empirical reflects how labour-market constraints and cost-driven resource allocation translate into tighter operational planning and scheduling environments. Operational contexts exposed to stronger market pressure display patterns consistent with constrained roster margins and frequent reliance on operational flexibility to maintain schedule integrity. These conditions align with the literature-based expectation that commercial objectives, when combined with limited staffing availability, embed pressure directly into day-to-day operations rather than appearing as episodic stressors. As a result, workload intensity and reduced planning buffers emerge as systemic features of certain business models (ACMI and LCC) reinforcing the role of commercial pressure as a mechanism through which resource constraints shape operational behaviour and risk exposure.

A complementary alignment emerges in relation to Crew Interoperability. The empirical results indicate that organisational fragmentation and cross-operator arrangements are associated with reduced clarity of roles and weaker integration of safety practices. This supports the literature-based argument that resource constraints encourage reliance on fragmented operational structures, which in turn complicate accountability.

The interaction between labour-market dynamics and **Generational Risk Behaviour** is also reflected in the quantitative evidence. Early career stages show greater exposure to employment instability and associated vulnerability, while more experienced cohorts display relatively greater contractual security. This pattern is consistent with the literature's emphasis on how economic vulnerability among younger personnel suppresses reporting behaviour and reinforces presenteeism, particularly in contexts characterised by high turnover and limited mentoring capacity.

A further alignment is observed in relation to **Workforce Shortages**, where the empirical characterisation reflects the structural pressures described in the literature. Indicators point to staffing constraints that compress operational buffers and increase reliance on minimum staffing configurations, limiting organisational resilience to disruption.

Finally, the empirical patterns associated with the **ACMI** operating context reflect the labour-market dynamics highlighted in the literature. Operational environments characterised by demand volatility and reliance on wet-leasing exhibit features consistent with employment instability. These conditions align with the literature's emphasis on the challenges of integrating oversight, safety management and reporting practices across lessor and lessee structures, as well as the cumulative fatigue and reduced stability experienced by personnel operating under temporary or mobile arrangements.

Taken together, the empirical evidence suggests that resource constraints and labour-market dynamics manifest through multiple, interrelated pathways rather than a single dominant mechanism. The quantitative patterns do not contradict the theoretical expectations identified in the literature and instead provide contextual support.

3.1.3.5 Employment and working conditions

In relation to Atypical Contracts, the quantitative results reflect differentiated exposure to non-standard employment arrangements across operational environments. Indicators related to contract type and employment status point to a concentration of atypical arrangements in specific segments (ACMI and LCC). These patterns support the interpretation that non-standard employment structures remain a salient feature of certain operational models, shaping the context in which personnel assess the personal and professional consequences of reporting fatigue, unfitness or safety concerns.

A complementary alignment emerges when considering **commercial pressure**, where employment conditions interact with operational demands. The empirical evidence indicates that environments characterised by tighter rostering and higher operational pressure often coincide with less stable employment configurations. This overlap is consistent with the literature-based concern that degraded working conditions amplify vulnerability to operational pressure, reinforcing incentives for presenteeism and limiting individual margins to manage fatigue or uncertainty without perceived employment risk.

The influence of employment conditions is further reflected in **Crew Interoperability**. Survey responses associated with cross-operator arrangements and fragmented organisational structures indicate that personnel operating across different organisational and contractual environments may experience differing perceptions regarding operational coordination, communication channels and reporting pathways. These findings should be interpreted as reflecting operational complexity within certain multi-operator or cross-border environments, rather than indicating that specific contractual arrangements inherently result in unclear roles or responsibilities.

A further alignment is observed in relation to **Homebase Changes**, where the empirical characterisation highlights the prevalence of geographically mobile employment arrangements in specific operational contexts. Indicators capturing base instability and mobility point to employment configurations in which predictability of duty location and access to stable routines are reduced.

The quantitative results also reflect the mechanisms described under **Workforce Shortages**. Indicators associated with staffing availability and turnover suggest that certain operational environments operate with limited personnel buffers. This aligns with the literature's depiction of shortages as a structural feature that intensifies workload, constrains rest opportunities and increases reliance on remaining personnel, thereby reinforcing the interaction between employment conditions and operational resilience.

Finally, the empirical patterns associated with the **ACMI** operating model provide contextual support for observations identified in the literature review concerning the operational and organisational characteristics of wet-lease environments. Indicators reflecting cross-border operations and wet-lease arrangements point to operating contexts characterised by higher levels of organisational interface, workforce mobility and employment transience, which are inherent features of the ACMI business model. The literature reviewed in Annex C identifies that such operational configurations may require enhanced coordination across lessor and lessee structures, particularly with regard to communication processes, allocation of responsibilities and the integration of safety management and oversight functions across organisational boundaries.

Taken together, the empirical evidence suggests that Employment and Working Conditions manifest through multiple, interlinked RAs rather than a single dominant pathway. The quantitative results do not contradict the theoretical expectations identified in the literature and instead refine the initial mapping by indicating how contractual arrangements, employment stability and organisational fragmentation shape the operational context in which safety-related behaviour occurs.

3.2 Analysis on risk areas and safety precursors

The relationships between operational RAs and SPs are examined through an approach that distinguishes between literature-based interpretation, empirical evidence, and analytical synthesis. The content is organised into three complementary components interpreting how risk conditions may connect to safety-relevant mechanisms observable in operational practice.

First, the section presents a review of relevant literature to outline conceptual linkages between selected RAs and SPs. This initial step establishes a baseline describing how operational risk conditions have been discussed in existing research and safety practice as being associated with human and organisational precursor mechanisms. The literature reviewed is not exhaustive, and the associations presented reflect the authors' interpretation of prior studies. This material is provided for contextual purposes and does not constitute validated conclusions.

Second, the section introduces the empirical characterisation of SPs based on the available evidence from occurrence reporting and related operational information. This analysis examines how precursor-related signals appear in reported events, how they evolve over time, and how they vary across operational contexts. This step represents the core analytical component of the section and provides the data-driven basis for subsequent interpretation, while explicitly recognising that reporting data may reflect both operational reality and reporting practices.

Third, the section concludes with a synthesis of the main analytical conclusions, consolidating the key empirical patterns identified across the analysis and highlighting the most consistent signals emerging from the evidence base.

3.2.1 Relations between Risk areas and Safety precursors

The relationships between operational Risk Areas (RAs) and Safety Precursors (SPs) are assessed using a structured approach combining literature-based interpretation, empirical evidence from survey and occurrence data, and analytical synthesis across the different evidence streams. The purpose of this subsection is not to validate causal mechanisms or present conclusions, but to establish a baseline describing how specific RAs have been associated in the literature with human performance and organisational precursors relevant to aviation safety.

The literature reviewed is extensive but not exhaustive, and the interpretations presented reflect the authors' synthesis of existing sources. The associations described should therefore be understood as informative and contextual and do not constitute the conclusions of the analysis. Rather, they provide a reference framework against which the findings derived from the Safety Performance Indicators (SPIs) are compared in later sections.

A key limitation of the study is that it does not provide a direct empirical demonstration of RA to SP linkages. The available data allow the empirical characterisation of SPs through SPI based analyses, but they do not enable the consistent, one to one attribution of observed precursor patterns to specific upstream RAs.

The subsection is organised by RA, summarising how each has been discussed in the literature in relation to a set of SPs. This narrative approach supports the later data driven characterisation of SPs by clarifying the theoretical pathways through which RA conditions may be reflected in safety critical performance.

To improve transparency, the RA to SP relationships identified in the literature review are summarised through an RA to SP mapping matrix. This mapping is interpretative and non-exhaustive and is intended as a contextual baseline describing how each Risk Area has been associated in the literature with human performance and organisational precursors. These literature-based relationships are subsequently contrasted with the SPI based characterisation of Safety Precursors presented in later sections. In the mapping matrix, Fraud risk is not mapped, as the literature reviewed did not provide prior evidence supporting a linkage to the Safety Precursors considered in this study.

Table 5: Mapping of RAs to SPs.

Risk Area	Fatigue	Workload	Stress	Pressure	Complacency	Norms	Distraction	Lack of comm-	Lack of assertiveness	Lack of awareness	Lack of knowledge	Lack of teamwork	Lack of resources
Pilot retirement age		•								•			
Homebase changes	•		•				•						
Crew interoperability								•	•				
Atypical contracts	•	•	•	•							•		
Workforce shortages	•	•	•										•
ACMI operations	•		•			•		•		•	•		
Generational risk behaviour		•	•				•			•			
Commercial pressure	•	•	•	•		•							
Fuel management		•											
Go-around decisions	•				•	•			•	•		•	
Pilot discretion use	•		•	•	•								

Fraud risk													

3.2.1.1 Atypical Contracts

The literature reviewed in Annex C identifies that atypical employment models, including bogus self-employment, agency-mediated hiring and pay-to-fly arrangements, may create conditions associated with reduced employment stability, increased contractual complexity and less clear allocation of organisational responsibilities. Several reviewed studies further indicate that these arrangements can influence reporting behaviour, perceptions of organisational support and broader safety culture dimensions, thereby contributing to latent operational vulnerabilities across multiple safety precursors.

Across sources, **fatigue** appears as a core vulnerability: while business models dependent on atypical contracts frequently schedule duties at the upper legal limits, contributing to cumulative exhaustion and microsleeps. In parallel, **Lack of Knowledge** is cited where temporary or pay-to-fly personnel receive less structured or recurrent training, entering operations with limited experience and fewer opportunities to consolidate essential competencies.

Workload is also intensified under these models, with high aircraft utilisation, dense rosters and unpredictable standby duties generating sustained task saturation. Frequent changes of base or temporary postings introduce additional logistical and cognitive load. Literature further highlights that atypical contracting amplifies **pressure**, as fear of losing income or flying hours discourages refusal of unsafe duties, open communication or assertion of professional judgement. This dynamic suppresses hazard reporting and reinforces "pilot pushing."

Finally, **stress** is described as a chronic background condition for crews in precarious employment. Financial volatility, debt from training routes such as pay-to-fly, and confusion over tax and social-security obligations contribute to heightened anxiety, reduced job satisfaction and a sense of being peripheral to the organisation. These factors degrade mental well-being and reduce the cognitive margin required for effective operational performance.

Overall, the literature portrays atypical contracting as a multidimensional erosion of the safety environment, characterised by fatigue, reduced competence, task overload, coercive pressure and chronic stress. While extensive, this evidence base is not exhaustive, and the findings should be viewed as a structured interpretation of patterns identified across published studies. They provide a clear conceptual signal of how employment precarity can act as a latent driver of safety risk through its influence on human-performance precursors.

3.2.1.2 Commercial pressure

The literature portrays commercial pressure as a systemic force that reshapes operational behaviours, organisational norms and individual decision-making in ways that can erode safety margins. When financial or performance objectives dominate, crews face an environment in which speed, efficiency and on-time execution are implicitly valued above thoroughness, recovery and reflective judgement. These findings emerge from a broad, albeit not exhaustive, body of research, and serve as an informed conceptual baseline pending comparison with other lines of evidence in the wider study.

A second pattern relates to **fatigue**, which is structurally embedded in cost-driven operating models. Literature shows how carriers seeking maximal aircraft utilisation commonly roster crews up to the legal limits, treating Flight Time Limitations as performance thresholds rather than safety safeguards. The resulting accumulation of exhaustion amplifies the risk of microsleeps, reduces situational awareness and fosters “pilot pushing,” whereby crews feel compelled to fly despite clear signs of fatigue in order to maintain schedule integrity.

Commercial imperatives also drive significant levels of **stress** among aviation personnel. The tension between safety obligations and financial performance is shown to create environments where crews fear that reporting hazards or declaring unfitness may jeopardise future opportunities or financial stability. This chronic economic and organisational pressure contributes to heightened anxiety, emotional strain and depressive symptoms, weakening the psychological resilience required for high-stakes decision-making.

In parallel, literature highlights the emergence of distorted **norms** through “practical drift.” Under sustained commercial pressure, local workarounds, such as skipping minor checks to avoid delays, begin as isolated deviations but gradually become routine and eventually normalised. This shift erodes procedural integrity, blurs the boundary between compliance and expediency, and fosters organisational cultures where safety deviations are tacitly tolerated as long as commercial targets are met.

A further and closely related precursor is **pressure** itself. Financially driven expectations lead to an “Efficiency-Thoroughness Trade-Off” in which crews feel silently evaluated on their ability to prioritise timeliness over adherence to safety procedures. This dynamic manifests in press-on-itis, notably in critical phases of flight such as unstable approaches, where crews may attempt to complete the flight rather than initiate a go-around due to concerns about delays, fuel usage or operational repercussions.

Lastly, literature associates commercial pressure with high levels of **workload**. Cost-reduction strategies often result in lean staffing, fewer operational buffers and compressed turnaround times. These conditions increase mental and physical load, elevate task saturation and reduce the margin for error during high-intensity operations. Crews may also be required to perform additional duties beyond their core safety functions, further stretching human performance limits.

Overall, the literature depicts commercial pressure as a multifaceted driver of human-factor degradation, shaping patterns of complacency, accumulated fatigue, chronic stress, procedural erosion, coercive pressure and excessive workload. Together, these mechanisms illustrate how prioritising operational output over human performance can distort safety-critical decisions, influence behavioural norms and weaken the organisational foundations of safe flight operations.

3.2.1.3 Crew interoperability

The literature indicates that crew interoperability, particularly in multi-AOC operator groups or wet-lease structures, creates an operational environment marked by fragmented oversight, unequal employment conditions and potential inconsistencies in procedures. These structural characteristics might affect how crews communicate, coordinate and assert themselves in safety-critical situations. Although the evidence reviewed is extensive, it is not exhaustive; the insights presented here therefore serve as an informed conceptual baseline rather than a definitive account of all possible dynamics.

A recurring theme across the literature concerns **lack of assertiveness**, which becomes markedly amplified when crew members work under atypical employment arrangements or within fragmented organisational structures. Temporary or agency-hired personnel frequently describe a "culture of fear," shaped by job insecurity, fear of contract non-renewal and concerns about reduced flying hours. This environment inhibits their willingness to challenge decisions, refuse unsafe duty extensions or report fatigue. The problem is magnified in mixed-crew operations where steep authority gradients, often between senior flight crew and junior cabin crew, especially when the latter are externally contracted, deter lower-ranking personnel from speaking up, even when clear safety risks are present. In such contexts, financial dependency linked to zero-hour or pay-to-fly models further reduces assertiveness, as the fear of income loss overrides professional judgement and the obligation to self-declare unfitness to fly.

Closely related with diminished assertiveness is **lack of communication**, which the literature identifies as a systemic issue in interoperable operations. Crews deployed across different AOCs frequently encounter inconsistent Standard Operating Procedures, variations in aircraft configuration or terminology, and ambiguity regarding the chain of command. These discrepancies weaken the formation of shared mental models and hinder coordinated decision-making. Communication challenges are exacerbated by the lack of joint training opportunities and limited face-to-face interactions in multi-operator environments, preventing crews from developing trust or familiarity prior to flight. As a result, essential safety information may be misunderstood or omitted, particularly in time-critical situations where seamless coordination is required.

Overall, literature portrays crew interoperability as a structural condition that undermines the interpersonal dynamics and procedural cohesion necessary for safe operations. Reduced assertiveness, fractured communication pathways and inconsistent operating standards collectively weaken team coordination and the crew's ability to detect, escalate and manage risks. These insights provide a clear conceptual narrative of how interoperability, when driven by cost and flexibility demands rather than safety alignment, can erode foundational human-factor protections within the operational environment.

3.2.1.4 Fraud risk

The literature reviewed for this study did not identify any relevant or sufficiently robust sources explicitly linking fraud risk (e.g., falsification of records, training documentation, duty logs, or related oversight circumvention) to the set of Safety Precursors considered in the study. Therefore, no literature-based conceptual linkage is reported here, and Fraud risk remains unmapped.

3.2.1.5 Fuel management

The literature identifies fuel management as a safety-critical task in which workload plays a decisive role in shaping planning accuracy and monitoring performance. Because fuel decisions depend on sustained cognitive attention, any fluctuation in workload, can degrade the crew's ability to manage fuel reliably during operations.

Workload plays a recurrent role in degrading fuel-management performance. High workload and fatigue undermine the cognitive capacity required to validate load sheets, interpret trajectory-based predictions and monitor in-flight consumption trends. Under task saturation, crews may miss deviations between planned and actual fuel burn or mishandle energy states during critical phases. Conversely, operational underload on long, highly automated segments reduces engagement and increases the likelihood of missed fuel-progression checks. Time pressure during turnarounds also encourages procedural shortcuts, including truncated verification steps that are designed to prevent fuel-related errors.

Overall, the evidence shows that workload fluctuations create latent conditions that weaken the robustness of fuel-planning and monitoring processes. While not exhaustive, these findings offer a structured interpretation of how workload alone can act as an underlying driver of fuel-related safety risk.

3.2.1.6 Go-around decisions

The literature portrays go-around decision-making as a critical safety domain in which reluctance or delay to initiate a missed approach amplifies the risk of unstable approaches and unsafe landings. Evidence shows that this reluctance is shaped by multiple human-performance precursors that collectively erode adherence to stabilisation criteria during the most vulnerable phase of flight.

Across sources, **Complacency** emerges as a core vulnerability. Overconfidence in the ability to "salvage" an unstable approach leads pilots to discount formal stability gates and rely on past success rather than procedural thresholds. Automation-induced disengagement further delays the recognition of unsafe energy states, while the absence of recent negative consequences reinforces a belief that continuing is acceptable, prioritising completion of the landing over the required go-around action.

Fatigue is also identified as a recurrent determinant. The transition from monitoring to active manoeuvring inherent in a go-around demands cognitive resources that fatigued crews struggle to mobilise. Degradation of executive functions increases plan-continuation bias, slowing recognition of deviations and reducing the likelihood that crews will challenge the intention to land. High Time Since Awake correlates with errors of omission that further delay the decision.

A **Lack of Assertiveness** particularly affects the Pilot Monitoring, who may hesitate to challenge a Captain continuing an unstabilised approach. High authority gradients, fear of criticism and organisational cultures lacking a non-punitive stance on go-arounds suppress necessary interventions. In such environments, initiating a go-around may be perceived as a personal failure, causing critical safety callouts to remain unspoken.

In parallel, **Lack of Awareness** undermines the crew's ability to detect when the approach can no longer be stabilised. Reduced anticipatory and functional awareness leads pilots to miss cues related to speed, sink rate or flight-path deviations, often due to fixation, distraction or cognitive overload. This not only delays the decision to go around but also increases the risk of poor execution when it is eventually commanded, particularly if the crew lacks awareness of the spatial challenges inherent to the manoeuvre.

Lack of Teamwork further degrades decision-making. A breakdown in shared situational awareness or unclear role distribution weakens monitoring performance and communication. Silence is frequently misinterpreted as agreement to continue rather than a lapse in coordination. Inadequate go-around briefings leave crews unprepared to respond cohesively when unexpected threats emerge.

Finally, **Norms** play a decisive role. A "normalization of deviance" is widely documented, with data indicating that the vast majority of unstable approaches are continued to landing. Informal cockpit practices, such as personal thresholds for stabilisation, supplant formal SOPs, reinforced by peer behaviour and the absence of negative outcomes. Over time, these deviations become embedded cultural expectations, systematically weakening the procedural barrier intended to mandate a go-around.

Overall, the literature depicts go-around reluctance as a multidimensional erosion of safety margins shaped by complacency, fatigue, reduced assertiveness, degraded awareness, poor teamwork and procedural drift. While not exhaustive, these findings offer a structured interpretation of how human-performance precursors converge to delay or suppress the go-around decision during the most safety-critical moments of flight.

3.2.1.7 Generational risk behaviour

The literature frames generational risk behaviour as a growing safety concern shaped by evolving lifestyle patterns, shifting cultural expectations and heterogeneous attitudes toward work-life boundaries, risk perception and personal well-being. These factors influence how crew members allocate attention, interpret operational cues and regulate workload, creating distinct vulnerabilities across demographic groups.

Across studies, **Distraction** emerges as a central precursor. Changing lifestyle norms and the erosion of boundaries between personal and professional life create persistent cognitive intrusion, where family, social commitments or digital connectivity compete with safety-critical monitoring. Crews struggling to maintain a “normal life” within irregular rosters experience reduced mental detachment during duty periods, sustaining an internal distraction load. Layover cultures built around “work hard, play hard” dynamics further diminish restorative downtime, leading to a physiological state in which individuals are present but not fully engaged. Emotional dysregulation amplifies this vulnerability by making attention more susceptible to internal emotional cues than to operational demands.

Generational patterns also shape **Lack of Awareness** through divergent mechanisms of overconfidence and inexperience. Older pilots with extensive flight hours may develop an overconfidence bias, underestimating risks or overestimating personal mastery, which blunts recognition of deteriorating conditions. In contrast, younger or less experienced pilots often struggle with accurate situation evaluation due to limited experiential knowledge, increasing the likelihood of judgment errors. Both groups may exhibit weaker perceptions of “just culture,” with younger and older employees showing less faith in reporting structures and systemic safety nets than mid-career colleagues, reducing awareness of how their actions fit within the organisation’s broader risk-management ecosystem.

Stress is also intensified by generational and cultural shifts, particularly in relation to financial precarity and emotional regulation. Younger crew members frequently face unstable contracts, high training debts and limited career predictability, producing chronic psychosocial stress that undermines mental well-being. This cohort displays elevated vulnerability to depression and anxiety, partly linked to work-related uncertainty. At the same time, individual differences in emotional regulation and coping strategies can magnify stress responses across age groups; pilots with avoidant or dysregulated coping styles experience reduced self-confidence and heightened psychological strain, limiting the cognitive margin needed for safe operational performance.

Finally, **Workload** is influenced by both age-related cognitive changes and lifestyle-driven fatigue. Older pilots may experience declines in processing speed and fluid reasoning, making complex or novel tasks disproportionately demanding despite strong crystallised experience; high-intensity situations can therefore generate cognitive overload. Younger pilots, conversely, often report higher baseline fatigue driven by lifestyle demands, social pressures and insufficient recovery, reducing their physiological capacity to handle operational workload. Additionally, industry cultures that normalise "pilot pushing" expose crews of all ages to excessive duty hours, compressing rest opportunities and pushing human-performance limits.

Overall, the literature depicts generational risk behaviour as a multifaceted erosion of safety margins arising from distraction, uneven situational awareness, psychosocial stress and workload vulnerabilities. These precursors interact with cultural norms, lifestyle patterns and employment conditions to shape how different cohorts perceive and manage operational risk. While not exhaustive, this evidence base provides a structured interpretation of how generational and cultural dynamics act as latent drivers of safety-critical behaviours across the aviation workforce.

3.2.1.8 Homebase changes

The literature portrays homebase changes as a significant operational stressor that undermines crew stability, performance and decision-making. Frequent or insufficiently managed relocations disrupt the predictability and personal continuity that aviation professionals rely on to sustain cognitive readiness, generating a constellation of human-performance precursors that degrade safety margins.

Across sources, **Distraction** emerges as a primary vulnerability. Forced mobility creates persistent external distraction as crews must continuously navigate the logistical complexity of living in one location while operating from another. The mental load associated with long-distance commuting, arranging temporary accommodation, and managing shifting travel schedules competes directly with attention needed for safety-critical tasks. Internal distraction is similarly amplified: feelings of loneliness, disconnection from support networks, and the inability to attend family events become intrusive mental preoccupations during duty periods. Administrative uncertainties further fracture attentional focus, reducing the cognitive bandwidth available for flight preparation.

Fatigue is also substantially intensified by base misalignment. Extended commuting inflates Time Since Awake before duty, often without being captured by formal duty-time regulations, creating a silent fatigue risk pathway. Historical cases, such as the Colgan Air 3407 accident, underscore the severe performance impairment associated with extreme commuting. Additionally, long-term outstation assignments and hotel-based living diminish sleep quality by depriving crew members of the restorative consistency of a familiar rest environment. Early wakeups required to accommodate travel from temporary accommodation further compress sleep opportunities, reinforcing chronic sleep debt and increasing reliance on fragmented rest strategies that fail to fully restore alertness.

In parallel, **Stress** is structurally embedded in the experience of forced mobility. Employment arrangements that allow operators to unilaterally reassign bases generate chronic uncertainty, eroding pilots' sense of control over their personal and professional lives. This instability complicates long-term planning, weakens family and social support structures, and fosters ongoing anxiety about future relocation demands. Financial and logistical pressures act as persistent psychosocial stressors that degrade mental well-being. Over time, these cumulative pressures heighten irritability, emotional exhaustion and reduced resilience, all of which impair decision-making during operational tasks.

Overall, the literature describes homebase changes as a multidimensional erosion of operational readiness, driven by distraction, fatigue and chronic stress. These precursors interact with lifestyle disruption, financial strain and organisational mobility policies to undermine cognitive stability and weaken safety-critical decisions. While not exhaustive, this evidence provides a structured interpretation of how poorly managed relocations act as latent drivers of human-performance degradation across the aviation system.

3.2.1.9 Pilot discretion use

The literature frames the recurrent use of pilot discretion as a structural erosion of fatigue-management safeguards, where operators increasingly rely on Commander's Discretion (CD) to preserve schedule integrity rather than to manage unforeseen contingencies. This practice masks deeper systemic issues—such as insufficient standby coverage, inadequate roster buffers and persistent operational delays—and shifts responsibility for operational continuity from organisational planning to individual pilots, creating multiple human-performance vulnerabilities.

Across sources, **Complacency** emerges as a central precursor. When CD becomes a routine operational tool rather than a last-resort measure, crews and operators alike begin to accept deviation from regulated duty limits as normal. High reported rates of discretionary extensions indicate a drift toward a "normalization of deviance," where continued operational success despite eroded safety margins reinforces the belief that extending duty is benign. This creates a false sense of reliability in which prudent planning and sufficient staffing are deprioritised, as organisations implicitly rely on pilots to absorb systemic inefficiencies through discretionary extensions.

In parallel, **Fatigue** is directly amplified by this reliance. By design, CD permits flight crews to exceed scientifically derived duty limits intended to protect alertness and cognitive function. Rosters built to the maximum legal thresholds leave little margin for disruption, meaning even minor delays trigger duty extensions that push crews into zones of high fatigue and into the Window of Circadian Low. Pilots describe the decision to extend as a "bet on the future," where the true physiological capacity to maintain performance is uncertain. Over repeated cycles, systemic dependence on CD accelerates cumulative fatigue, increasing vulnerability to lapses in attention and degraded performance during safety-critical phases.

Pressure is also a significant driver of discretion use. Survey data demonstrate widespread fear of organisational consequences when refusing to extend duties, particularly among pilots in precarious employment conditions. This environment of implicit coercion leads crews to accept extensions to avoid being viewed as uncooperative or risking negative repercussions. In jurisdictions where this pressure is most acute, pilots report feeling compelled to prioritise commercial imperatives over regulated fatigue protections, contradicting the regulatory requirement for a non-punitive decision environment.

Finally, **Stress** is structurally embedded in the exercise of discretion. The burden of determining whether operational continuation remains safe falls disproportionately on the commander, who must balance disrupted schedules, passenger expectations and crew fitness without adequate organisational support or buffer capacity. This decision context produces significant anxiety and cognitive strain, particularly when pilots fear post-event scrutiny or disciplinary action. The emotional load associated with these high-stakes judgments depletes the cognitive resources needed for effective communication, coordination and decision-making during extended duty periods.

Overall, the literature depicts pilot discretion use as a multidimensional degradation of the fatigue-risk-management ecosystem. Complacency, fatigue, pressure and stress converge to normalise extensions, obscure systemic planning failures and place disproportionate responsibility on individuals to sustain operational continuity. While not exhaustive, these findings provide a structured interpretation of how recurrent discretion use functions as a latent driver of safety risk by pushing crew performance beyond the boundaries intended by regulatory protections.

3.2.1.10 Pilot retirement age

The literature frames the extension of the pilot retirement age beyond 65 as a safety-relevant policy shift that introduces risks when not accompanied by robust provisions for health monitoring, cognitive assessment and transition planning. While older pilots possess extensive experience and strong crystallised knowledge, evidence suggests that age-related cognitive and physiological changes create vulnerabilities that require careful management to avoid degradation of performance in dynamic or high-workload environments.

Across sources, **Lack of Awareness** emerges as a key precursor. Aging is consistently associated with declines in fluid intelligence, working memory and perceptual-motor speed, abilities essential for processing novel information, integrating changing cues and maintaining situational awareness under time pressure. Although experience can compensate during routine operations, research shows that older pilots exhibit slower information-processing rates and reduced visual-spatial capacity, which delay hazard recognition and weaken monitoring of automated systems. Moreover, age-related reductions in cognitive inhibition make it more difficult to filter irrelevant inputs or discard outdated procedural habits, potentially distorting the pilot's mental model of the operational environment during rapidly evolving situations.

In parallel, **Workload** management becomes more challenging with aging due to a natural reduction in cognitive "processing resources." While accumulated experience improves efficiency in familiar tasks, older pilots display increased susceptibility to overload when confronted with novel, high-intensity or multitasking demands. Literature highlights that declines in executive function, including planning and task-switching abilities, can lead to rushed actions, missed steps or errors of omission when operational tempo accelerates. Conditions described as "progressive dysexecutive tendencies" further complicate performance in complex scenarios, increasing the risk that older pilots may shed tasks or struggle to manage competing demands during critical phases of flight.

Overall, the literature depicts retirement-age extension as a RA where cognitive aging, workload vulnerability and reduced inhibitory control intersect. Experience remains an invaluable asset, but without updated medical screening, tailored workload strategies and structured transition pathways, extending retirement age can introduce latent safety risks. While not exhaustive, these findings provide a structured interpretation of how age-related cognitive changes interact with operational demands, underscoring the need for evidence-based safeguards when adjusting retirement policies.

3.2.1.11 ACMI operations

The literature depicts ACMI operations as a structurally distinct segment of the aviation industry, where global fleet mobility, lean staffing models and older aircraft create a unique operational ecosystem with specific safety vulnerabilities. The wet-lease model, built around high utilisation and rapid deployment across diverse regulatory and cultural environments, introduces a series of human-performance precursors that can erode resilience when not adequately mitigated.

Across sources, **Fatigue** emerges as a principal precursor. ACMI crews frequently operate from long-term outstations, living for extended periods in airport hotels that limit psychological detachment and disrupt the restorative routines associated with home-base rest. This environment creates a "structural fatigue trap," where accumulated tiredness develops beneath regulatory thresholds and is exacerbated during high-demand leasing periods such as summer peaks. The business model's dependence on intense aircraft utilisation further compresses duty margins, often pushing crews toward chronic sleep restriction and high levels of cumulative fatigue.

Stress is also consistently reported as a defining feature of ACMI employment conditions. Long-term separation from family networks and the social isolation of outstation life undermine emotional well-being and weaken resilience. The precarious nature of ACMI contracts contributes to heightened anxiety about career stability and organisational support. Pilots in these arrangements often describe a sense of detachment both from the home organisation and from the host airline, creating chronic psychosocial stress that diminishes coping capacity during operational tasks.

The wet-lease model also fosters hazardous **Norms** due to the operational interface between two organisational cultures. When the lessor and lessee apply different interpretations of crew duty limits, maintenance cycles or operational procedures, informal workarounds may emerge to reconcile inconsistencies. Over time, these adaptations can drift from formal SOPs, creating a normalization of deviance. Moreover, fear of jeopardising contract renewal or personal employment status may inhibit fatigue reporting, suppressing critical safety signals in an environment where regulatory definitions may not fully reflect the lived experience of ACMI crews.

Lack of Awareness becomes a systemic risk due to fragmented safety-data flows. Lessees often operate without access to the lessor's OFDM outputs, incident data or trend analyses, creating a structural blind spot in their Safety Management Systems. This information asymmetry prevents the host airline from forming an accurate picture of operational risk, delaying the recognition of emerging patterns until disruptions or incidents highlight unseen vulnerabilities.

In parallel, **Lack of Knowledge** arises from operational mismatches between crews and the environments in which they are deployed. Although technically qualified, ACMI crews may face unfamiliar aircraft configurations, equipment layouts or cabin procedures compared to the lessee's standard operations, increasing the likelihood of workflow errors. Local route knowledge may also be insufficiently consolidated during pre-deployment, leaving crews without the contextual understanding needed to anticipate local operational risks.

Finally, **Lack of Communication** is amplified by the interaction of different corporate, national and linguistic cultures. Divergent CRM philosophies, inconsistent terminology and language barriers between wet-lease flight crews, cabin crews and ground staff complicate coordination during time-critical situations. Ambiguity regarding operational control responsibilities between the lessor and lessee further slows the transmission of safety-critical information, creating delays or gaps in collective situational understanding.

Overall, the literature portrays ACMI operations as a high-variability environment where fatigue, stress, hazardous norms, gaps in awareness, limited contextual knowledge and communication breakdowns intersect. These precursors arise from structural characteristics of the wet-lease model and function as latent drivers of reduced operational resilience. While not exhaustive, these findings offer a structured interpretation of the safety challenges inherent to ACMI operations and highlight the need for strengthened oversight, harmonised procedures and robust support systems for mobile crews.

3.2.1.12 Workforce shortages

The literature portrays workforce shortages as a systemic stressor that weakens operational resilience and amplifies human-performance vulnerabilities across airline operations. When staffing levels fall below operational needs, crews are repeatedly required to work at the edge of regulatory limits, creating conditions in which fatigue, resource deficits, stress and elevated workload converge to undermine safety performance.

Across sources, **Fatigue** emerges as a central precursor. Airlines operating with minimum or short-crewed complements frequently assign duty periods at the maximum Flight Time Limitations, which leaves crews with insufficient rest opportunities between shifts. The lack of staffing buffers means that sickness, delays or seasonal demand force remaining personnel to absorb additional duties, accelerating cumulative exhaustion. Research consistently links chronic understaffing with increased wakefulness before duty, reduced restorative rest and a higher likelihood of in-flight microsleeps and degraded performance during critical phases.

Lack of Resources further undermines operational reliability. Shortages of ground handlers, maintenance staff and operational support reduce the availability of time, oversight and cross-checking mechanisms that normally function as safety nets. Pressure to maintain schedules encourages shortcuts or omitted checks when supervision or peer support is limited. Training capacity is similarly strained, as insufficient instructor availability and limited simulator access delay or compress training cycles, resulting in staff entering operations with low recency and insufficient consolidation of key competencies.

In parallel, **Stress** becomes widespread in understaffed environments. Job insecurity, fear of contract loss and concerns about being perceived as unreliable create a climate where crews hesitate to report sickness or fatigue. This culture of fear promotes presenteeism and erodes trust in organisational support systems.

Finally, **Workload** increases significantly when staffing is insufficient. The reduction in personnel forces individuals to take on multiple safety and service duties simultaneously, often leading to task saturation. Minimum cabin complements require crew members to manage several critical responsibilities at once, increasing both physical and cognitive demand. Route expansion without corresponding staffing growth adds further time pressure, causing rushed processes, reduced threat monitoring and an elevated susceptibility to error during turnarounds and time-critical activities.

3.2.1.13 Skills and training gaps

The literature depicts skills and training gaps as a progressive erosion of operational competence, where insufficient investment in structured learning, recency and knowledge transfer weakens both individual and collective performance. When training becomes repetitive, fragmented or limited in scope, crews lose technical depth, cognitive resilience and the ability to manage unexpected or time pressured situations.

Across sources, **Complacency** emerges as an important precursor. Recurrent training that lacks challenge fosters excessive confidence in personal abilities and in system reliability. When exercises become predictable, engagement declines and individuals default to routine behaviours rather than active monitoring. Limited exposure to automation limitations reinforces a belief that systems will function correctly without vigilant oversight, weakening anticipation of hazards.

Lack of Awareness is closely tied to deficiencies in training. Situational awareness depends on accurate mental models that are built and reinforced through practice. When these models are incomplete, personnel may miss relevant cues or misinterpret system indications, leading to breakdowns in comprehension and projection. Fatigue also plays a role, particularly when staff receive insufficient training on fatigue management. In multi crew settings, limited joint training impairs the development of shared mental models and collective awareness.

Lack of Resources further undermines proficiency. Shortages of instructors, simulators and training time restrict opportunities to maintain or rebuild skills, especially during periods of high demand. Economic constraints often reduce training for temporary or subcontracted staff, forcing individuals to rely on improvisation and on the job learning rather than structured preparation. This reduces organisational resilience and weakens safety buffers.

Lack of Knowledge is the direct result of insufficient or fragmented training pathways. Extended gaps in practice lead to measurable declines in procedural memory and manual handling skills. Subcontracted or temporary staff may also lack familiarity with specific operator procedures due to diverse training backgrounds. The retirement of experienced personnel without structured knowledge transfer results in the loss of tacit expertise that younger staff need for effective decision making.

Finally, **Workload** increases sharply when skills decline. Lower proficiency requires individuals to use effortful controlled processing rather than automatic performance, consuming cognitive resources and accelerating task saturation. Inexperienced or undertrained personnel rely on shortcuts or struggle with unfamiliar tasks, making even routine operations mentally demanding. Limited training on workload management strategies further reduces capacity to cope with high operational tempo.

3.2.2 Characterisation of Safety Performance Indicators

This section shifts the analysis to understand the safety impact of the SPs derived from the RAs. The methodological framework is described in Section 2.5. First, SOIs are reported as a reproducible baseline of indicators designed for annual monitoring, enabling assessment of how SP-related safety performance evolves over time and providing a reference point for evaluating potential mitigation strategies. Second, RTIs are presented to characterise the current state of ECR reporting culture and reporting capability, providing essential context for interpreting observed patterns. Finally, the results of the extended inference analysis are summarised, accounting for organisational and operational context when examining associations with SP-related occurrences and with the reported severity of outcomes.

To properly interpret the result that follow, classification approach defined in Subsection 2.3.5.2 should be recalled. An occurrence is classified as SP-related if at least one SP, according to the mapping framework in Annex B.3.1, is reported in the ECR occurrence record. This designation is descriptive rather than causal, indicating that the SP is documented as contributing or associated factor alongside the safety event.

All analyses are conducted on Fixed Wing Scheduled Commercial Air Transport occurrences. Unless stated otherwise, results cover 2015 to 2024. In selected cases, the time window is narrowed to specific years where required by the analytical focus or data constraints.

3.2.2.1 SPIs of safety outcomes

The following subsection presents the SOIs, structured around the dimensions defined in the methodological framework in Subsection 2.5.1.

3.2.2.1.1 Frequency

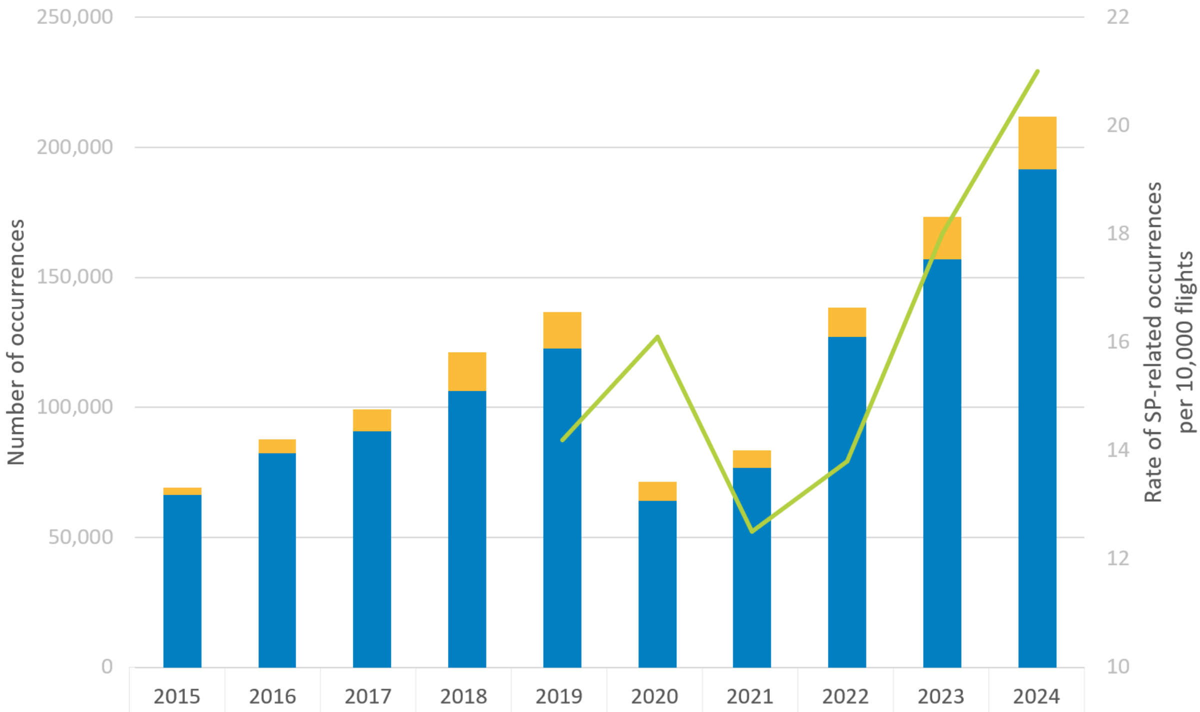
The frequency of SP-related occurrences in absolute terms is shown in Figure 37. The figure presents the annual number of SP-related and non-SP-related occurrences reported to the ECR between 2015 and 2024, together with the rate of SP-related occurrences per 10,000 flights.

Between 2015 and 2019, SP-related occurrences increased by a factor of 5.4, compared with a factor of 1.8 for non-SP-related occurrences. As a result, the SP-related share of all reported occurrences rose from 3.8% in 2015 to 10.35% in 2019. In 2020–2021, counts in both categories decreased sharply, reflecting the reduction in air traffic and operational activity during the COVID-19 period. Both categories decreased by approximately 50%. From 2021 to 2024, SP-related occurrences experienced an almost threefold increase, reaching 20,404 reported occurrences, the highest level in the period analysed. Over the same period, non-SP-related occurrences increased by approximately a factor of 2.5, reflecting a general recovery in reporting volume and operational exposure. This is reflected in the increasing share of SP-related occurrences. In 2024, SP-related occurrences represented 9.6% of all reported occurrences in the ECR sample, compared to 8.2% in 2023 and 6.8% in 2022.

This trend should be interpreted with caution as it may be influenced by different factors, including an increased presence of such hazards in operational context, changes in reporting behaviour as well as variability in the completeness and quality of occurrence reporting in the ECR, and increased awareness of their potential safety impact.

Figure 37 also shows the rate of SP-related occurrences per 10,000 flights for the years 2019 onwards, as flight exposure data is only available for analysis in the context of the D4S Programme. From 2021 onwards, the rate increased each year, reaching 21 SP-related occurrences per 10,000 flights in 2024.

Overall, the results indicate that SPs represent a growing component of the reported occurrence landscape and constitute an increasingly relevant dimension for safety monitoring and analysis.



	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
SP-related	2,626	5,328	8,543	15,088	14,146	7,157	6,872	11,461	16,351	20,404
Non-SP-related	66,358	82,246	90,753	106,144	122,500	64,165	76,667	126,983	156,874	191,408
SP-related rate					14.2	16.1	12.5	13.8	18	21

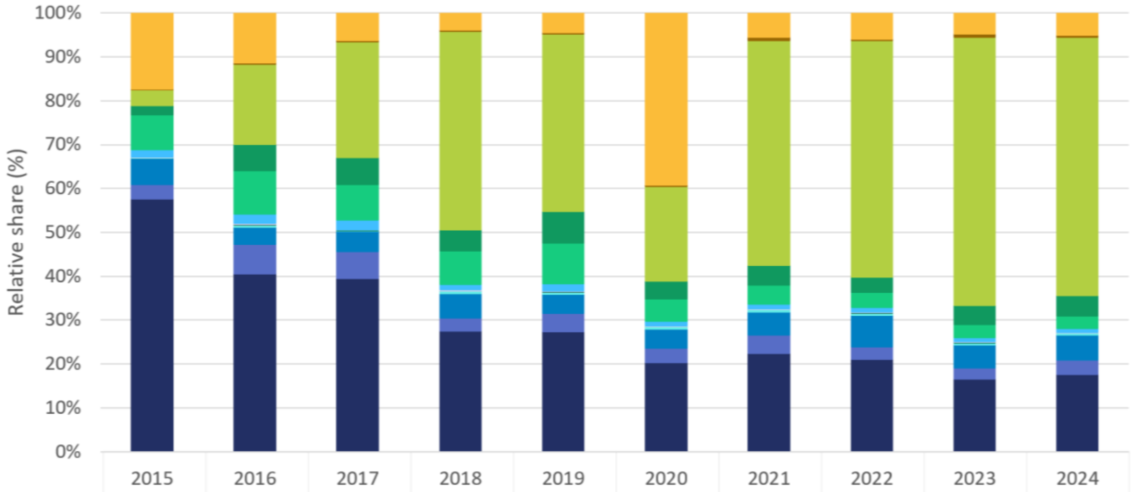
Figure 37: Absolute numbers of SP-related occurrences and Non-SP-related occurrences along with SP-related occurrences rate per 10,000 flights for the period 2015–2024

To better understand where latent safety risks are concentrated, the analysis now turns to the composition of SPs to identify which human and organisational factors are most prominent. Figure 38 shows the relative distribution of SPs reported in SP-related occurrences between 2015 and 2024. As a single occurrence may be associated with more than one precursor, the shares reflect co-occurrence patterns rather than exclusive attribution.

The composition changes substantially over the period analysed. In 2015–2017, SP-related occurrences are mostly driven by lack of communication, which represents the largest share in the early years. Even then, fatigue is already gaining weight year by year. This gradual shift is temporarily interrupted during the COVID-19 disruption, when operating conditions and reporting patterns change. After this period, fatigue becomes an increasingly large share of SP-related occurrences each year, reaching almost 60% by 2024 and emerging as the most prevalent SP category. This sustained increase may reflect a combination of a higher exposure to fatigue risk, along with a greater awareness and willingness to report this hazard.

Workload precursor show a clear peak in 2020, in line with the operational disruption during COVID-19, and then decline in relative terms as operations normalise. This is consistent with a short-term shift in exposure and reporting conditions, including changes in staffing levels and operational load. Other precursor categories remain relatively stable over time and account for a smaller share of the profile.

Overall, the recent rise in SP-related occurrences in absolute terms appears to be driven mainly by the growth in fatigue reports. Lack of communication is lower in proportion that in the early years, but its contribution is still an 18%, constituting the second SP more relevant.



	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Workload	17.3	11.3	6.1	3.9	4.5	39.2	5.6	5.9	4.7	5.0
Norms	0.1	0.4	0.3	0.2	0.2	0.3	0.8	0.4	0.8	0.5
Fatigue	3.5	18.2	26.2	45.2	40.6	21.5	51.1	53.9	61.2	58.9
Lack of knowledge	2.6	2.6	5.0	4.2	8.4	5.0	7.2	5.6	7.5	5.6
Lack of awareness	7.8	9.8	8.0	7.7	9.4	5.0	4.3	3.5	3.0	2.8
Pressure	1.6	2.0	2.2	1.3	1.6	1.2	1.1	1.0	0.9	0.9
Lack of teamwork	0.1	0.3	0.1	0.2	0.2	0.1	0.2	0.2	0.1	0.1
Complacency	0.1	0.1	0.1	0.0	0.1	0.1	0.0	0.1	0.2	0.1
Stress	0.1	0.5	0.8	0.5	0.6	0.6	0.6	0.6	0.4	0.4
Lack of resources	5.9	3.9	4.7	5.6	4.3	4.3	5.3	7.2	5.3	5.7
Distraction	3.3	6.7	6.1	3.0	4.3	3.4	4.2	2.7	2.5	3.3
Lack of communication	57.6	40.6	39.3	27.5	27.3	20.3	22.4	21.2	16.7	17.6

Figure 38: Relative distribution of Safety Precursors in SP-related occurrences for the period 2015–2024

3.2.2.1.2 Impact

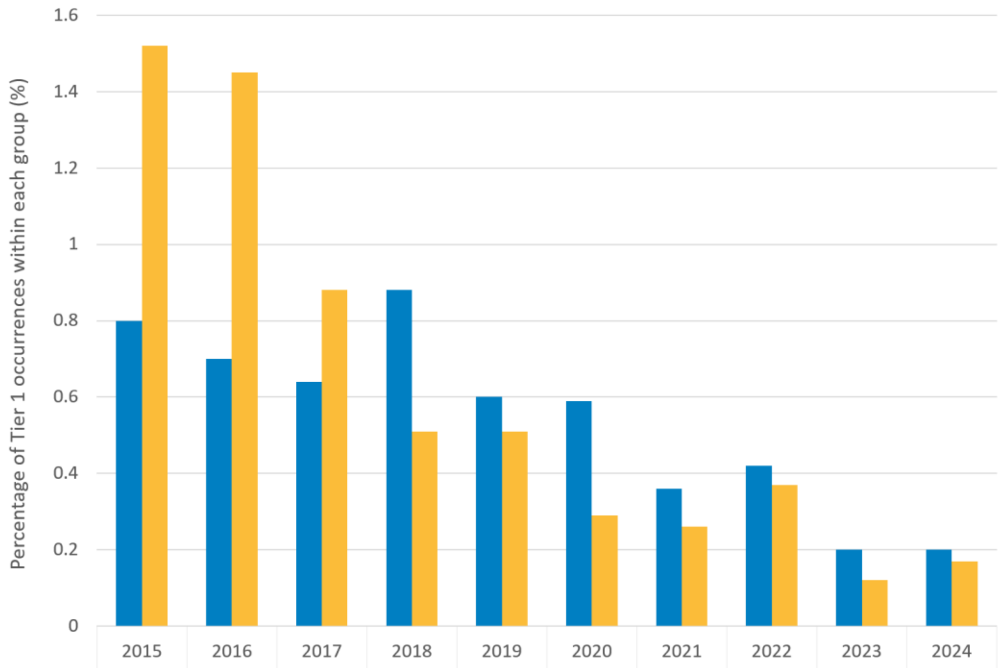
Following the analysis of the frequency of SP-related occurrences, this section examines their impact based on the reported severity classification. For analytical purposes, the standard ECR severity categories are grouped into Tier 1, covering accidents and serious incidents, and Tier 2, covering incidents, observations, occurrences without safety effect and not determined categories.

Figure 39 presents the share of Tier 1 occurrences within the SP group and the non-SP group over 2015 to 2024, enabling a comparison of severe outcome rates across the two groups. Tier 2 is not shown separately, as it is the direct complement of Tier 1 within each group. Both shares are higher in the pre-COVID years, with the SP group peaking in 2015 and 2016, followed by a significant decline thereafter. This decrease may reflect a change in the severity of the occurrences, but it may also be influenced by changes in reporting practices and classification quality.

From 2021 onwards, the Tier 1 share is slightly higher in non-SP-related than in SP-related occurrences, although differences remain small and slightly vary over time. By 2024, the difference of both shares is minimal at 0.03%.

In this context, despite the increase in overall reporting volumes in recent years for both SP-related and non-SP-related occurrences, this is not reflected in a corresponding increase in Tier 1 outcomes. This indicates that the growth in reporting is primarily absorbed by lower-severity categories within Tier 2, rather than by accidents or serious incidents.

Given that Tier 1 events are rare and therefore particularly sensitive to modest changes in reporting volume and classification, the small differences observed in recent years should be treated with caution. On this basis, over the last 3 years the figure suggests similar levels of accidents and serious incidents between SP and non-SP-related occurrences.



	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Non-SP-related	0.80	0.70	0.64	0.88	0.60	0.59	0.36	0.42	0.20	0.20
SP-related	1.52	1.45	0.88	0.51	0.51	0.29	0.26	0.37	0.12	0.17

Figure 39: Percentage of Tier 1 occurrences relative to SP-related and Non-SP-related total occurrences respectively within each group for the period 2015-2024

The frequency of SP-related Tier 1 occurrences is shown in Figure 40. The figure presents the annual number of SP-related fatal accidents, non-fatal accidents and serious incidents reported between 2015 and 2024, together with the Tier 1 rate per 1 million flights. Accidents are further distinguished as fatal and non-fatal to separate occurrences involving loss of life from those considering aircraft damage without fatalities.

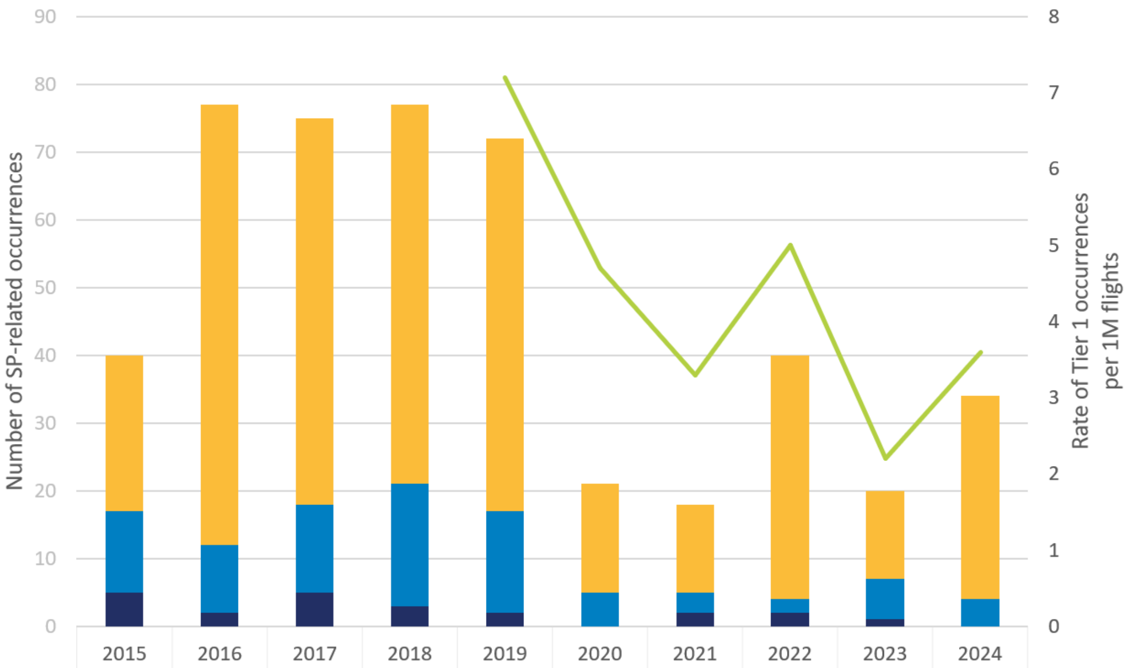
Tier 1 outcomes represent high-impact safety events and therefore occur infrequently, which results in higher variability over the years in absolute terms. Given the low number of events, absolute counts at this severity level should be interpreted with caution and in the context of exposure. Additionally, personnel-related event types are not immediately available in the ECR and should be considered provisional until validated by the R996/2010 safety investigation[27]. Once confirmed, the corresponding ECR records are updated based on the final report, which may be issued up to a year after the event, ensuring that the database reflects the investigation's conclusions.

A comparison between Figure 37, which contains the volume of reports, and Figure 40 shows that, although air traffic and overall reporting volumes recovered in the post-COVID period, this increase is not reflected in the absolute number of SP-related Tier 1 occurrences. Tier 1 volumes remain below pre-COVID levels, with only limited peaks observed in 2022 and 2024, which may also be explained by the reporting processes described above.

This pattern is also reflected in the Tier 1 rate per 1 million flights. In 2019, 7.2 SP-related Tier 1 occurrences were reported per 1 million flights. In the post-COVID period, the maximum rate was observed in 2022, at 5.0 per 1 million flights, and declined further to 3.6 per 1 million flights in 2024. Despite the inherent volatility associated with rare events, the Tier 1 rate remains below pre-COVID levels.

Overall, while exposure to SPs has increased over time, this has not translated into a corresponding increase in the severity of reported occurrences. High-severity SP-related outcomes remain rare and have decreased relative to traffic levels compared to the pre-COVID period.

[27] Regulation (EU) No 996/2010 of the European Parliament and of the Council on the investigation of civil aviation accidents and incidents, available at: https://www.easa.europa.eu/en/document-library/regulations/regulation-eu-no-9962010 (accessed January 2026)



	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Serious Incidents	23	65	57	56	55	16	13	36	13	30
Non-fatal accidents	12	10	13	18	15	5	3	2	6	4
Fatal accidents	5	2	5	3	2	0	2	2	1	0
Tier 1 rate					7.2	4.7	3.3	5.0	2.2	3.6

Figure 40: Absolute numbers of Tier 1 SP-related occurrences along with SP-related Tier 1 occurrences rate per 1M flights for the period 2015–2024

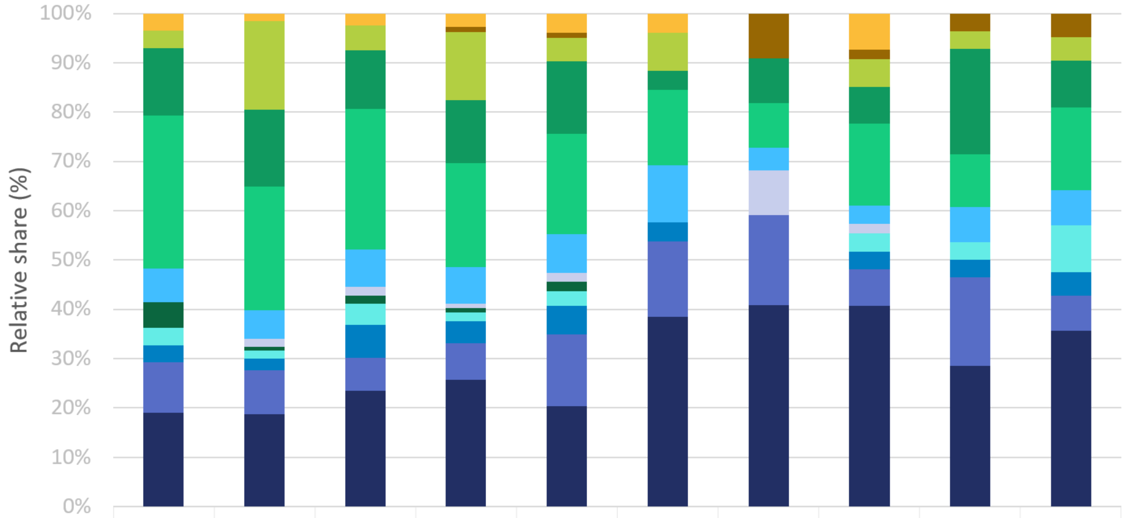
Figure 41 shows the relative distribution of SPs within SP-related Tier 1 occurrences over the period 2015–2024. For the following analysis, given the small number of high-severity occurrences, these changes over the years are best understood as being driven by individual cases rather than as indicating sustained shifts in underlying risk.

Compared with Figure 38, which shows the distribution of precursors across all SP-related occurrences, Tier 1 occurrences exhibit a distinct profile. While fatigue is the most prevalent precursor in terms of overall volume, it is not prominent among high-severity outcomes. By contrast, lack of communication accounts for a larger share of Tier 1 occurrences and has gained presence in high severity occurrences in the post-COVID period.

Lack of communication and lack of awareness are the most frequently present precursors in high-severity occurrences, although they display different temporal patterns. In the pre-COVID years, lack of awareness is more commonly reported within Tier 1 cases, 31% in 2015, while lack of communication represents 19% in 2015. Across the period, the share of Tier 1 occurrences that include lack of awareness declines to 17% in 2024, whereas lack of communication becomes increasingly prevalent reaching almost 36% in 2024. When translated these relative shares into absolute counts, the shift shows that lack of communication increases from 11 to 15 cases, while lack of awareness decreases from 18 to 7 cases.

Lack of knowledge remains broadly stable before 2020, drops sharply in 2020 and peaks in 2023, being present in approximately 21% of Tier 1 SP-related events, before declining again in 2024. Other precursors show more irregular patterns over time. Distraction increases between 2019 and 2021 and again in 2023 being associated with almost 18% of Tier 1 SP-related occurrences, pressure peaks in 2020, and stress presence highly increases in 2024, being recorded in almost 10% of cases. Fatigue shows higher shares in 2016 and 2018 but remains low in later years, appearing in fewer than 5% of Tier 1 occurrences in 2024.

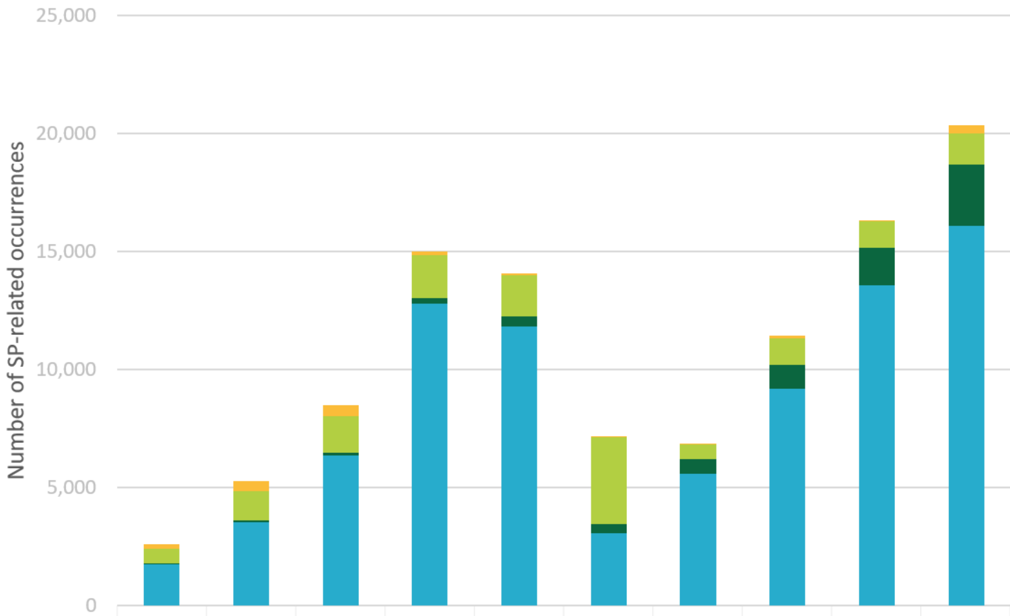
Overall, the figure indicates that precursors related to lack of communication, awareness and knowledge are more prevalent in high-severity occurrences than those related to workload or fatigue. By their nature, these precursors reflect breakdowns in information flow, understanding and coordination, which, when combined with other operational factors, are more likely to contribute to escalation into severe outcomes.



	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Workload	3.5	1.6	2.5	2.8	3.9	3.9	0.0	7.4	0.0	0.0
Norms	0.0	0.0	0.0	0.9	1.0	0.0	9.1	1.9	3.6	4.8
Fatigue	3.5	17.9	5.0	13.8	4.9	7.7	0.0	5.6	3.6	4.8
Lack of knowledge	13.8	15.5	11.8	12.8	14.6	3.9	9.1	7.4	21.4	9.5
Lack of awareness	31.0	25.2	28.6	21.1	20.4	15.4	9.1	16.7	10.7	16.7
Pressure	6.9	5.7	7.6	7.3	7.8	11.5	4.6	3.7	7.1	7.1
Lack of teamwork	0.0	1.6	1.7	0.9	1.9	0.0	9.1	1.9	0.0	0.0
Complacency	5.2	0.8	1.7	0.9	1.9	0.0	0.0	0.0	0.0	0.0
Stress	3.5	1.6	4.2	1.8	2.9	0.0	0.0	3.7	3.6	9.5
Lack of resources	3.5	2.4	6.7	4.5	5.8	3.9	0.0	3.7	3.6	4.8
Distraction	10.3	8.9	6.7	7.3	14.6	15.4	18.2	7.4	17.9	7.1
Lack of communication	19.0	18.7	23.5	25.7	20.4	38.5	40.9	40.7	28.6	35.7

Figure 41: Relative share of Safety Precursors in Tier 1 occurrences for the period 2015-2024

After examining Tier 1 outcomes, the analysis now turns to Tier 2 occurrences to assess how SP-related reporting relates to lower-severity events. Tier 2 accounts for the large majority of SP-related reports and therefore shows how changes in SP-related reporting are distributed across the lower-severity categories.

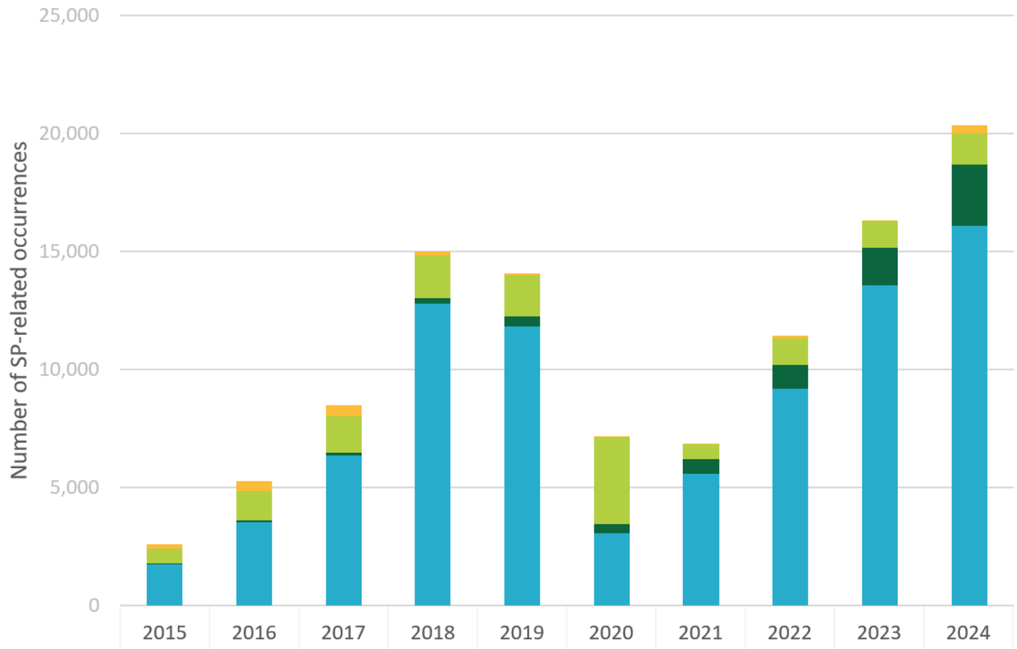


	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Not determined	210	426	437	155	63	18	56	106	143	380
Occurrence without safety effect	616	1,238	1,565	18,142	1,771	3,687	599	1,117	1,135	1,307
Observation	22	74	5,100	3,217	419	368	630	1,010	1,569	2,603
Incident	1,738	3,513	6,366	12,797	11,821	3,063	5,569	9,186	13,584	16,080

Figure 42 shows the annual number of SP-related Tier 2 occurrences by severity category. Tier 2 accounts for the large majority of SP-related occurrences and therefore captures how the increase in SP-related reporting is distributed across severity categories.

This figure shows that the post-COVID increase in SP-related reporting is almost entirely absorbed by the incidents category, which accounts for 79% of SP-related Tier 2 occurrences in 2024, and to a lesser extent, by observations, which represent 13% in 2024.

Overall, the increase in SP-related reporting is concentrated in lower-severity classifications rather than shifting towards higher-severity categories. This suggests that SPs currently manifest primarily as early indicators of latent risk rather than as drivers of high-severity outcomes, and therefore warrant continued monitoring as part of preventive safety management. Additionally, it should be considered that, unlike accidents and serious incidents under Annex 13/R996/2010, SP occurrences are coded close to the date of the event, which means their assessment can be available sooner.



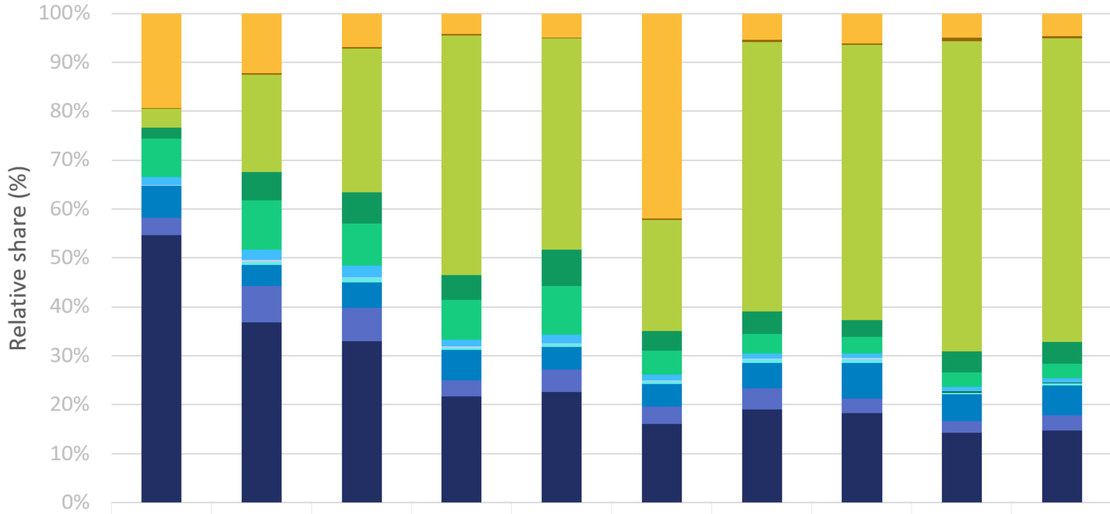
	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Not determined	210	426	437	155	63	18	56	106	143	380
Occurrence without safety effect	616	1,238	1,565	18,142	1,771	3,687	599	1,117	1,135	1,307
Observation	22	74	5,100	3,217	419	368	630	1,010	1,569	2,603
Incident	1,738	3,513	6,366	12,797	11,821	3,063	5,569	9,186	13,584	16,080

Figure 42: Absolute numbers of Tier 2 SP-related occurrences for the period 2015–2024

Figure 43 presents the relative distribution of SPs within SP-related Tier 2 occurrences. As seen in Figure 39 Tier 1 represents, in most years, less than 1% of the total volume. As a result, the Tier 2 profile drives the overall SP-related distribution and closely reflects the patterns observed in the volume-based figures.

Fatigue is the dominant precursor and its increasing presence is primarily reflected in Tier 2 events. This may indicate higher exposure and/or increased reporting of fatigue, but it is not accompanied by a corresponding increase in Tier 1 outcomes, suggesting that the severity associated to these events remains at low levels.

By contrast, lack of communication and lack of awareness show a different severity profile. While absolute Tier 1 counts remain very limited, these precursors account for a larger share within the Tier 1 subset than within Tier 2 when viewed in relative terms. Therefore, even with low absolute counts, their higher relative share in Tier 1 makes them important precursors to monitor given their potential relevance to high severity outcomes.



	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Workload	19.3	12.2	6.9	4.3	4.9	42.0	5.4	6.1	4.9	4.7
Norms	0.2	0.4	0.3	0.2	0.2	0.3	0.5	0.4	0.8	0.4
Fatigue	3.9	19.8	29.4	49.0	43.2	22.7	55.1	56.2	63.5	62.2
Lack of knowledge	2.2	5.8	6.4	5.0	7.4	4.0	4.6	3.5	4.3	4.4
Lack of awareness	7.8	10.1	8.5	8.2	10.0	4.9	4.0	3.3	3.0	2.9
Pressure	1.7	2.1	2.4	1.4	1.7	1.2	1.0	1.0	0.8	0.9
Lack of teamwork	0.1	0.4	0.1	0.2	0.2	0.1	0.2	0.2	0.1	0.1
Complacency	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.1	0.2	0.1
Stress	0.0	0.6	0.8	0.5	0.6	0.6	0.6	0.6	0.4	0.4
Lack of resources	6.6	4.3	5.2	6.2	4.6	4.6	5.3	7.4	5.4	6.2
Distraction	3.5	7.3	6.8	3.3	4.6	3.5	4.2	2.9	2.4	3.1
Lack of communication	54.6	36.9	33.0	21.7	22.6	16.1	19.1	18.3	14.3	14.7

Figure 43: Relative share of Safety Precursors in Tier 2 occurrences for the period 2015-2024

3.2.2.1.3 Risk assessment

The ERCS provides a risk-oriented perspective on reported occurrences by combining information on the most likely accident outcome and the proximity of the occurrence to that outcome, assessed through a review of barrier effectiveness . As explained in Subsection 2.5.1.1, ERCS classification is available from 2023; accordingly, the analysis in this section is based exclusively on occurrences classified using the ERCS in 2023 and 2024.

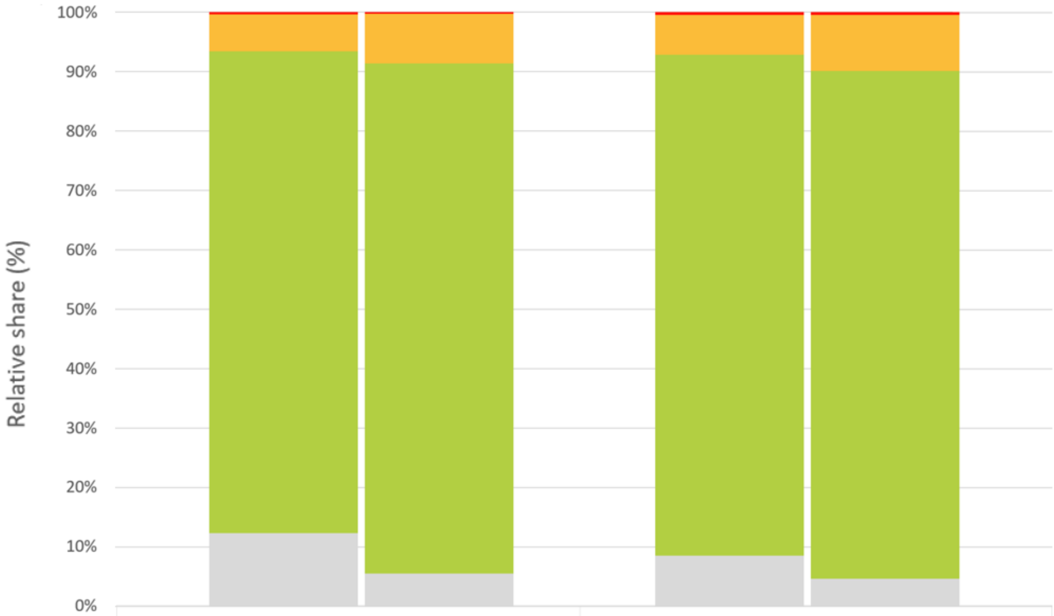
ERCS scores are grouped into four categories: grey for no implication to safety, green for low risk, yellow for medium elevated risk and red for high risk. Figure 44 shows the distribution of these risk categories for SP-related and non-SP-related occurrences over time.

The proportion of occurrences classified as high risk is low in both groups and remains small relative to the other categories for both years. A slight increase in the share of high-risk classifications can be observed from 2023 to 2024; however, this increase remains limited in magnitude and occurs from a low base.

Non-SP-related occurrences consistently show a marginally higher share of medium risk compared to SP-related occurrences, by approximately 2–3%. Additionally, SP-related occurrences show a higher proportion of cases classified as having no safety impact, although this proportion decreases from 2023 to 2024.

In both groups, the majority of occurrences are classified as low risk, indicating that most reported occurrences are assessed as posing limited safety risk.

Overall, the figure shows that occurrences associated with SPs do not have a higher risk profile than those not associated with precursors. This supports the interpretation of SPs as indicators of exposure and latent conditions, rather than as indicators of high-risk outcomes.



	2023		2024	
	SP-related	Non-SP-related	SP-related	Non-SP-related
High	0.4	0.3	0.5	0.5
Elevated	6.2	8.3	6.7	9.4
Low	81.1	85.8	84.3	85.4
No implication to safety	12.3	5.6	8.5	4.7

Figure 44: ERCS Score risk profile for SP-related and non-SP-related occurrences for 2023 and 2024

Although the ERCS score is not mandatory, reporting has increased in 2023–2024, reaching approximately 70% completeness for the period. The remaining share corresponds to blank or pending values. Results based on ERCS scores should therefore be interpreted in light of this partial data coverage.

Figure 45 shows for each SP two complementary measures, the volume of occurrences with ERCS score reported associated with each precursor and the aggregated ERCS risk score associated with those occurrences. This analysis allows a comparison between how frequently precursor risk is reported and the level of risk with which it is typically associated.

The figure shows that mostly lack of communication, along with lack of awareness, lack of knowledge and distraction are associated with comparatively higher aggregated ERCS risk scores, despite representing a smaller volume of reported occurrences. By contrast, fatigue accounts for the largest volume of SP-related occurrences but is associated with a comparatively lower aggregated risk score.

It should nevertheless be noted that variability in reporting quality, taxonomy usage, and contextual detail limits the extent to which robust qualitative or quantitative conclusions can be derived exclusively from occurrence-reporting data.

The figure suggests that the safety relevance of precursors lies less in how often they are observed and more in how they affect the system's ability to manage emerging threats. Lack of communication, awareness, knowledge and distraction, while less reported, are more represented in the higher-ERCS subset, so the aggregated ERCS signal is driven by these higher-risk cases.

By contrast, fatigue mainly affects baseline human performance and increases the likelihood of errors but does not in itself determine whether those errors escalate into high-risk outcomes. Its relevance therefore lies more in increasing exposure than in driving escalation.

This highlights the value of SPs as a lens on how risk develops and propagates within the system, not only on how frequently events are reported.

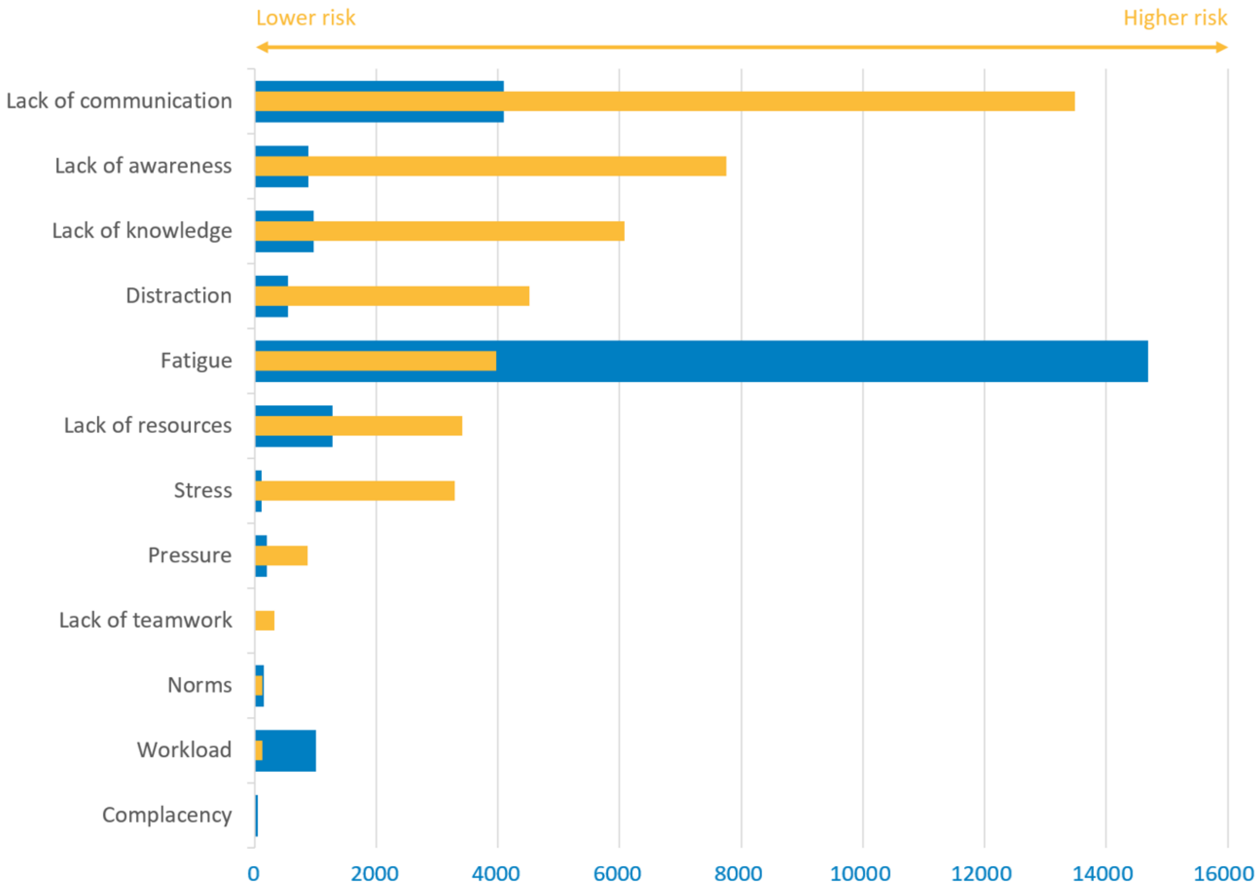


Figure 45: Volume of occurrences with ERCS score reported associated with each SP and the aggregated ERCS risk score associated with those occurrences for 2023 and 2024

3.2.2.2 SPIs of reporting trends

In addition to monitor SPIs, it is important to understand how effectively the ECR system captures safety information through occurrence reporting. In this section, increases in overall reporting, excluding accidents and serious incidents, may reflect improved willingness and capability to report, as well as more mature safety management practices. For this reason, this section reviews reporting trends to support a more informed reading of SPIs and to assess how the quality and characteristics of reports evolve over time.

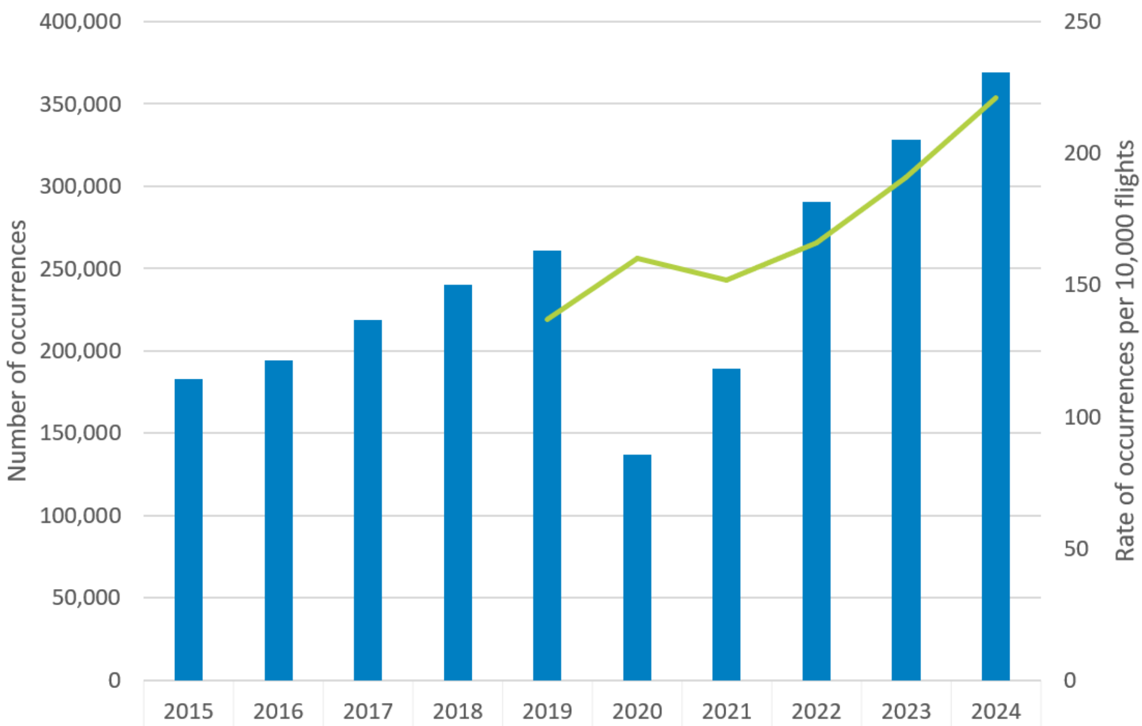
Figure 46 shows the total number of occurrences reported to the ECR between 2015 and 2024, together with the corresponding reporting rate, in order to place reporting volumes in the context of overall aviation activity in Europe.

In absolute terms, reporting shows an increasing trend over the period. In the pre-COVID years, the number of reported occurrences increased by 43% between 2015 and 2019. This trend was disrupted in 2020, when reporting dropped sharply by 48% compared with 2019 due to COVID-19.

As traffic recovered, reporting volumes increased by 54% between 2021 and 2022, and by a further 27% between 2022 and 2024.

A clearer picture emerges when considering the reporting rate. Although the absolute number of reports decreased during the COVID period, the rate of reporting continued to increase, reflecting the sharper reduction in traffic volumes. After a slight decrease in 2021, the reporting rate recovered to pre-COVID levels in 2022 and increased further by 33% by 2024.

The upward trend in both reporting volumes and rate may not necessarily imply a rise in the actual safety occurrences or a degradation of the safety performance at European level; rather, it could be interpreted as a enhancement of the safety culture and reporting maturity across aviation organizations.



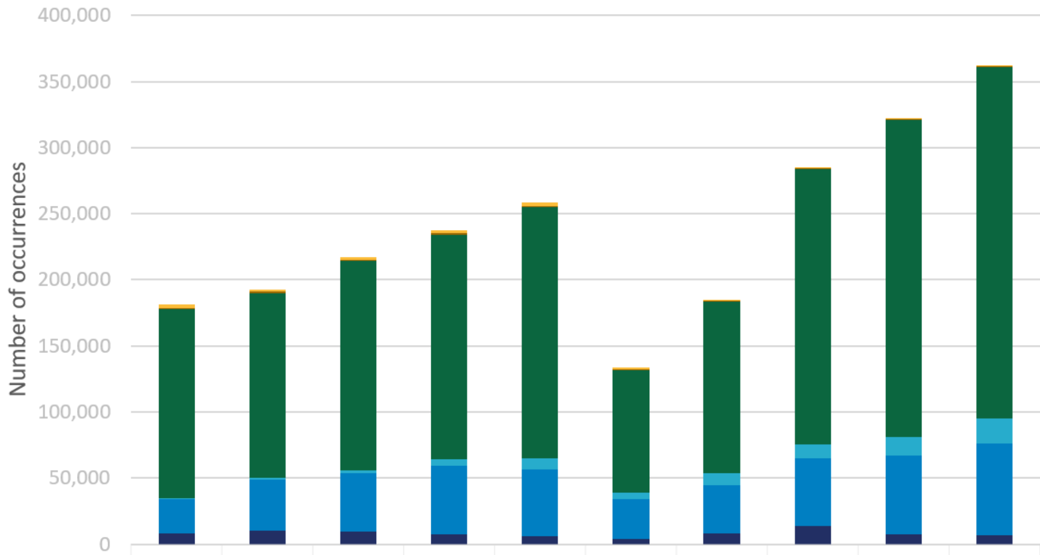
	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Total ECR occurrences	183,148	194,347	219,116	240,463	261,076	136,797	189,196	290,485	328,480	369,029
Rate					137	160	152	166	191	221

Figure 46: Total number of ECR occurrences along with the rate of the occurrences reported per 10,000 flights for the period 2015-2024

To understand what is driving the reporting increase, Figure 47 disaggregates total ECR occurrences into absolute volumes by *Occurrence Class*, making it possible to compare the contribution of higher-severity and lower-severity categories.

This breakdown shows that most of the increase is concentrated in lower-severity categories in pre-COVID and in post-COVID periods. Between 2015 and 2019, reported *Incidents* increased by 33%, *Observations* increased by 1,36%, and *Occurrences without safety effect* rose by 90%. Between 2021 and 2024, these classes continued to grow, with *Incidents* increased by 105%, *Observations* by 111%, and *Occurrences without safety effect* by 87%. In contrast, high-severity categories show a different pattern: *Accidents* decreased by 33% over 2021-2024, while *Serious Incidents* remain low in absolute terms with low fluctuations over 2021-2024, which is expected for rare events.

From these figures alone, it is not possible to determine whether underlying exposure has increased, or whether pre-existing exposure is simply being captured more consistently through reporting. The pattern appears to suggest that a larger share of lower-severity occurrences is now being recorded in the ECR, which may be consistent with improvements in reporting culture and reporting practices**.**



	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Accident	2,807	1,810	1,901	2,180	2,143	1,565	1,077	1,125	828	726
Serious incident	764	846	975	1,110	1,142	832	494	686	506	742
Incident	142,898	140,168	158,789	169,725	190,129	92,397	129,703	208,334	240,295	265,873
Observation	572	1,265	1,968	5,476	8,356	5,261	8,879	10,756	13,605	18,720
Occurrence without safety effect	26,444	38,227	44,188	51,820	50,134	29,757	36,973	51,206	59,667	69,273
Not determined	7,724	10,395	9,363	7,230	6,228	4,007	7,847	13,461	7,637	6,800

Figure 47: Total number of occurrence per 'Occurrence Class' for the period 2015-2024

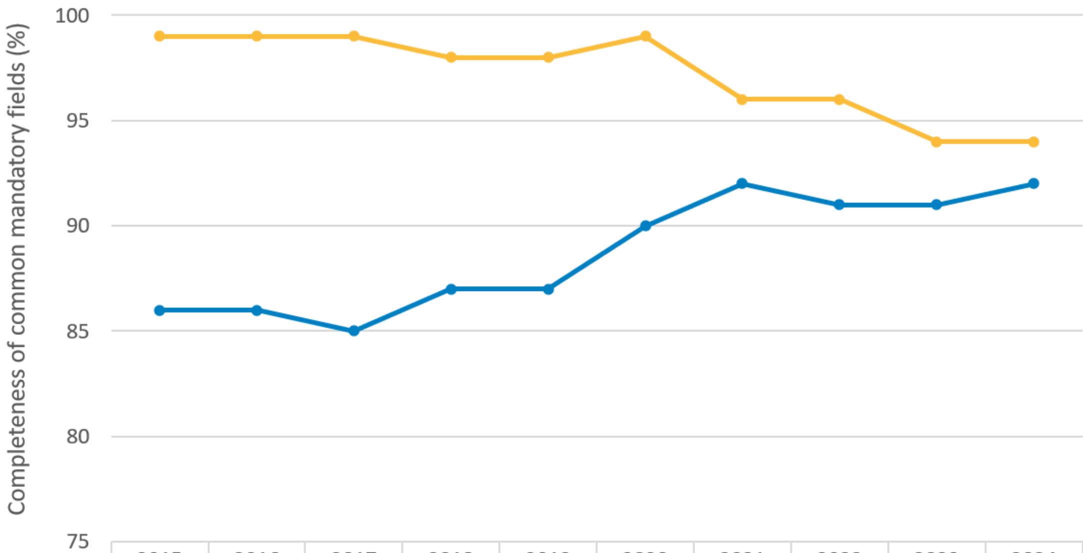
Under Regulation (EU) No 376/2014, a set of common mandatory fields is defined as the minimum information required to ensure that an occurrence report can be properly understood, analysed and used for safety purposes. These fields cover core elements of the occurrence, including the headline, responsible entity, occurrence status, state area of location, location name, occurrence class and occurrence category.

To assess the reporting completeness over time, Figure 48 shows the average completeness of the common mandatory fields by year, both for the complete scope of ECR occurrence records and for SP-related occurrences, providing an overview of how reporting quality has evolved alongside changes in reporting volume.

The figure shows that, for all the ECR, the completeness of the common mandatory fields has improved over time, increasing by around 6% over the last nine years, and has stabilised in recent years at around 91–92%. For SP-related occurrences, completeness was already higher compared to the rest of occurrences in 2015, close to full completion in the early years of the series. In recent years, however, completeness has declined slightly and has stabilised at around 94% in 2023 and 2024, yet still showing a generally better reporting quality than the rest of ECR records.

This pattern for SP-related occurrences can be understood in the context of a broadening of reporting towards less severe safety events, for which not all fields may be necessarily perceived as equally relevant or are systematically completed given the nature and outcome of the occurrence. Additionally, this may reflect the fact that, at the time of initial reporting, certain fields, particularly those related to *Event Type* personnel information, may not yet be available and are therefore included in the occurrence record during subsequent follow-up activities.

On balance, the figure suggests that the growth in reporting volume has been accompanied by a broadly stable and still high level of completeness, supporting the interpretation that the ECR continues to provide a reliable basis for safety monitoring and analysis, even as the scope of reporting expands.

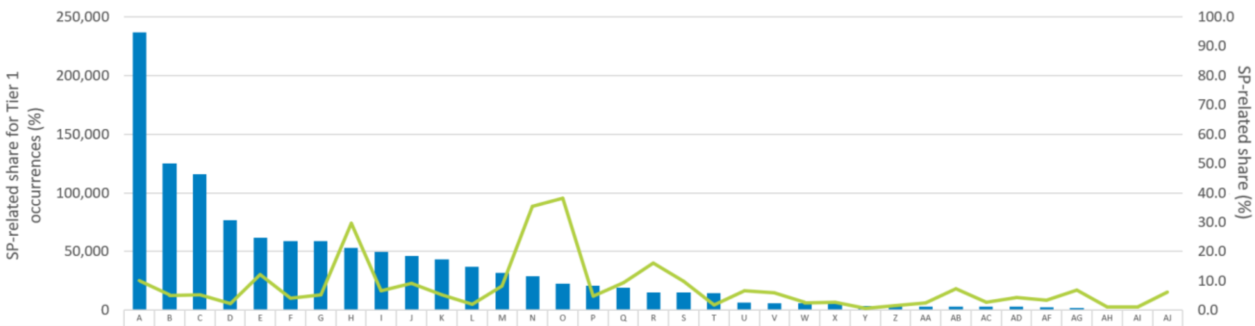


	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Total ECR occurrences	86	86	85	87	87	90	92	91	91	92
SP-related occurrences	99	99	99	98	98	99	96	96	94	94

Figure 48: Average completeness of the common mandatory fields for the period 2015-2024

Figure 49 presents, for each anonymised state[28], the total number of reported occurrences for the aviation scope alongside the percentage share of SP-related occurrences for the period 2015-2024. This dual representation enables a comparative assessment between reporting magnitude and relative SP contribution.

The analysis shows that states with higher total reporting volumes do not necessarily exhibit a higher share of SP-related occurrences. While the overall average remains around 8–10%, three states exceed a 30% share. This disparity suggests that SP-related occurrences are not being identified and classified consistently across states. The observed variation may reflect a combination of differences in reporting practices, exposure profiles, and safety culture, rather than purely operational risk differentials.



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
Total Volume Member State	236,93	125,18	115,90	76,529	61,507	59,001	58,883	53,004	49,518	46,463	43,493	36,751	31,749	29,099	22,688	21,042	19,248	15,172
Ratio SP-related	10.1	5.2	5.2	2.3	12.2	4.0	5.2	29.6	6.7	9.2	5.3	2.1	8.2	35.4	38.1	4.7	9.4	16.1

	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AF	AG	AH	AI	AJ
Total Volume Member State	15,043	14,770	6,701	6,000	5,742	5,565	3,860	3,312	3,263	3,130	3,101	2,981	2,228	1,774	450	90	33
Ratio SP-related	9.8	1.7	6.7	6.0	2.6	2.8	0.6	1.5	2.5	7.3	2.7	4.3	3.4	6.9	1.1	1.1	6.1

Figure 49: Volume of occurrences per state along with the relative share of SP-related occurrences aggregated for the period 2015-2024

[28] The states presented in the analysis reflect the responsible entities as recorded in the ECR database.

Figure 50 follows the same structure and methodology as the previous figure, with the analysis specifically applied to Tier 1 outcomes[29]. The analysis shows that, similarly to the previous figure, there is no clear relationship between the volume of Tier 1 outcomes reported by a state and the percentage share of SP-related occurrences.

States with higher numbers of Tier 1 outcomes do not systematically exhibit a higher proportion of SP-related occurrences, and conversely, some states with lower Tier 1 volumes present comparatively higher SP-related shares. This suggests that differences in SP-related shares are more related to reporting and coding practices than to underlying severity profiles.

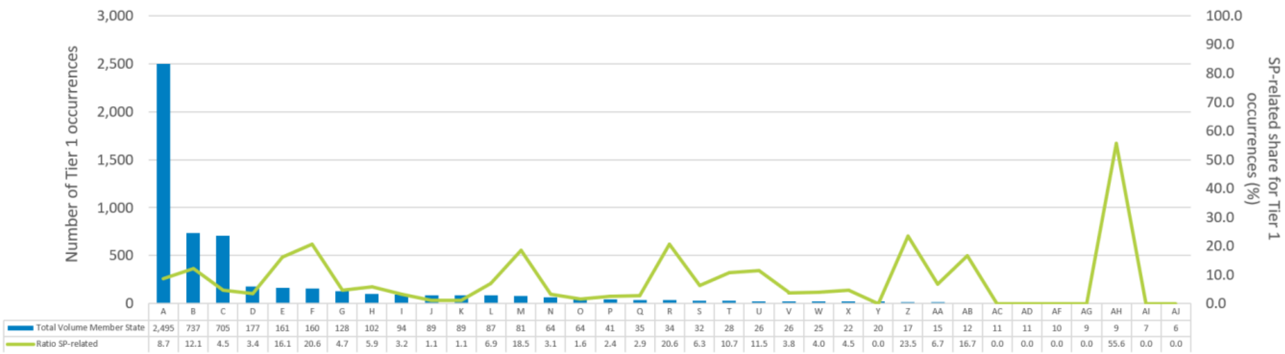


Figure 50: Volume of Tier 1 occurrences per state along with the relative share of SP-related occurrences aggregated for the period 2015-2024

3.2.2.3 Inferential analysis of Safety Precursors and safety outcomes

SOIs in Section 3.2.2.1 provide a useful situational awareness on how SPs affect safety. However, aviation safety performance reflects the interplay of operational context, organisational conditions, and human performance. Therefore, it is important to understand how these factors relate to each other or to SOs once considered jointly. This section uses inferential analysis to estimate the direction and magnitude of key statistical associations and to assess whether observed patterns persist after accounting for operational factors.

This analysis focuses on occurrences reported in **2024**, a period characterised by higher reporting volume and to minimise heterogeneity linked to year differences in reporting volume and reporting practices. As explained in Section 2.5.3.1.1, the analysis further focuses on **low-cost and network carriers**, which together account for most reported occurrences and provide sufficient statistical power, and stability for multivariate modelling.

[29] The letters from both figures do not correspond to the same state.

For that purpose, two different analyses are implemented. First, the distribution of SPs across population groups is analysed to assess whether certain operator types are systematically more exposed to, or more likely to report, specific precursors. Second, the association between the presence of SPs and the severity of reported outcomes is examined, to assess whether SP-related occurrences across operator groups translate into differences in risk severity.

In both analysis, results are presented in three steps: preliminary analysis of the analytic sample; bivariate comparisons to test whether a measurable statistical association is present between each factor and the outcome of interest; and multivariable models that incorporate operational controls to assess whether any observed association persists after accounting for operational context.

3.2.2.3.1 Association between safety precursors and population groups

Given differences in operating models and reporting contexts, the prevalence of SP-related occurrences may vary across operator groups. The analysis assesses whether these differences persist after accounting for operational context or whether the observed associations are largely explained by operational and contextual factors rather than by socio-economic characteristics intrinsic to the groups.

Preliminary analysis

1. Distribution and heterogeneity of precursors

Table 6 summarises, for each SP and each population group, the average share of reported occurrences with the given precursor at the operator level, together with the standard deviation (SD) of these shares across operators. This provides information both on the typical prevalence of each precursor within the group and on the degree of heterogeneity across operators, indicating whether the pattern is broadly shared across the group or concentrated in a subset of operators.

Overall, lack of communication, distraction, lack of awareness and lack of knowledge, display relatively good levels of homogeneity across operators, indicating that their prevalence is broadly similar across operators within each group. This suggests that subsequent regression results for these precursors can be interpreted as reflecting general group-level patterns rather than being driven by a small number of atypical operators.

However, fatigue, lack of resources, pressure and workload exhibit higher variability across operators in both low-cost and network carriers. This indicates that these precursors are concentrated in a subset of operators rather than being uniformly distributed across the group. Nevertheless, they still provide a useful group level indication of how these precursors relate to the outcomes of interest, provided the results are read with caution given the uneven distribution of these precursors across operators in the group.

Finally, several precursors, including stress, complacency, lack of teamwork, and norms, are very rare and given they standard deviation typically concentrated in some airlines. These precursors contribute little to explaining variation in reported occurrences and are therefore unlikely to yield stable or informative regression estimates. Therefore, these precursors are not included in the following analysis.

Table 6: Mean percentage (%) and Standard Deviation (SD) of the share of SP-related against all reported occurrences across operators by operator group for each safety precursor for 2024

Safety Precursor	LCC		Network	
	Mean (%)	SD (+/-)	Mean	SD (+/-)
Lack of communication	1.99	1.66	1.74	1.34
Distraction	0.20	0.34	0.34	0.52
Lack of resources	0.76	2.43	0.29	0.60
Stress	0.03	0.09	0.08	0.30
Complacency	0.01	0.04	0.02	0.06
Lack of teamwork	0.00	0.00	0.00	0.00
Pressure	0.23	0.67	0.05	0.09
Lack of awareness	0.51	0.59	0.30	0.48
Lack of knowledge	0.39	0.54	0.33	0.53
Fatigue	3.73	10.33	2.07	8.05
Norms	0.04	0.10	0.02	0.04
Workload	0.26	0.43	0.62	1.69

2. Multicollinearity diagnostics

Prior to estimating the regression models, pairwise correlations among all precursors and control variables were examined in order to assess potential multicollinearity. Pearson correlations were used given the binary and categorical nature of several variables.

No correlations indicative of severe multicollinearity were detected. The observed correlations remain well below conventional thresholds, suggesting that the multivariate estimates are not driven by redundancy among predictors. The complete correlation matrix is reported in Annex B.4.1.1.1.

Bivariate analysis

Before turning to the multivariate models, simple bivariate associations between operator type and each SP are examined. This analysis provides a first indication of whether certain precursors are more or less prevalent among low-cost carriers relative to network carriers, without adjusting for operational context.

The results of this analysis are summarised in Table 7. Figure 51 provides a graphical explanation of the key concepts used to understand the table.

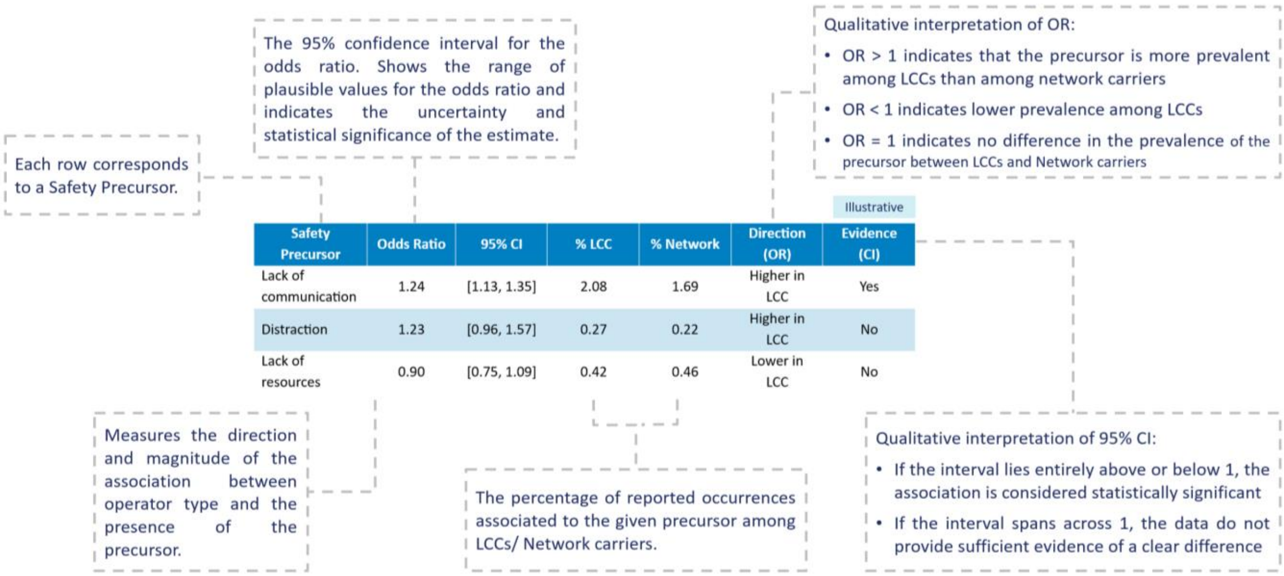


Figure 51: Illustrative guide of the bivariate analysis results

Table 7 suggests that the bivariate associations provide a first descriptive benchmark. Several precursors, including lack of communication, lack of awareness, lack of knowledge, fatigue, and workload, exhibit statistically significant crude associations with operator type, reflecting differences in their prevalence between low-cost and network carriers.

For lack of resources, distraction, and pressure, confidence intervals provide no clear bivariate evidence of a difference in prevalence between low-cost and network carriers, suggesting that any apparent association is detectable without accounting for operational context.

Table 7: Bivariate associations between operator group and safety precursors: crude odds ratios, 95% confidence intervals, and mean prevalence by group

Safety Precursor	Odds Ratio	95% CI	% LCC	% Network	Direction	Evidence

					(OR)	(CI)
Lack of communication	1.24	[1.13, 1.35]	2.08	1.69	Higher in LCC	Yes
Distraction	1.23	[0.96, 1.57]	0.27	0.22	Higher in LCC	No
Lack of resources	0.90	[0.75, 1.09]	0.42	0.46	Lower in LCC	No
Pressure	1.48	[0.96, 2.29]	0.1	0.07	Higher in LCC	No
Lack of awareness	1.78	[1.44, 2.21]	0.46	0.26	Higher in LCC	Yes
Lack of knowledge	1.90	[1.56, 2.32]	0.56	0.3	Higher in LCC	Yes
Fatigue	0.46	[0.43, 0.49]	2.53	5.38	Lower in LCC	Yes
Workload	0.48	[0.37, 0.62]	0.17	0.34	Lower in LCC	Yes

Multivariate analysis

Associations in Table 7 do not account for differences in operational context. The multivariate analysis therefore examines whether these patterns persist once operational and contextual factors are considered.

For the correct interpretation of the operator-group coefficient, it should be noted that it depends on what is already absorbed by the operational controls. By accounting for key operating conditions and exposure drivers (night operations, flight phase, haul length, and adverse weather), the model compares low-cost and network operations under more similar operating contexts. Any remaining association with operator group should therefore be interpreted as a residual difference not explained by observed operational factors, potentially reflecting unobserved organisational and structural factors.

The operational controls included in the model were selected to capture a set of consistently available operational exposure variables considered broadly relevant across occurrence contexts.

However, the analysis does not fully capture all dimensions of operational complexity that may differ between business models, such as airport infrastructure characteristics, ATM congestion, network structure, airspace complexity, or differences between primary and secondary airport operations.

Table 8 summarises results from separate logistic regressions run for each SP. For each model, it reports the odds ratio and the corresponding 95% confidence interval for the LCC group as the reference variable, therefore representing how much more or less is associated the presence of SP for an LCC operator.

Model performance varies across precursors, with higher discriminative ability for fatigue and more moderate performance for the remaining precursors, reflecting the multifactorial nature of safety reporting. Full model outputs, including coefficients and standard errors for all control variables as well as model performance metrics (pseudo-R^2 and AUC), are reported in Annex B.4.2.2.

Across most of the regressions, the inclusion of operational controls leads to an attenuation of the estimated odds ratio compared with the bivariate analysis in Table 7. This pattern indicates that part of the crude differences between LCC and network carriers partly reflect differences in operational conditions. After accounting for this context, the remaining association with operator type is still present for several precursors but is smaller in magnitude.

For lack of resources no significant association is revealed from the bivariate analysis but an association emerges after controlling for operational context. Therefore, once occurrences are compared under similar operational conditions, LCC operations show higher odds of reporting a lack-of-resources precursor than network carrier. However, Table 6 highlights heterogeneity across LCC operators for this precursor, suggesting that the adjusted group-level association may be driven by a subset of airlines.

After controlling for operational conditions, lack of communication, lack of awareness, and lack of knowledge remain more prevalent among LCCs than among network carriers. This suggests that these differences are not fully explained by operational context and are likely to reflect more systematic differences between operator types. In addition, Table 6 shows relatively low dispersion across operators within the LCC group for these precursors, indicating that the observed patterns are broadly representative of the group as a whole rather than being driven by a small number of individual airlines.

In contrast, fatigue remains less prevalent among LCCs once operational conditions are taken into account, implying a higher adjusted prevalence among network carriers. However, dispersion across operators is higher for this precursor as shown in Table 6, suggesting that this pattern may vary more substantially across individual airlines and should therefore be interpreted with greater caution. A similar pattern is observed for workload, but in this case although dispersion across operators is lower, the precursor is relatively infrequent in both operator groups.

Finally, it is examined those precursors for which the bivariate analysis provided no significant association. For lack of resources, an association emerges after controlling for operational context. Therefore, once occurrences are compared under similar operational conditions, LCC operations show higher odds of reporting a lack-of-resources precursor than network carrier. However, Table 6 highlights heterogeneity across LCC operators for this precursor, suggesting that the adjusted group-level association may be driven by a subset of airlines.

For distraction and pressure, the adjusted estimate is still not statistically significant with the multivariate analysis. This suggests that the differences observed in the bivariate analysis were largely attributable to differences in operational profiles, and that there is no clear residual association with operator type once these are considered. In addition, both sample sizes are low in both groups (below 0.3% on average), so estimates are based on limited underlying volume and should be interpreted cautiously.

Table 8: Summary of the logit regressions results for each SP (OR, 95% CI and coefficient interpretation)

Safety Precursor	LCC OR	LCC 95% CI	Adjusted Association	Evidence (CI)
Lack of communication	1.22	[1.10, 1.34]	Higher in LCC	Yes
Distraction	1.01	[0.78, 1.31]	-	No
Lack of resources	1.28	[1.04, 1.58]	Higher in LCC	Yes
Pressure	1.17	[0.74, 1.84]	Higher in LCC	No
Lack of awareness	1.43	[1.14, 1.79]	Higher in LCC	Yes
Lack of knowledge	1.42	[1.16, 1.75]	Higher in LCC	Yes
Fatigue	0.68	[0.63, 0.73]	Lower in LCC	Yes
Workload	0.66	[0.49, 0.87]	Lower in LCC	Yes

To complement the regression results, predicted probabilities were derived to provide an absolute-scale interpretation of the model effects. While the regression coefficients quantify associations, probability estimates offer a clearer view of their practical magnitude. These probability estimates are indicative and should be interpreted as approximate magnitudes rather than as precise operational values. The reference profile represents the model's baseline operational scenario, defined by the reference categories for all covariates: a flight operated by a network carrier, during daytime, with no relevant weather conditions, in cruise, and long-haul. For those precursors with clearer associations within the operator groups in their estimation, the probabilities are:

- Lack of communication: the predicted probability increases from 2.15% under the baseline scenario to 2.61% when only the operator changes to LCC.
- Lack of awareness: the predicted probability rises from 0.09% in the baseline to 1.14% for an LCC operation under the same conditions.
- Lack of knowledge: the predicted probability changes from 0.08% in the baseline scenario to 0.12% when the operator is LCC.
- Lack of resources: the predicted probability increases from 0.68% to 0.87% when only the operator category switches to LCC.
- Fatigue: the predicted probability decreases from 10.44% in the baseline scenario to 7.31% for an LCC operation.
- Workload: the predicted probability decreases from 0.27% in the baseline scenario to 0.17% for an LCC operation.

3.2.2.3.2 Association between severity and safety precursors

Preliminary analysis

1. Distribution assessment

Table 9 reports the number and share of high-severity outcomes among SP-related and non-SP-related occurrences. The Tier 1 shares reported here are computed on the regression sample, which is restricted to LCC and Network operators and to occurrences with complete information on the operational covariates. This restriction changes the composition of both SP-related and non-SP-related groups relative to the full dataset illustrated in Figure 39. As a result, the proportion of high-severity events is higher among SP-related occurrences than among non-SP-related ones.

Considering that Tier 1 outcomes are rare overall, representing a very small fraction of all reported occurrences, the estimated proportions are sensitive to modest changes in sample definition and should therefore be interpreted cautiously, serving primarily as contextual information for the subsequent analysis.

Table 9: Number of total and Tier 1 occurrences along relative share (%) of occurrences within SP-related and Non-SP-related groups for 2024

	N occurrences	N Tier 1	% Tier 1
SP-related occurrences	7,480	20	0.27
Non-SP-related occurrences	94,588	115	0.12

Table 10 further disaggregates Tier 1 outcomes within the SP-related group by precursor category. Almost half of the Tier 1 outcomes are associated with lack of communication, with the remainder distributed across several precursors with very small counts per category. This level of sparsity prevents reliable estimation of specific precursor effects, as estimates would be unstable and dominated by sampling variation rather than systematic differences.

Table 10: Summary of Safety Precursors volume for SP-related Tier 1 occurrences

Safety Precursor	N Tier 1
Lack of communication	9
Distraction	1
Lack of resources	2
Stress	1
Lack of awareness	2
Lack of knowledge	2
Fatigue	2
Norms	1

For this reason, the inferential analysis focuses on whether the presence of any precursor is associated with higher severity, rather than on differences across individual precursors. Nevertheless, because overall Tier 1 outcomes are still rare, model estimates are subject to higher uncertainty and may be sensitive to reasonable specification choices. The regression is therefore used to assess whether the association between SP-related status and severity remains directionally consistent after adjustment, rather than to provide highly precise risk quantification.

2. Multicollinearity diagnostics

As the SP-related variable is included in the model, multicollinearity diagnostics are re-assessed, using pairwise Pearson correlations and VIFs. No correlation indicative of severe multicollinearity was detected. The observed correlations remain well below conventional thresholds, suggesting that the multivariate estimates are not driven by redundancy among predictors. The complete correlation assessment is reported in Annex B.4.2.1.

Bivariate analysis

Table 11 summarises crude associations between selected factors and Tier 1 outcomes. Consistent with the descriptive Tier 1 shares, SP-related occurrences show higher crude odds of Tier 1 outcomes, indicating a stronger unadjusted association than for non-SP-related occurrences. LCC operations exhibit a similar pattern relative to network carrier, the reference operator group. However, the confidence intervals are relatively wide, reflecting the limited number of Tier 1 outcomes and the resulting uncertainty in the estimated magnitudes.

Table 11: Bivariate associations between Tier 1 outcomes and the two study variables (SP-related occurrences and operator groups): crude odds ratios, 95% confidence intervals, and coefficient interpretation

Independent variables	Odds Ratio	95% CI	Direction (OR)	Evidence (CI)
SP-related	2.20	[1.37, 3.54]	Higher in Tier 1	Yes
LCC	1.74	[1.22, 2.47]	Higher in Tier 1	Yes

As SP-related and non-SP-related occurrences may differ in operational context and Tier 1 outcomes are rare, the bivariate associations should be interpreted cautiously and assessed under adjustment. The subsequent regression therefore evaluates whether SP-related status remains associated with higher severity after accounting for key operational characteristics.

Multivariate analysis

Table 12 reports the multivariable logistic regression results. The adjusted odds ratios for SP-related status and LCC operations remain above 1, indicating higher odds of a Tier 1 outcome for occurrences with these characteristics. However, confidence intervals widen in the multivariable model, reflecting limited precision given the rarity of Tier 1 outcomes. Compared with the bivariate analysis, both odds ratios are slightly higher after adjustment.

Night operations are associated with lower odds of a Tier 1 outcome. The other operational covariates do not show clear independent associations when assessed jointly, potentially as limited inferential resolution at the individual covariate level given the rarity of Tier 1 outcomes.

Operational covariates are nevertheless retained because their primary role is to account for differences in operational context between SP-related and non-SP-related occurrences and to test whether the SP-related association persists under adjustment. To assess the stability of the main findings, additional specifications were estimated by adding and removing subsets of operational controls. Across these reasonable alternatives, the direction of association for SP-related status and LCC operations remained consistent, supporting their interpretation as robust adjusted associations within the limits imposed by rare events outcomes.

As Tier 1 outcomes are rare events, relative measures can appear large even when the absolute probability remains low. The reference profile represents the model's baseline operational scenario, defined by the reference categories for all covariates: a non-SP-related occurrence in a flight operated by a network carrier, during daytime, with no relevant weather conditions, in cruise, and long-haul. Under this reference profile, the probability of having an occurrence reported as Tier 1 is approximately 0.12%.

- Having an odd ratio of 2.42 what means is that holding the other factors at the reference profile, if we consider now an SP-related then this probability goes from 0.12% approximately to 0.29%
- If we now come back to the reference profile conditions and instead of being operated by a network is operated by LCC, as the odd ratio is 1.89, the probability shifts from 0.12% approximately to 0.22%

This translation into absolute terms supports an operationally relevant interpretation: the associations are meaningful for prioritisation, while the underlying risk remains low in absolute magnitude.

Predicted probabilities are conditional on the analytic sample and model specification and should not be interpreted as stable absolute risk estimates. They are provided to convey order of magnitude and are expected to evolve as sample composition, reporting completeness, and available operational covariates change.

Table 12: Summary of the logit regression results for Tier 1 outcomes (OR, 95% CI and coefficient interpretation)

Independent variables	Odds Ratio	95% CI	Adjusted Association	Evidence (CI)
SP-related	2.42	[1.48, 3.96]	Higher in Tier 1	Yes
LCC	1.81	[1.23, 2.67]	Higher in Tier 1	Yes

3.2.3 Conclusions on the analysis of risk areas and safety precursors

Across the RAs considered, the literature review converges on a recurrent set of HF/HP and organisational precursors. From a monitoring perspective, this implies that RAs are more likely to become visible in Safety Outcomes through repeated precursor patterns that can be tracked in occurrence systems (ECR), rather than through RA labels alone.

This analysis examines how the SPs identified in the RA review are reflected in occurrence-based evidence. Using the ECR as the primary data source, it characterises the frequency, severity, and risk profile of SP-related occurrences over time and across operational contexts.

All results rely exclusively on ECR data and should be interpreted considering the database's inherent constraints, including variable completeness, level of quality of occurrence records, and heterogeneous reporting practices across organisations. As the ECR is a live system, the findings reflect the dataset as extracted in December 2025 and may evolve as records are updated or reporting practices mature.

The conclusions are also influenced by the precursor-mapping methodology and by the taxonomy used to identify precursors within ECR records. An occurrence is classified as SP-related when at least one mapped precursor is documented. This designation is descriptive rather than causal: the presence of a precursor denotes an associated or contributing factor, not a proven causal mechanism. Multiple precursors may appear within a single occurrence, so distributions reflect co-occurrence patterns and remain sensitive to classification choices and reporting practices. As this represents an initial iteration of the mapping approach, the methodology may be refined in future cycles through expert input, to strengthen consistency and interpretability.

<u>Safety Operational Indicators</u>

Frequency

"For the scope of the ECR study, increases in SP-related reporting are observed within the occurrence dataset. This reflects growing visibility of HF/HP exposure within the occurrence landscape, although the data cannot distinguish whether this stems from heightened operational pressure, improved detection, stronger reporting awareness, differences in data quality (e.g., better coding for recent occurrences), or patterns related to the geographical distribution or state of the operator. What is clear is that SPs represent a progressively larger share of reported events, with fatigue and communication-related precursors accounting for most of this growth."

The following quantitative indicators underpin this overall conclusion and provide further detail on how SP-related reporting has evolved over the study period.

- SP-related reporting grows faster than non-SP reporting across both the pre-COVID period and the post-COVID recovery, indicating that SPs are gaining relative weight within the reporting landscape.

- When adjusting for traffic exposure, a similar pattern emerges. From 2019 onwards, the SP-related occurrence rate increases year-on-year after 2021, indicating that the observed growth cannot be attributed to traffic recovery alone.
- The composition of SP-related reporting has become increasingly concentrated in a small set of precursors, with a marked shift in the post-COVID period.
    - Fatigue dominates the profile in 2024, accounting for nearly 60% of all SP-related occurrences and driving much of the overall growth. Lack of communication remains the second most prominent precursor, around 18% in 2024.
    - Beyond these leading contributors, a second tier of precursors, such as lack of knowledge (5.7%), lack of resources (5.6%) and workload (5.0%), provides additional insight into recurring human and organisational vulnerabilities. Other precursors with smaller but non-negligible shares are distraction (3.3%) and lack of awareness (2.8%).

Impact

"Severity indicators show that the growth in SP-related reporting reflects an expansion in lower-severity occurrences rather than an increase in accidents or serious incidents. The latter Tier 1 outcomes remain rare and have decreased relative to traffic exposure. Within this small subset, the precursor pattern indicates that escalation risk is more closely associated with lack of communication and awareness factors. Fatigue, which stands out as the main precursor in volume, is concentrated in lower-severity reporting rather than in the high-severity."

This conclusion is supported with the following indicators.

- Across 2015–2024, Tier 1 outcomes represent a very small share of both SP-related and non-SP-related occurrences and are highly sensitive to reporting volume and classification practices. From 2021 onwards, Tier 1 shares are marginally higher in non-SP occurrences, but the differences are negligible. Recent increases in SP-related reporting therefore do not translate into a higher proportion of accidents or serious incidents compared with the non-SP reporting landscape.
- Within SP-related occurrences, Tier 1 outcomes have decreased relative to traffic exposure compared over the years. Therefore, when SPs are reported, they are predominantly associated with lower-severity occurrences, particularly *Incidents* and to a lesser extent *Observations* rather than with an increase in serious outcomes.
- The precursor breakdown adds an important nuance to the severity profile.
    - In Tier 2, fatigue dominates and shapes the overall SP-related composition, meaning that the increase in fatigue reporting is largely reflected in lower-severity outcomes.

- In Tier 1, however, the precursor pattern shifts: lack of communication and, to a lesser extent, lack of awareness and lack of knowledge, account for a proportionally larger share of high-severity SP-related occurrences than their corresponding share in Tier 2.

Risk Assessment

"ERCS analysis indicates that SP-related occurrences do not exhibit a higher system-level risk profile than non-SP occurrences. High-risk classifications remain rare in both groups, and most SP-related reports fall within low-risk categories, reflecting the strong influence of high-volume precursors such as fatigue. Lack of communication and awareness precursors, although less frequent, appear more often in the subset of SP-related occurrences with higher ERCS assessments, consistent with their greater representation in the few Tier 1 cases, meaning that within the precursor group they are associated with comparatively higher-risk situations."

The ERCS-based assessment, available from 2023 onwards and currently reaching approximately 70% data completeness, complements the severity analysis by incorporating both outcome severity and escalation potential, including indications of whether safety barriers remained effective.

- At aggregate level, ERCS profiles for SP-related and non-SP-related occurrences are broadly comparable. *High-risk* classifications remain rare in both groups, increasing only slightly in 2024 from a low base. Most occurrences fall into *low-risk* categories, and SP-related reports show a higher proportion of *no safety impact* outcomes, while non-SP occurrences present a marginally higher share of medium-risk assessments.
- This aggregate pattern aligns with the composition of SP-related reporting. Fatigue, by far the most frequent precursor, tends to be associated with lower aggregated ERCS scores, indicating that it functions primarily as a high-frequency exposure signal rather than a consistent contributor to higher-risk outcomes.
    - Conversely, lack of communication, awareness, knowledge and distraction precursors, although lower in overall volume, are proportionally more represented in the limited subset of SP-related occurrences with higher ERCS assessments. This pattern aligns with their greater relative presence in the few Tier 1 cases, indicating that these precursors feature more often in the small set of higher-severity SP-related situations.

Inferential Analysis

"Inferential analysis shows that some SP-reporting patterns differ between low-cost and network carriers even under comparable operational conditions. When examining severity, SP-related occurrences display higher conditional odds of Tier 1 classification once operational factors are considered, although the absolute probability remains low and subject to rare-event sensitivity and sample constraints."

The inferential analysis provides an additional insight to understand Safety Precursors relate to operator type and reported severity once operational conditions are taken into account. Two complementary perspectives were analysed: the distribution of SPs across operator groups, and the association between SP presence and outcome severity. While the inferential models control for key operational factors such as night operations, weather, flight phase and haul type, the operator variable captures the residual differences between these carrier types that may stem from organisational practices, crew management approaches or reporting culture.

Both analyses focus on 2024 data and on low-cost and network carriers, as this subset concentrates most reported occurrences and offers sufficient volume and operational comparability to enable robust multivariable modelling.

In this context, the inferential results should be viewed as a first methodological step that provides magnitude insight and helps demonstrate the analytical potential of the reporting system; as coverage and maturity of reporting improve, these analyses are expected to become progressively more stable and informative.

Association between SPs and operator groups

Overall, the attenuation of crude differences after introducing operational controls indicates that part of the raw LCC–network gap is explained by differences in operational profiles, reinforcing the need to interpret group differences considering the operational context.

After adjustment for available operational covariates, lack of communication, lack of awareness and lack of knowledge remain more likely to be reported in LCC occurrences than in network-carrier occurrences, and the relatively low dispersion across operators suggests these are broad group-level patterns.

By contrast, fatigue (and to a lesser extent workload and lack of resources) shows substantial heterogeneity across operators, indicating that any group-level signal may be driven by subsets of airlines and is therefore best treated as a cue for targeted follow-up rather than a uniform sector-wide difference.

Association between severity and SPs

After comparing occurrences under broadly similar operator group and operating conditions, SP-related tagging remains associated with higher odds of Tier 1 classification in the 2024 analytic sample. However, because Tier 1 outcomes are rare, the absolute probability remains low and the magnitude should be interpreted mainly in terms of direction and prioritisation value.

This pattern does not fully mirror the system-level SOI severity picture, where Tier 1 shares appear broadly similar between SP and non-SP groups in recent years. The difference is likely driven by rare-event sensitivity and coverage constraints: the inferential model is necessarily restricted to records with complete operator and covariate information (and to LCC/network), which can change the composition of both comparison groups relative to the full SOI series. In practical terms, this is not just a statistical caveat—it highlights a regulatory-relevant limitation: severity inference and risk prioritisation become materially constrained when operator tagging and contextual fields are incomplete or inconsistently populated.

3.3 Other relevant analysis

This section presents a set of additional analyses that go beyond the two main analytical pillars of this study, the use of KSIs to support the assessment of RA, and the use of SPIs to inform the evaluation of SPs.

First, the section introduces an approach to enable the comparison of survey-based KSIs across different operator groups with operational data provided by participating operators. Within the scope of this study, three KSIs have been selected as illustrative examples, as they were directly comparable with the available operational datasets. The analysis demonstrates how perceived conditions reported in the surveys can be systematically contrasted with observed operational practices. While only a limited number of KSIs are presented, the proposed approach is scalable and can be extended to additional indicators, subject to the availability and consistency of relevant operational data.

Second, the section examines the situation of the pilot profession in Europe, drawing on a set of survey questions addressing career attractiveness, working conditions, and longer-term professional outlook. This analysis provides contextual insight into broader labour market dynamics affecting pilots and helps observe the current and evolution of the European aviation workforce.

Third, a statistical analysis is conducted to identify groups of survey questions that capture common underlying concepts. Through factor analysis and internal consistency testing, individual items are aggregated into higher-level dimensions. These are then analysed across operator groups, allowing for a more robust assessment than relying on single survey questions, and thereby strengthening the interpretative power of the results.

Finally, the section briefly addresses the qualitative insights obtained from the open question, with the aim of identifying the topics most frequently raised by respondents. This analysis provides an indication of which issues are most important to respondents, including topics that may already have been addressed elsewhere in the report.

3.3.1 Cross-source analysis: Survey & Operator data

This subsection presents a cross-source analysis comparing selected survey-based indicators with operator-reported operational data. The objective is to assess the degree of consistency between perceived conditions reported by respondents and observed operational practices, and to illustrate how survey results can be compared using additional data sources form operator groups.

3.3.1.1 Context & evolution of the case study approach

The original study design envisaged the development of three targeted case studies intended to complement the quantitative evidence derived from the survey and other data sources. These case studies were conceived as qualitative deep dive exercises with three main purposes: first, to explore potential causal links between selected KSIs and specific socio economic or risk related factors; second, to validate or contextualise broader statistical patterns by incorporating real world operational insights; and third, to extract practical lessons that would support the refinement and future scalability of the methodology.

Because of time constraints and difficulties in coordinating the expected level of data provision, it was not possible to fully implement the planned case studies. Nevertheless, two operators, one representing a low cost model and the other an ACMI model, voluntarily provided partial datasets containing internally monitored metrics relevant to several KSIs. Although these datasets no longer allow for the development of a complete case study in the original sense, they still offer valuable operational evidence. For this reason, the available information was repurposed into a focused cross source comparison aimed at assessing the consistency between survey based indicators and operator reported observations, particularly in those areas where the data are factual and directly comparable.

3.3.1.2 Methodological adaptation

Given the limited but structured nature of the data received from the participating operators, the comparison focused on a small and representative subset of KSIs for which both operators supplied metrics or measurable proxies. The selection process considered three key criteria:

- Relevance to the operational context of both contributing operators;
- Strong representation and reliability of the indicator within the survey results;
- Analytical suitability for examining alignment or divergence between perceived conditions and observed operational metrics.

Although a larger number of KSIs could, in principle, be explored through a cross operator comparison, operators do not monitor the same types of operational data, and the level of detail and availability of information varies across organisations. For this reason, the analysis first reviewed all data shared by each operator to identify indicators for which a genuine basis for comparison existed. From this review, only a subset of KSIs was selected. This subset is sufficiently representative to demonstrate that cross source comparisons are feasible and that operator sourced evidence can meaningfully support or enrich the construction of certain KSIs. It also provides a practical illustration of how future iterations of the Article 89 process could increasingly incorporate operational data, thereby complementing survey based information, litrerature review and ERC data analysis.

To ensure comparability, operator reported data was normalised where required and adapted so that they could support, with as much fidelity as possible, the reconstruction of the selected KSIs.

3.3.1.3 Comparative KSI results and analysis

The analysis focuses on assessing consistency between reported perceptions and observed operational practices, with the aim of strengthening confidence in the selected indicators. Based on the data obtained, this cross-source comparison could be performed for three KSIs. While limited in scope, this exercise demonstrates that, if additional operator data become available from other operator groups, the same approach could be replicated to extend further reinforce the robustness of the study.

KSI FM01 – Commander fuel discretion

KSI FM01 (Commander fuel discretion) refers to the extent to which pilots are using commander's discretion to uplift fuel beyond planned operational requirements. The indicator is intended to reflect operational decision-making behaviour in situations where fuel policies, cost considerations, and safety margins may interact.

The survey-based analysis of KSI FM01 presented in Section 3.1.2.2.6 highlights a differentiation across operator groups. Flight crew operating in LCC environments reported a higher propensity to use commander's discretion compared to those operating under ACMI models. Approximately 80% of LCC respondents indicated that they were very likely to use discretion to uplift fuel beyond standard operational requirements, compared to around 55% among respondents operating in ACMI contexts. This pattern suggests a higher perceived uplift of discretionary fuel decisions within LCC operations.

To further contextualise these perceptions, operator-reported operational data was reviewed for the two participating operators. Figure presents the monthly discretionary fuel uplift reported by each operator, aggregated over the 2025 period.

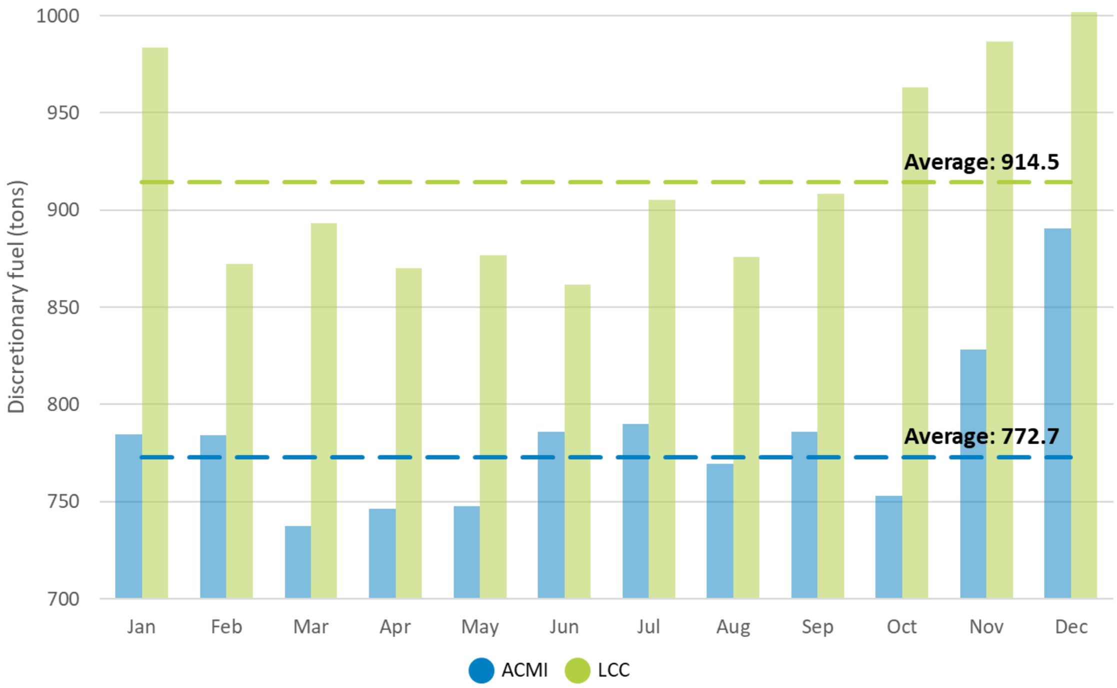


Figure 52: Monthly discretionary fuel uplift by operator type (2025)

The operator group data similarly indicates higher discretionary fuel uplift levels for the LCC operator compared to the ACMI operator across the observed period. On average, discretionary fuel uplift is approximately 18% higher for the LCC operator (914.5) than for the ACMI operator (772.7). While absolute values are influenced by network characteristics and operational profiles, the difference between the two models suggests an alignment between reported perceptions in the survey and observed operational practices captured through operator-reported data.

To contextualise the magnitude of the discretionary fuel uplift observed in the operator data, external industry evidence suggests that the carriage of additional fuel beyond planned requirements is a common operational practice aimed at increasing operational robustness against uncertainties such as delays, weather deviations, and air traffic control constraints. For example, operational analyses published by Honeywell indicate that, in a representative airline context, approximately 4.48% of total fuel consumption is attributable to unused fuel carried to destination, while around 1.04% is associated with fuel uplifted above what could be considered a reasonable buffer. Although these percentages are not directly comparable to the absolute values reported here, they provide an order-of-magnitude reference indicating that discretionary fuel margins of the scale observed in this study are not atypical in airline operations[30].

KSI WS03 – Perceived staffing shortage

KSI WS03 (Perceived staffing shortage) refers to the extent to which staff report that their department does not have sufficient personnel. The indicator reflects perceived staffing adequacy at operational level and is particularly relevant in contexts where resilience relies on the availability of standby resources.

The survey-based analysis of KSI WS03 in Section 3.1.2.2.12 indicates differences across operator types. In low-cost carrier (LCC) environments, 32.5% of flight crew and 39.4% of cabin crew respondents strongly agreed that staffing levels are insufficient to manage daily workload safely and effectively. By comparison, the corresponding proportions among respondents operating under ACMI models were lower, at 23.1% for flight crew and 28.4% for cabin crew. These results point to a higher perceived staffing strain within LCC operations across both crew groups.

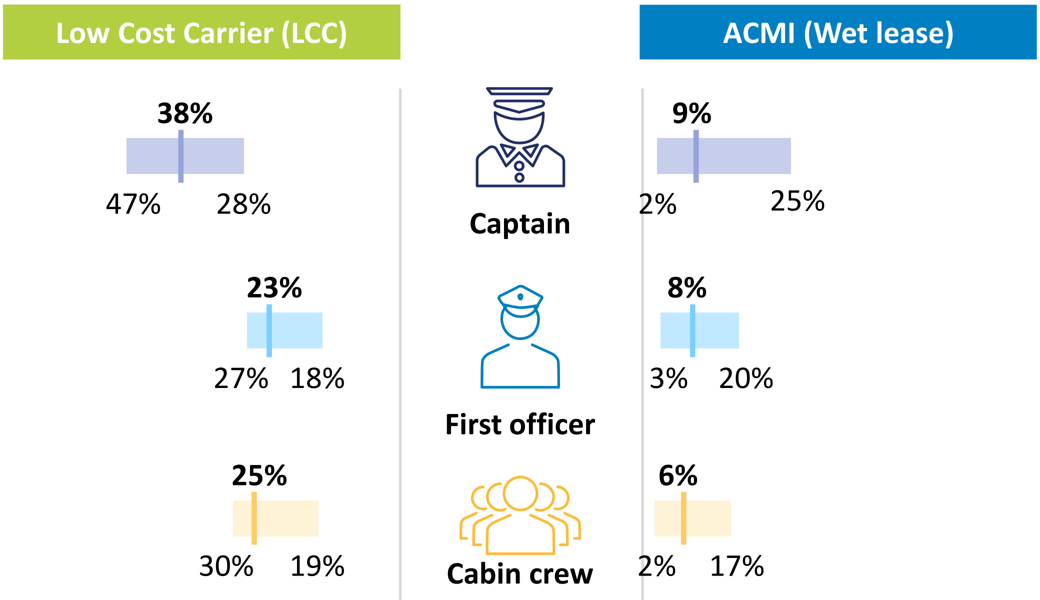


Figure 53 presents the standby crew activation rate for the two participating operators, disaggregated by role.

Figure 53: Standby crew activation rate by role and operator type.

[30] Honeywell Aerospace. (2019). *Managing Contingency Fuel Uplift with Advanced Analytics* (White paper No. N61-126-000-001). Honeywell International Inc.

The operational data show higher standby activation rates for the LCC operator across all roles compared to the ACMI operator, with the most pronounced differences observed for captains. While this pattern reflects a greater reliance on standby resources to absorb short-term operational variability, the absolute activation levels observed remain within ranges commonly reported in airline reserve-crew planning literature. It should be noted that standby is designed to offer operational resilience by accepting that there will be unplannable contingencies.

From an operational-resilience perspective, published research indicates that standby or reserve crew utilisation is typically expected to operate at levels of up to approximately 40%[31], depending on network structure and seasonality. Against this background, the activation rates observed in the operator-provided data appear to remain contained and do not, in themselves, indicate structural staffing shortages or degraded staffing resilience.

The variability observed across roles and time periods is largely attributable to the seasonality of operations, with peak-season demand requiring higher short-term absorption capacity and consequently increased standby utilisation. In this context, the operational data suggest that staffing buffers remain broadly adequate, even in high-utilisation environments.

These findings also highlight a potential divergence between operational data and perception-based indicators. While the survey-based KSI WS03 captures higher perceived staffing pressure among personnel operating in LCC environments, the available operator data do not show corresponding evidence of sustained understaffing, suggesting that perceived pressure does not necessarily translate into measurable staffing shortfalls in reported operational practice.

This divergence is likely attributable to the limitations of survey acquired data, more prone to self-selection bias. As a result, similar divergences between objectively verifiable operational data and perception-based indicators should be expected across other KSIs derived from the same survey framework.

KSI PD02 – Frequency of Commander's discretion use

KSI PD02 (Frequency of discretion use) refers to the extent to which crew report using Commander's Discretion as a regular rather than an exceptional event. The indicator reflects how frequently discretion is applied within routine operations instead of being limited to isolated or exceptional circumstances.

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[31] Sohoni, M. G., Lee, Y., Klabjan, D., & Johnson, E. L. (2011). *Operational airline reserve crew planning*. **Transportation Science, 45**(3), 331–344.
https://www.researchgate.net/publication/220366542_Operational_airline_reserve_crew_planning

The survey-based analysis of PD02 presented in Section 3.2.1.9 highlights differences across operator groups. Among flight crew operating in LCC environments, 33.95% of respondents indicated that commander's discretion is used frequently rather than as an exceptional measure, compared to 23.6% among those operating under ACMI models. A similar pattern is observed among cabin crew, with 37.5% of respondents in LCC environments compared to 20.5% in ACMI. Taken together, these results suggest a higher perceived normalisation of discretionary practices within LCC operations.

By contrast, operator-reported data indicates lower levels of commander's discretion use in absolute operational terms. According to the data provided, the overall rate of discretion use is approximately 1.22% for the LCC operator and 0.87% for the ACMI operator. While these values confirm that discretion remains an infrequent event within routine operations for both models, and the higher rate observed for the LCC operator mirrors the relative differences identified in the survey responses. A review of the available operational reports indicates that, for the LCC operator, most commander's discretion cases involve FDP extensions of less than one hour. Like in other cases this divergence is likely attributable to the limitations of survey acquired data, more prone to self-selection bias.

From a safety perspective, this divergence between perceived frequency and recorded operational rates does not imply inconsistency or misreporting. Rather, it illustrates the difference between how discretion is experienced and interpreted by crew in day-to-day operations and how it is registered through formal operational metrics, taking into account that only 2 operator data sets have been analysed. In this context, external evidence from a European pilot fatigue survey reports that 18.7% of pilots used commander's discretion to extend the FDP two or more times within a four-week period, a perception-based finding that stands in contrast to the low absolute usage rates reported by operator data[32]. This illustrates the difference between how discretion is experienced and interpreted by crew in day-to-day operations and how it is registered, measured and analysed through formal operational metrics, and subsequently reported to the authority.

3.3.2 EU pilot profession outlook

This subsection provides an overview of the current situation and outlook of the pilot profession in Europe, drawing on selected survey questions related to working conditions, career sustainability,

[32] European Cockpit Association. (2023). A report on a fatigue survey of European pilots (independent analysis by Baines Simmons).

https://www.eurocockpit.eu/sites/default/files/2023-08/A%20report%20on%20a%20fatigue%20survey%20of%20European%20Pilots_2023_FINAL.pdf and professional perspectives. The analysis offers contextual background to the survey findings and helps frame the results within broader European labour market dynamics affecting the pilot workforce.

Overlook on pilot future supply

Survey responses indicate a predominantly pessimistic outlook regarding the future supply of qualified pilots in the EU over the next five years. A clear majority of respondents expect the situation to deteriorate, with 37% anticipating a slightly worse situation and a further 25% expecting a significantly worse outcome. By contrast, only around 8% of respondents in total expect an improvement (either slightly or significantly), while the remainder anticipate stability or express uncertainty.

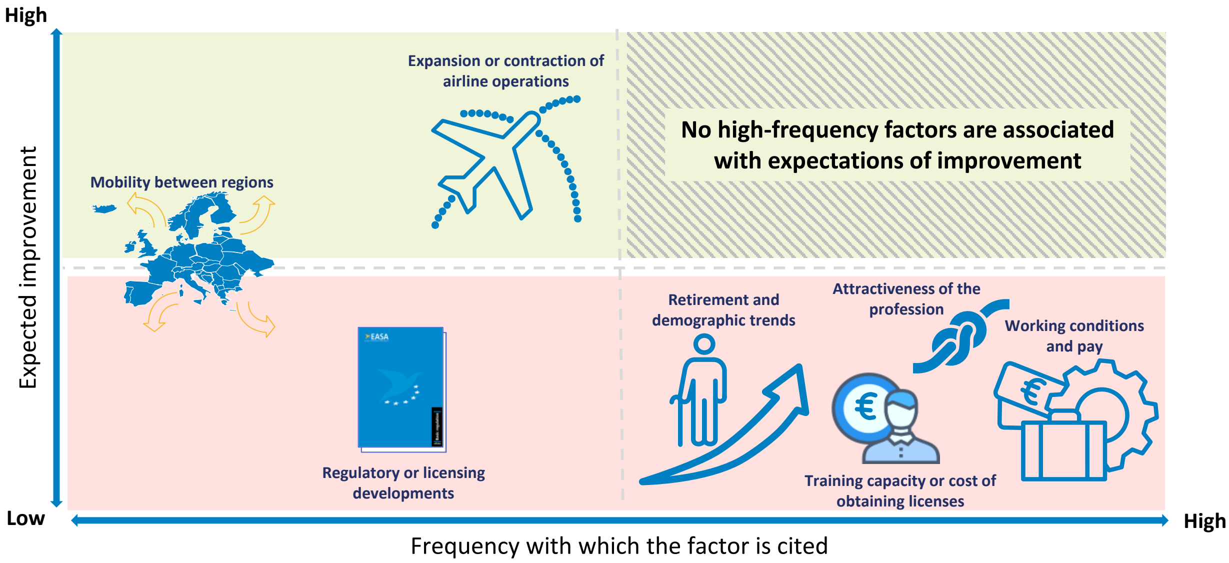

Figure 54: Perceived drivers shaping expectations of future pilot supply in the EU.

Among respondents who expect a deterioration in pilot supply, the perceived drivers are concentrated around three core dimensions. The most frequently factor is the attractiveness of the profession, followed by working conditions and pay, and by training capacity or the cost of obtaining licences. This aligns with wider sector evidence showing that working conditions remain a structural concern for aircrew[33]. For the smaller group of respondents who anticipate an improvement, the reasons cited partially overlap with those identified by pessimistic respondents. Attractiveness of the profession again emerges as a key factor, but in this case, it is typically

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[33] Ghent University (UGent) in cooperation the EU Social Partners ENAA (European Network Airlines Association), ECA (European Cockpit Association) and ETF (European Transport Workers Federation), Evolving Social Challenges for Aircrew and the Need for Regulatory Response. https://www.eurocockpit.eu/news/eu-study-highlights-aviation-safety-concerns-linked-regulatory-social-gaps

associated with expansion or contraction of airline operations and with potential improvements in working conditions and pay.

Notably, several dimensions appear to have limited influence on expectations in either direction. Mobility between regions or operators, regulatory or licensing developments, and other unspecified factors are rarely identified as decisive drivers of change, whether positive or negative.

Overall, the results indicate that the future evolution of pilot supply in Europe is primarily determined by two factors: the attractiveness of the profession and working conditions and pay. These dimensions dominate expectations in both positive and negative directions. If these two levers are effectively managed, stakeholders may have the ability to shift the balance of pilot supply in their favour. Conversely, failure to address them is likely to reinforce a worsening supply outlook, regardless of other regulatory or structural measures.

Pilot mobility perceptions and individual intentions

Beyond expectations about future supply, survey responses also provide insight into pilot mobility patterns. In this context, results point to a perception that European pilots are increasingly leaving EU airlines to work in other regions of the world. Around 40% of respondents observe this happening frequently, with a further 34% reporting that it occurs occasionally. This perception is consistent with recent sector-level evidence indicating that experienced European pilots are increasingly attracted to fast-growing markets outside the EU, particularly in the Middle East or China, where airlines offer more competitive remuneration packages and employment conditions, driven by strong traffic growth and sustained demand for flight crew.[34]. By contrast, only 8% indicate that they have not observed such movements at all.

[34] European Labour Authority (ELA), Sector analysis on air transport, June 2025. https://www.ela.europa.eu/sites/default/files/2025-06/Sector_analysis_on_air_transport.pdf

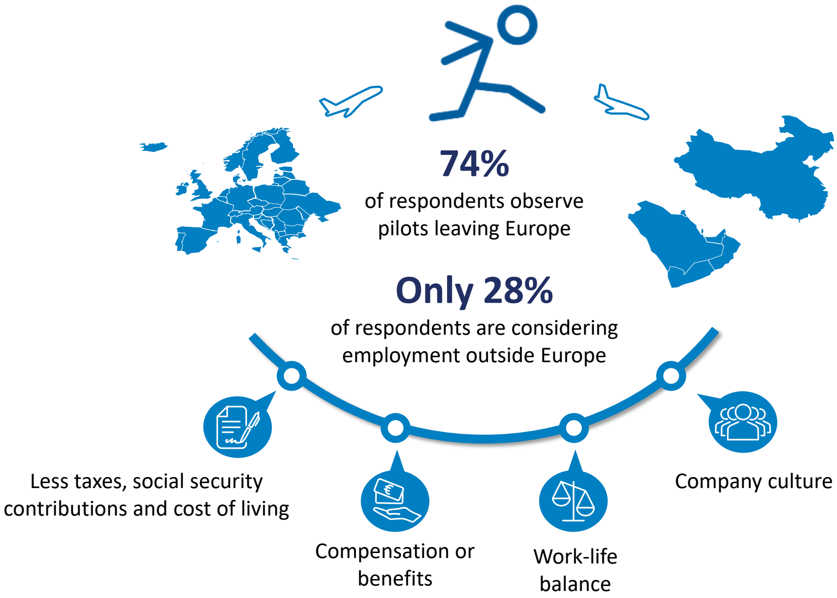

Figure 55: Gap between perceived pilot mobility trends and individual intentions.

However, when shifting from perception to individual intentions, a notable discrepancy emerges. Despite the widespread belief that pilots are leaving Europe, only 13% of respondents state that they are very likely to seek employment outside Europe within the next 12 months, while around 40% consider it very unlikely. This contrast highlights a gap between what pilots observe in the market and what they personally plan to do. Most pilots in this group do not identify a concrete push factor motivating a move away from their current company.

For the 28% of respondents who are likely or very likely to consider employment outside Europe, motivations are primarily poor work–life balance and better compensation or benefits, followed by dissatisfaction with management or company culture and high taxes, high social security contributions and high cost of living. By contrast, factors such as career progression constrained by seniority-based systems, limited career growth due to lack of airline expansion, and personal reasons play a marginal role in shaping decisions, suggesting that these dimensions are either already adequately addressed within Europe or do not offer a comparative advantage in external markets.

Overall, the analysis shows that decisions to stay or leave are not primarily driven by career structure or personal circumstances, but rather by economic pressures and quality-of-life considerations. Compensation levels, taxation, work–life balance, fatigue and company culture emerge as the decisive levers shaping pilot mobility. If these factors are not effectively addressed, the strong perception of outward pilot flows risks translating into a sustained shortage of experienced pilots within the European aviation sector.

Access to the profession and overall attractiveness

Beyond mobility dynamics, survey responses also offer perceptions affecting access to the pilot profession. Respondents indicate that the largest barrier to new talent becoming a pilot in the EU is the high financial cost of training and licensing (31%), which it was one of the main concerns related to the future of pilots supply. This aligns with industry evidence that, in practice, the key entry requirement has increasingly become the ability to self-finance training, with training costs commonly cited at approximately €100,000. [35]

Beyond cost, the next most selected barriers relate to whether the profession feels sustainable over time: uncertainty about career stability and job security (24%) and a perceived lack of work–life balance (19%). Importantly, the "work–life balance" concern is consistent with findings from pilot sleep/fatigue research: early duty start times materially restrict sleep opportunity, with the strongest restriction observed for duties starting around 04:00–05:00, where pilots obtain around 5.5 hours of sleep on average prior to duty. Taken together, the pattern is coherent: entry is constrained primarily by upfront affordability, and the profession's appeal is further weakened by concerns about stability and the physiological reality of fatigue. [36]

To complement the analysis of specific drivers affecting pilot supply and mobility, respondents were asked to provide an overall assessment of how the attractiveness of the pilot profession in Europe has evolved over the past five years. The responses point to a clear and consistent deterioration in perceived attractiveness. A substantial majority of respondents consider the profession to be less appealing today than five years ago, with around 46% rating it as less attractive and a further 20% as much less attractive. Taken together, this indicates that nearly two thirds of respondents perceive a sustained decline in the profession's appeal over time. By contrast, only a very small minority perceive an improvement, with around 1% stating that the profession is much more attractive than five years ago.

3.3.3 Survey question grouping

Following the analysis of the survey data, Kaiser-Meyer-Olkin (KMO) testing and exploratory factor analysis explained in Section 2.3.5.1. These results provided a basis for the identification of statistically driven groupings of survey questions. In parallel, additional groupings were defined manually based on conceptual alignment where relevant dimensions, not always fully captured through purely data-driven clustering, were adequately represented.

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[35] European Cockpit Association (ECA), *Pilot shortage in Europe: Fact or fiction?* https://www.eurocockpit.eu/positions-publications/pilot-shortage-europe-fact-or-fiction

[36] Roach et al. (2012), Duty periods with early start times restrict the amount of sleep obtained by short-haul airline pilots. https://pubmed.ncbi.nlm.nih.gov/22239926/

The underlying rationale for this approach is that individual survey questions act as partial indicators of broader latent constructs. Grouping conceptually aligned questions allows these constructs to be represented more robustly, reducing item-specific noise and providing a more stable analytical basis than single-item analysis.

All groupings resulting from both approaches were subsequently subjected to internal consistency testing using Cronbach's alpha. This step aimed to verify whether the selected questions within each group consistently measure the same underlying construct and can therefore be meaningfully aggregated. Only groupings demonstrating acceptable internal consistency were retained.

While the resulting scores do not represent perfectly normally distributed variables, their aggregation provides a smoothed approximation of the underlying construct behaviour, which is suitable for comparative analysis across operator groups when interpreted with appropriate caution. The aggregated indicators are therefore used to support relative comparisons and pattern identification, rather than precise distributional inference.

For clarity and analytical focus, the grouping exercise for flight crew and cabin crew is presented only for the ACMI, LCC, and network operator groups, which are considered of greater relevance for the objectives of this study. In the case of cabin crew, the scope of the grouping is further limited by the survey design, as cabin crew respondents were not exposed to the full set of questions used for flight crew. As a result, not all analytical dimensions could be consistently assessed across both personnel categories.

Accordingly, Table 13 presents the subset of validated survey question groupings retained for flight crew, limited to those demonstrating acceptable internal consistency based on Cronbach's alpha. The table summarises the final validated groups, the associated questions, and the corresponding Cronbach's alpha values.

Table 13: Validated survey question groupings.

Group name	Origin	Questions	Rationale	Cronbach alpha value (α)
Mental health	KMO	Q72, Q73, Q74, Q75, Q76	Captures self-reported psychological strain linked to sustained operational demands and workload.	FC: 0.913 CC: 0.914
Safety culture and reporting	KMO	Q49, Q67	Reflects confidence and perceived fairness in reporting errors or fatigue without negative consequences.	FC: 0.717

FTL boundary pressure	KMO	Q19, Q20, Q59	Measures perceived proximity of duty patterns to regulatory or contractual flight time limits.	FC: 0.884 CC: 0.798
Commander's discretion	KMO	Q35, Q40, Q41, Q61	Captures operational and organisational drivers influencing the use of commander's discretion.	FC: 0.760
Cross-AOC clarity	Manual	Q52, Q54, Q55, Q56, Q58	Captures clarity and confidence when operating under a different Air Operator Certificate (AOC).	FC: 0.856
Management pressure on safety decisions	Manual	Q17, Q40, Q60, Q71, Q93	Reflects perceived organisational pressure affecting safety-related decision-making.	FC: 0.691

The Cronbach's alpha results reported indicate that the selected question groupings demonstrate acceptable internal consistency, supporting their aggregation into composite dimensions. The following sections present the results for each composite dimension derived from the survey. For each dimension, aggregated scores are analysed to identify relative differences across operator groups. In general, higher scores indicate more favourable conditions, reflecting that the underlying dimension is perceived as being better addressed.

3.3.3.1 Mental health

This dimension captures self-reported psychological strain associated with sustained operational demands and workload. It aggregates multiple survey items reflecting fatigue, stress, and mental well-being, providing an integrated view of perceived mental health conditions across operational contexts. Figure 56 presents the distribution of the aggregated mental health scores for flight crew and cabin crew.

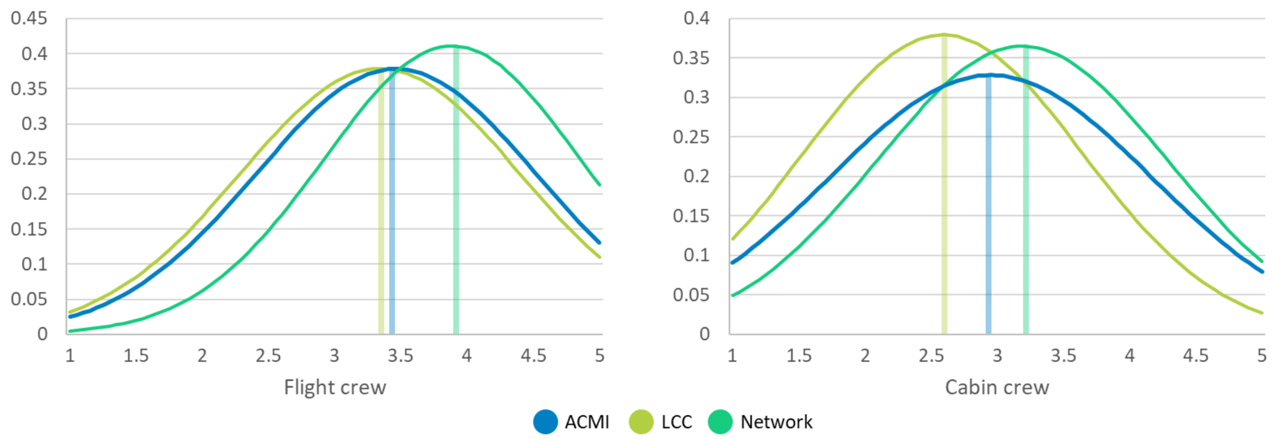

Figure 56: Distribution of mental health scores by operator type.

A clear pattern emerges across ACMI, LCC, and network operators for both flight crew and cabin crew. In general, LCC operations exhibit the lowest scores, indicating poorer perceived mental health conditions. These differences are statistically significant when compared with network operators, both for flight crew ($p < 0.001$) and for cabin crew ($p < 0.001$), confirming a robust separation between these operational models.

ACMI operators occupy an intermediate position and display scores that are closely aligned with those observed in LCC operations. The differences between ACMI and LCC are not statistically significant for either flight crew or cabin crew, suggesting broadly comparable perceived mental health conditions across these two environments.

By contrast, network operators consistently report the most favourable mental health outcomes. This distinction is particularly pronounced for flight crew, where the difference between network and ACMI operators is also statistically significant ($p < 0.001$). For cabin crew, the same ordering is observed, although with greater overlap between ACMI and network distributions, indicating a less pronounced separation across operator groups.

3.3.3.2 Safety culture and reporting

This dimension captures perceptions related to the fairness, transparency, and trustworthiness of organisational reporting systems, particularly regarding the ability to report errors, fatigue, or safety concerns without fear of negative consequences. Figure 57 presents the distribution of the aggregated mental health scores for flight crew. In general, higher scores indicate more favourable conditions, reflecting that the underlying dimension is perceived as being better addressed.

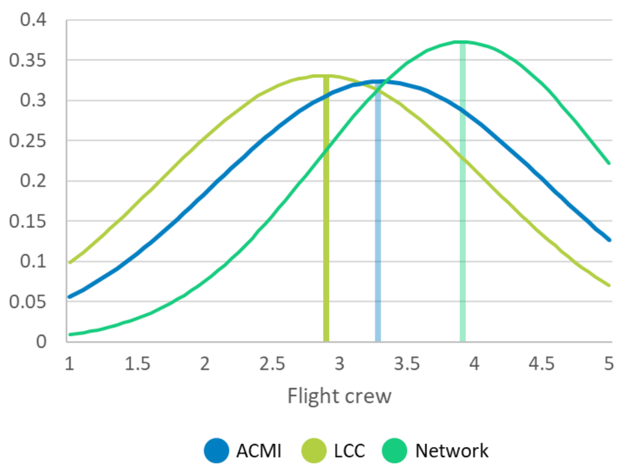

Figure 57: Distribution of safety culture and reporting scores by operator type.

LCC operators report the lowest scores, indicating a less favourable perception of reporting culture. These differences are statistically significant when compared with both ACMI and network operators ($p < 0.001$). ACMI operators occupy an intermediate position, with scores significantly higher than LCC but still significantly lower than those observed in network operators ($p < 0.001$).

Overall, the figure highlights a clear gradient in perceived safety culture and reporting, ranging from less favourable conditions in LCC, through ACMI, to the most favourable perceptions in network operators.

3.3.3.3 FTL boundary pressure

This dimension captures the perceived proximity of duty patterns to regulatory or contractual FTL boundaries. It reflects how frequently crews experience operations planned close to maximum allowable limits, providing insight into perceived scheduling pressure across different operational models.

Figure 58 presents the distribution of the aggregated mental health scores for flight crew and cabin crew.

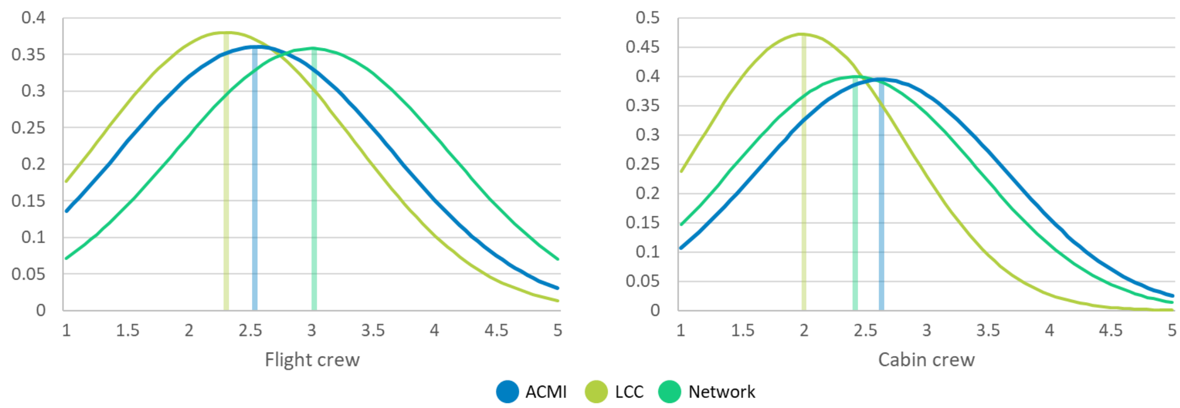

Figure 58: Distribution of FTL boundary pressure by operator type.

Flight crew and cabin crew exhibit distinct patterns, particularly in the comparison between ACMI and network operators. For flight crew, ACMI operators report significantly lower scores than network ($p < 0.001$), indicating that duty patterns are more frequently experienced as operating close to regulatory or contractual FTL limits. In this group, LCC shows the lowest scores, indicating high perceived pressure, with statistically significant differences compared to network operators ($p < 0.001$).

For cabin crew, the pattern differs. No statistically significant difference is observed between ACMI and network operators, with substantial overlap between their distributions. While LCC again reports the highest perceived FTL boundary pressure, with scores significantly below both ACMI and network operators ($p < 0.001$), the absence of a clear ACMI–network separation suggests that perceived scheduling pressure manifests differently for cabin crew than for flight crew.

3.3.3.4 Commander's discretion

This dimension captures the operational and organisational factors influencing the use of commander's discretion, particularly in situations where duty limits, scheduling constraints, or operational disruptions require flexibility.

Figure 59 presents the distribution of the aggregated mental health scores for flight crew.

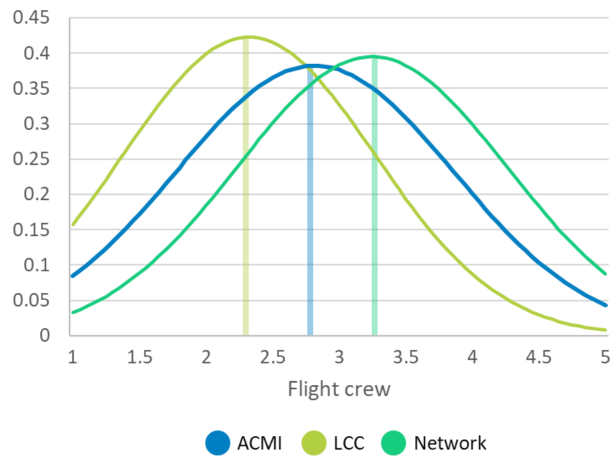

Figure 59:Distribution of commander's discretion scores by operator type.

The figure highlights a clear separation between network and LCC operators. Network operators report markedly higher scores, indicating lower use of commander's discretion, while LCC operators show the lowest values, with a difference close to one full point that is highly statistically significant ($p < 0.001$). ACMI operators fall in between, scoring significantly higher than LCC but still significantly lower than network operators ($p < 0.001$). Overall, the results indicate a clear gradient in the perceived use of commander's discretion, from significantly less favourable conditions in LCC (i.e. more use of discretion) to more favourable conditions in network operations (i.e. less use of commander discretion).

3.3.3.5 Cross-AOC clarity

This dimension captures the perceived clarity of roles, responsibilities, and operational procedures when operating under a different AOC. It reflects how clearly crews understand applicable SOPs and organisational interfaces in cross-AOC environments.

Figure 60 presents the distribution of the aggregated mental health scores for flight crew.

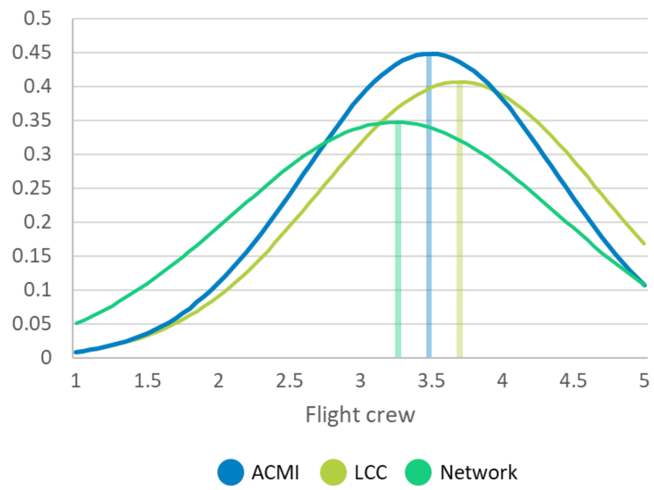

Figure 60: Distribution of Cross-AOC clarity scores by operator type.

In the cross-AOC clarity dimension for flight crew, the pattern differs from that observed in the previous dimensions. Network operators report lower levels of clarity, while LCC operators show the highest scores, indicating a reversal of the typical ordering seen elsewhere. The difference between LCC and network operators is statistically significant ($p \approx 0.03$), supporting the visual separation observed in the figure.

This inversion may reflect structural differences in operational practices. LCC operations may be more frequently exposed to cross-AOC or highly standardised operating environments, which may foster clearer role definition and greater familiarity with operating under varying organisational frameworks. By contrast, network operators may encounter cross-AOC operations less routinely, potentially leading to lower perceived clarity when such situations arise.

3.3.3.6 Management pressure on safety decisions

This dimension captures the perceived influence of organisational and managerial pressures on safety-related decision-making. It reflects whether operational, commercial, or performance objectives are experienced as constraining safety margins, providing insight into how management practices may shape individual decisions across different operational contexts. presents the distribution of the aggregated mental health scores for flight crew.

Figure 61 presents the distribution of the aggregated mental health scores for flight crew.

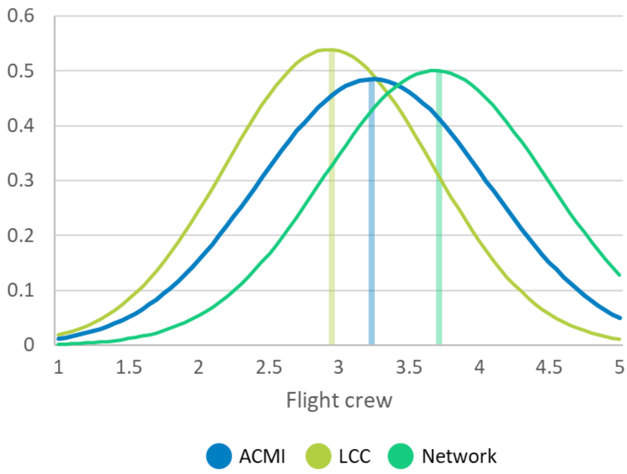

Figure 61: Distribution of management pressure on safety decisions scores by operator type.

In the management pressure on safety decisions dimension for flight crew, the figure again shows LCC operators as the least favourable group, with scores significantly lower than both network operators and ACMI ($p < 0.001$). This pattern suggests that flight crew in LCC environments perceive stronger management-driven pressure affecting safety-related decision-making.

By contrast, network operators report the most favourable perceptions, while cargo and regional operators also score significantly above LCC ($p < 0.001$). A plausible contributing factor is that more demanding rostering practices in LCC operations may translate into a stronger perception of performance pressures, which crews may experience as constraining safety margins when making on-the-day decisions.

3.3.3.7 Overall patterns

Across the dimensions analysed, a consistent pattern emerges by operational model. Low-cost carriers (LCC) tend to report less favourable outcomes across multiple dimensions, including mental health, safety culture and reporting, commander’s discretion, and management pressure on safety decisions. Network operators, by contrast, generally display the most favourable perceptions, while ACMI operators typically occupy an intermediate position, in several cases closer to LCC than to network operations.

Differences between flight crew and cabin crew indicate that these patterns are not uniform across personnel categories. While several dimensions show similar ordering across both groups, others, such as FTL boundary pressure, exhibit distinct behaviours, particularly in the relative positioning of ACMI and network operators. This suggests that the operational drivers shaping perceived risk may differ by role within the same context.

3.3.4 Analysis of survey open responses

The survey included an open question allowing respondents to share any additional concerns or observations they considered relevant to aviation safety ("Please share with us any additional concerns or observations you think are important and could impact aviation safety."). This question provided an issues that may fall outside the predefined survey items or emphasis on problems previously addressed. For the purposes of this assessment, the qualitative review focuses only on the three main operator categories of interest: LCC, network carriers, and ACMI. Out of 4,987 survey respondents, 2,044 submitted a non-empty comment (≈ 41%). Response rates differed by operator type, with higher participation in the open-ended question among LCC and ACMI respondents (both ≈ 49%) compared to network carrier respondents (≈ 38%).

Next, the main recurring themes identified from the open responses are presented. These themes are discussed in order of decreasing frequency of appearance across the comments. The open responses also included additional observations that were mentioned less frequently. While these less recurrent topics may still be relevant at an individual or local level, they are not presented in detail in this section to maintain analytical focus on the most prevalent patterns.

Fatigue, rostering practices, and recovery limitations

Fatigue-related issues are the most recurrent theme overall and are particularly dominant among LCC respondents, where they are mentioned in approximately 50% of comments, compared to 35% in network and 45% in ACMI. Concerns frequently relate to rosters being perceived as planned close to limits, insufficient real-world recovery despite formal rest compliance, and cumulative fatigue driven by improper management of operational disruptions. Within LCC comments, fatigue is often explicitly tied to rostering practices such as last-minute changes, standby utilisation and tight scheduling.

Commercial and operational pressure

A second dominant theme relates to perceived pressure to protect operational performance (e.g., punctuality, disruption recovery, schedule completion). This is most prominent in LCC comments (approximately 30%) and less frequent in network and ACMI. Where raised, respondents often frame pressure as shaping safety-relevant decisions indirectly, for example reluctance to disrupt operations or perceived pushback after conservative choices. In LCC responses, fatigue and pressure are frequently discussed together, indicating that respondents perceive an interaction between tight operational targets and reduced recovery margins.

Employment conditions, contractual arrangements, and financial stressors

A share of comments link safety concerns to employment conditions (pay stability, sick pay, contract structures, job security). This theme is particularly pronounced among ACMI respondents

(26%) and LCC (22%), while appearing less frequently in network. In ACMI comments, employment conditions are more often described as structurally connected to mobility. In LCC comments, employment-related concerns are more often framed around productivity expectations and the financial consequences of unfitness declarations.

Safety culture and reporting confidence

Mentions of reporting confidence shortcomings are more frequent in LCC than in network or ACMI. Where raised, respondents often highlight a perceived gap between formal Just Culture messaging and lived experience, including hesitancy to report fatigue or operational concerns due to fear of negative consequences or reprimands.

High-Level Conclusions on Risk Areas (RAs) and Safety Precursors (SPs)

Risk Areas (RAs)

Pilot retirement age – No demonstrated safety risk identified. Workforce remains broadly mature across most operator models, with LCCs showing a younger demographic profile. Pilots above 65 remain a limited proportion overall.

Home base changes – Identified as a potential operational and fatigue-related vulnerability, particularly where frequent mobility, commuting burden and temporary accommodation reduce recovery opportunities and affect work-life balance.

Crew interoperability – ACMI operations show structurally higher exposure to cross-AOC operations. However, no widespread evidence of procedural confusion was identified where interoperability frameworks are mature and embedded.

ACMI operational model – Associated with differentiated socio-economic conditions, including mobility and contractual complexity, but no direct causal link to adverse safety outcomes was demonstrated.

Atypical employment contracts – More frequently reported in ACMI and LCC contexts. Findings indicate possible effects on reporting confidence and perceived job security, rather than direct evidence of reduced safety performance.

Commercial pressure / operational pressure – Recurrently identified as an enabling condition linked to fatigue, stress and presenteeism, particularly in relation to roster pressure and operational efficiency demands.

Workforce shortages – Considered a relevant systemic pressure contributing to workload concentration, reduced resilience and reduced recovery margins, especially in operationally constrained environments.

Commander discretion usage – Differences observed across operator groups, with some indications of higher operational pressure around duty limits. Findings remain indicative and not evidence of non-compliance.

Fatigue management environment – Fatigue emerges as the most visible and consistently reported precursor across surveys, literature and occurrence reporting.

Just Culture / reporting confidence – Reporting hesitancy remains visible in some operator contexts, particularly among younger and LCC respondents, suggesting perception gaps between formal Just Culture policies and day-to-day practice.

Training, knowledge and awareness – No systemic degradation identified, although recurrent concerns remain linked to communication, procedural clarity and operational coordination.

Resource constraints and outsourcing complexity – Fragmented operational structures and subcontracting arrangements may complicate oversight, interoperability and reporting pathways, particularly in ACMI environments.

Safety Precursors (SPs)

Fatigue – Strongest and most internally consistent precursor signal across all evidence sources. Reporting increased significantly between 2019–2024, especially in lower-severity occurrences.

Lack of communication – Second most visible precursor in ECR occurrence data. Mainly associated with coordination breakdowns, incomplete information transfer and interoperability-related operational complexity.

Stress and pressure – Widely reflected in literature and survey indicators, but less directly visible in occurrence reporting data.

Workload – Frequently associated with workforce shortages, operational pressure and reduced recovery opportunities. More visible in survey evidence than in objective occurrence outcomes.

Presenteeism – Identified as a latent organisational vulnerability where personnel continue operating despite reduced fitness due to operational or contractual pressures.

Reduced psychological safety – Potentially affects voluntary reporting behaviour and willingness to report fatigue or operational concerns.

Procedural ambiguity – Limited but visible precursor, mainly in operational contexts involving cross-AOC flying or fragmented operational structures.

Coordination and interoperability issues – More visible in complex or multi-operator environments, although generally not reflected as high-severity occurrence drivers.

Circadian disruption and commuting burden – Recognised as contributing factors to cumulative fatigue and reduced recovery.

Loss of experience / mentoring capacity – Workforce turnover and shortages may weaken operational resilience and supervisory support over time.

Reporting culture variability – Differences in reporting sensitivity and confidence likely influence ECR visibility and should not be interpreted directly as differences in underlying safety performance.

4 Conclusions, lessons learned and recommendations

This section brings together the main outputs of the exercise conducted under the study and presents them in a format intended to support continuity across future cycles. First, it sets out the conclusions drawn from the evidence used in the assessment, keeping the interpretation descriptive and within the defined scope of the analysis. Second, it summarises the lessons learned identified during project execution, reflecting where the practical application of the approach indicates opportunities to refine and improve consistency in future iterations. Finally, these lessons are translated into recommendations aimed at strengthening the application of the framework over time through adjustments across the key steps of the methodology.

4.1 Conclusions

The following section presents the conclusions of the study, based on the methodology proposed to support the assessment of the SEFs Risk Model described in Section 2. The results do not establish causalities but identify empirically observed associations and statistically robust relationships within the available data.

First, a set of cross-cutting conclusions is presented, synthesising the study evidence into the main transferable findings on the observed associations between SEFs, operational conditions, and safety performance at system level. Subsequent conclusions are then organised by RA to contextualise these system-level findings and illustrate how they may manifest in specific operational domains.

For each RA, the report assesses whether KSI patterns align with the SEF-related mechanisms identified in the literature (fully documented in Annex C.1), and whether expected precursors in the literature are reflected in ECR reporting trends. As ECR data do not allow attributing precursors to a specific Risk Area, they are treated as cross-cutting signals. For further details, see Section 3.2.2.

Survey and ECR data are affected by methodological limitations and variations in reporting standards across stakeholders. Accordingly, the conclusions presented are dependent on the available data and should be interpreted strictly within the scope and limitations of those datasets.

Cross-cutting conclusions of the study

"While the literature and KSI patterns point to a broad set of potential HF/HP precursors linked to SEFs, occurrence reporting only shows clear volume signals for fatigue and lack of communication related events, with other precursors not reflected to the same extent. However, the latest EASA Best Intervention Strategy (BIS) on Aircrew Fatigue and related studies highlight large numbers of fatigue reports and high perceived fatigue prevalence, yet they also indicate that clear statistical links to safety occurrences or objective safety degradation are difficult to establish with available data."

Across Socio-economic factors (SEFs), the literature consistently points to a limited set of HF/HP precursors recurring across multiple Risk Areas, and Key Socio-economic Indicators (KSI) patterns indicate that the corresponding enabling conditions are present. However, this breadth is not consistently mirrored in ECR reporting: clear reporting signals are mainly observed for fatigue and lack of communication, whereas other literature-expected precursors are only weakly or inconsistently reflected in the reported sample.

- Fatigue provides the clearest and most internally consistent signal across the evidence base. The literature links fatigue to multiple SEF pathways, KSI patterns suggest that conditions that potentiate this precursor are present across several RAs, and fatigue-related concerns were the most recurring theme across additional survey analysis. This pattern is also reflected in ECR reporting: fatigue reporting increased steadily between 2019 and 2024 and, by 2024, it had become the most frequently reported precursor, being present in almost 60% of SP-related occurrences. Importantly, this increase is not primarily driven by high-severity occurrences. Instead, fatigue is increasingly recorded in lower-severity (Tier 2) events, which may reflect a combination of increased operational exposure together with greater reporting sensitivity and awareness within the reporting system. Furthermore, this could also reflect significant variations across NCAs in reporting standards and requirements.

  This interpretation should be considered in the context of the Safety Impact Assessment (SIA) conducted in support of the EASA Best Intervention Strategy (BIS) on Aircrew Fatigue. The SIA similarly observed an increase in fatigue-related reporting in the European Central Repository (ECR), including indicators such as the use of commander's discretion. However, the SIA also highlights significant limitations in the available occurrence data. In particular, the quality and completeness of information contained in ECR occurrence records were found to be insufficient to reliably determine the underlying causal factors associated with fatigue events. Follow-up information is often missing, and the contextual elements necessary to understand the operational drivers of fatigue are frequently absent. As a result, the SIA concludes that occurrence reporting alone does not provide a sufficiently robust basis for a comprehensive assessment of fatigue risk and that additional sources of information — particularly findings from oversight activities related to Flight Time Limitations (FTL) and Fatigue Risk Management (FRM) — are required to obtain a complete picture of fatigue-related safety risk.

- Lack of communication provides a second example of alignment across the evidence base. Communication breakdowns within the flight crew or between the crew and other operational actors is consistently identified in the literature as a cross-cutting precursor relevant to crew interoperability risk across the SEFs considered, and it is also visible in ECR reporting, where it ranks as the second most frequently reported precursor after fatigue. Although lack of communication is also present in Tier 1 occurrences, its reporting increase is driven mainly by Tier 2 events, indicating growing visibility in lower-severity occurrences.
- By contrast, stress, pressure and workload recur across several SEF-related mechanisms in the literature, and KSI patterns indicate that conditions compatible with these states are present across multiple RAs. However, they are comparatively less visible in ECR reporting.

The combined evidence should therefore be interpreted cautiously, distinguishing between indicative enabling conditions, as reflected in KSI patterns, conceptual expectations from the literature, and precursor visibility in ECR reporting, which may be shaped by reporter perception of relevance/exposure and by the practicality, usability of the taxonomy, data quality and quantity, and underreporting.

"KSI and ECR provide complementary but sometimes divergent evidence of SEF-related effects by operator group. Joint interpretation is essential to understand how these factors are perceived in day-to-day conditions and how (and to what extent) they are translated into occurrence-level safety outcomes and reported precursors."

Across several Risk Areas, KSI indicators reveal differentiated conditions between business models, in some cases noticeably so, with less favourable perceptions reported in LCC and ACMI operations and more stable or "resilient" conditions generally observed in network operators. These differences emerge in areas such as the prevalence of atypical contracts (particularly in ACMI), perceptions related to the frequency and appropriateness of discretion use, perceived proximity to legal duty limits, and the frequency of homebase changes (more pronounced in LCCs), with additional nuances depending on whether results are viewed from a flight crew or cabin crew perspective.

At the same time, these KSI patterns reflect survey-based perceptions captured under the inherent constraints of a questionnaire, and do not in themselves imply the presence of latent safety concerns. Rather, they point to perceived structural and operational differences in day-to-day working conditions across business models.

When contrasted with ECR outcomes, the inferential analysis implemented show more heterogeneous reporting patterns by operator group:

- Lack of communication is perceived to be more associated with LCCs than network operators, which may be more aligned with KSIs perception.
- In contrast, fatigue and workload show the opposite pattern, with higher reporting association among network operators than LCCs. For fatigue in particular, complementary information is obtained from survey comments. Concerns about reporting confidence are raised mainly by LCC respondents, who describe hesitancy to report fatigue due to perceived negative consequences or reprimands, and a perceived gap between formal Just Culture messaging and day-to-day practice.

Detailed conclusions

Atypical contracts

Literature reviewed for this study identifies that certain non-standard employment arrangements may create organisational and psychosocial conditions relevant to aviation safety, particularly in relation to employment stability, reporting culture, and workforce integration. The Ricardo et al. (2019) study on employment and working conditions in the EU aviation market highlights that arrangements such as agency-mediated employment, self-employment structures, pay-to-fly schemes, and complex cross-border contractual setups may generate legal and organisational ambiguity regarding employer responsibility, applicable labour protections, and access to organisational support. The study also reports stakeholder concerns that employment insecurity and economic dependency associated with some atypical arrangements may discourage aircrew from reporting fatigue, sickness, or other operational safety concerns due to perceived risks to continued employment or career progression, while emphasising that the evidence does not establish direct causality between atypical contracts and safety outcomes.

These findings are consistent with broader literature referenced in this study. Jorens et al. (2015), in their review of atypical employment in the aviation sector, identify that fragmented contractual structures and intermediary employment models may weaken workforce integration and create challenges related to oversight, accountability, social protection, and the application of labour rights across jurisdictions. Similarly, Reader, Parand and Kirwan (2016), in their analysis of European pilots’ perceptions of safety culture, observed that pilots employed under atypical contractual arrangements reported comparatively lower perceptions of organisational support, fatigue management, and elements of safety culture linked to trust and reporting confidence. Across the literature reviewed, these mechanisms are primarily discussed as potential contributors to increased operational pressure, stress, reduced psychological safety, and uncertainty regarding procedures, responsibilities, and reporting pathways, rather than as direct determinants of safety performance.

The literature further indicates that some cost-driven and highly flexible employment models may operate with leaner staffing structures and reduced operational buffers, creating conditions in which workload intensity and workforce instability may increase. However, the reviewed sources consistently emphasise that the existence of cross-border or non-standard employment arrangements should not in itself be interpreted as evidence of non-compliance or inherently less favourable conditions, as such arrangements may also reflect legitimate operational flexibility and the application of EU labour and jurisdictional principles within the internal aviation market.

KSIs related to atypical contracts and employment structures show differentiated patterns between ACMI, LCC, and network operators. ACMI operators exhibit the most distinctive profile, with 65% of respondents indicating they are not directly employed by the airline and 43% reporting employment arrangements such as self-employment, zero-hours, fixed-term, or pay-to-fly contracts. Both ACMI and LCC operators also report a comparatively high prevalence of employment contracts registered outside the airline's AOC State (State of certification), affecting approximately 57–65% of respondents. However, these findings should not be interpreted as automatically indicating social dumping, non-compliance, or inherently less favourable employment conditions. In several cases, they may reflect the application of EU labour and jurisdictional principles, including those established by the Court of Justice of the European Union in Joined Cases C-168/16 and C-169/16 (Nogueira and Others v Crewlink Ireland Ltd and Moreno Osacar v Ryanair), which clarified that the relevant employment context for aircrew must be assessed primarily in relation to the place from which professional activities are principally carried out, with the concept of "home base" representing an important factual element within that assessment.

At the same time, stakeholder input and literature reviewed for this study identify that certain ACMI employment models, particularly where contractual arrangements are established outside the EU operational context (e.g. non-EU contracts associated with EU-based operations), may create additional challenges related to regulatory oversight, employment protection, and workforce stability. ACMI and LCC operators also display the highest reported intention to leave, at around 25%, suggesting comparatively greater perceived contractual uncertainty and workforce mobility, while LCC respondents additionally report more frequent cross-border payroll and base-location mismatches. In contrast, network operators generally display greater contractual stability, a lower prevalence of atypical employment arrangements, and substantially lower intention-to-leave rates, particularly among flight crew (6.3%).

At the safety-occurrence level, the ECR provides a complementary signal of how this pathway may be reflected. Across 2015-2024, stress has been infrequently reported, representing 0.4% of SP-related occurrences, yet a 4% of stress related occurrences are associated with high severity outcomes in combination with other factors (which is elevated relative to the generally low prevalence of Tier 1 outcomes). Similar behaviour occurs with pressure, which represents only 0.9% of SP-related occurrences, but in this case only 1.3% of pressure-related occurrences are associated with high severity outcomes.

By contrast, across 2015–2024, fatigue reporting increases and by 2024, fatigue is the most frequently reported precursor, present in almost 60% of SP-related occurrences. This increase may reflect a combination of higher underlying exposure to fatigue-related conditions and changes in reporting culture.

Lack of knowledge linked to poor training remains a low-prevalence precursor compared with others, but it is consistently observed over time and accounts for 5.6% of SP-related occurrences in 2024. Notably, it is considerably represented among high-severity outcomes, being present in 9.1% of SP-related high-severity occurrences.

Finally, workload was a precursor considerably present among 2015-2016, with a peak during COVID period. Then, it remained lower but consistently present over time, accounting for around 5% of SP-related occurrences in 2024 and showing no association with Tier 1 outcomes in that year

Within the ECR, the association within the operator group is analysed from the inferential analysis for 2024. Lack of communication is more likely to be reported within LCC operators, while fatigue and workload are more associated with network carriers. For other related precursors, due to sample limitation, no clear operator-type association is observed. This contrast suggests that perceived exposure and occurrence-level reporting may differ across operator groups, conditional on reporting culture.

Commercial Pressure

Literature evidence indicates that commercial pressure systematically shifts priorities toward performance targets, creating trade-offs in which safety behaviours need to balance efficiency, punctuality and productivity demands.

Evidence from multiple studies links commercial pressure to **employment and working conditions**, as well as **health and lifestyle** impacts arising from precarious contracts, income dependent pay, and roster instability, which can limit crews' ability to protect rest and increase presenteeism, leading to chronic fatigue, circadian disruption, and degraded work–life balance. KSI results on commercial pressure confirm the presence of these mechanisms across the current aviation landscape, with LCC respondents reporting a higher perception that operations take place near FTL limits (around 14% of respondents) and a higher incidence of short notice roster changes below 24 hours (26%), indicating reduced predictability and recovery opportunities. Consistently, at the safety-occurrence level, fatigue has increasingly been reported within the ECR over recent years and remains the most frequently reported precursor, reflecting both a higher underlying exposure to fatigue-related conditions or evolving reporting practices.

The literature on SEF **health and lifestyle** indicates that commercial pressure can heighten stress by creating environments in which concerns about reporting hazards or declaring unfitness may be perceived as carrying negative consequences, particularly when combined with psychosocial stressors such as job insecurity and financial concerns. The KSI results for commercial pressure, when considered across all operator types, show limited evidence of severe perceived pressure, as only 3% of flight crew respondents report that pressure to maintain on time performance almost always compromises safety. However, within this overall picture, LCCs consistently record lower scores, and role-based differences are evident, with this perception increasing to 7% among cabin crew, indicating higher sensitivity to operational pressure compared to flight crew. Consistent with this, stress is infrequently reported within the ECR, although it appears in 9.5% of SP-related Tier 1 outcomes, typically in combination with other contributing factors.

The literature on SEF **resource constraints** links commercial pressure to cost reduction strategies that limit staffing levels and operational buffers, resulting in leaner operational configurations. The KSI results support this interpretation when comparing operator types, as LCCs consistently score lower among all groups, particularly regarding the use of commander's discretion. In this respect, 47% of LCC flight crew and 40% of LCC cabin crew respondents report that commander's discretion is not used appropriately, compared with 23% of flight crew and 20% of cabin crew in network operators, pointing to a perceived reduction in operational buffers and more constrained operational margins. Within the ECR, **workload** appears in around 5% of SP related reports between 2021 and 2024, generally in lower severity occurrences, suggesting that perceived resource constraints are more clearly captured through KSI indicators than through occurrence reporting alone.

The literature indicates that **norms** emerge under commercial pressure in relation to the SEF **work intensity**, particularly in environments where timeliness and productivity are implicitly prioritised. Studies describe how such conditions foster "practical drift," whereby delay-avoidance workarounds and behaviours such as "pilot pushing" become routine and gradually normalised. The KSI results are consistent with this dynamic when comparing operator types, as LCCs systematically score worst across indicators related to work intensity, reflecting higher perceived operational pressure and more constrained operational margins than other models. From a safety reporting perspective, norms are rarely recorded, appearing in only 0.5% of SP-related occurrences; however, when these are recorded, they show a relatively **high** presence in SP-related **Tier 1** events, similar to the pattern observed for stress.

As previously assessed from atypical contracts, perceived exposure and occurrence-level recording may differ across operator groups, as KSIs suggest higher rostering-related constraints in LCC operations, whereas the adjusted ECR comparison indicates fatigue and workload are more likely to be recorded in network-carrier occurrences.

Crew interoperability

Literature evidence indicates that lack of assertiveness in the context of crew interoperability is linked to the SEFs employment and working conditions, health and lifestyle, and education. Studies describe how fragmented organisational arrangements involving multiple AOCs within the same airline group can generate unequal employment conditions and perceived vulnerability among crews. These differences may reduce the willingness of crew members to escalate hazards, refuse duties, or declare unfitness. This effect is reinforced where variable operating environments, roster instability and psychosocial stressors interact with weakened psychological safety and difficulties in applying Just Culture principles in fragmented organisational settings. The KSI results indicate limited exposure to cross-AOC flying in both LCC and network operations, with low overall prevalence in these models. In contrast, ACMI operations score lowest on this indicator, reflecting the structural nature of their operating model, as a substantial share of respondents report routinely operating under an AOC different from the primary one. This higher exposure to cross-AOC arrangements in ACMI operations is consistent with the fragmented organisational settings described in the literature and with increased perceived vulnerability among crews. This precursor cannot be evaluated within the ECR, as no direct mapping with the current taxonomy could be established.

Literature also indicates that lack of communication (communication breakdowns within the flight crew or between the crew and other operational actors) under crew interoperability is associated with the SEFs **employment and working conditions, education, and resource constraints**. Research highlights how fragmented organisational structures weaken SOP standardisation and hinder the integration of Safety Management Systems, creating uncertainty regarding responsibilities for training, reporting and crew welfare. These conditions complicate information exchange and coordination across operational interfaces, particularly where harmonised training pathways and oversight are difficult to sustain. The KSI results indicate that roles and procedures are generally perceived as clear under crew interoperability, with fewer than 5% of respondents across operator types reporting unclear roles or procedures when operating under a different AOC. This suggests that, despite the fragmented organisational settings described in the literature, communication at the procedural and role-definition level does not appear to constitute a systemic issue, even where interoperability is applied. As such, the KSI findings do not directly support the assumption that organisational fragmentation translates into widespread ambiguity in roles or responsibilities. Within the ECR, lack of communication remains a prominent precursor, having been the most frequently reported between 2015 and 2017 and subsequently the second most common, representing around 18% of SP-related occurrences, and featuring in combination with other factors in 36% of SP-related Tier 1 outcomes, indicating that communication breakdowns are more visible at the occurrence level than through KSI perception indicators.

Fraud risk

For the fraud risk RA, the literature review is not broad enough to establish linkages with the SEFs considered in this study nor SPs. The analysis therefore remains limited to the interpretation of the KSIs. The results show that stakeholder confidence in existing fraud detection and prevention mechanisms is generally maintained across both LCC and network operations, with no indication of a widespread perception that the system is unable to address fraud-related behaviours. Differences between LCC and network operations are limited, as reflected in similar levels of reported low confidence in fraud detection (11.1% in LCC operations compared with 6.9% in network operations).

At the same time, perceptions of regulatory arbitrage are relatively common across the sector and do not show strong differentiation between LCC and network operators, with 57.7% of LCC respondents and 53.8% of network respondents reporting such perceptions. This points to concerns about uneven oversight practices between authorities that are shared across operating models, rather than being specific to a particular business model. Given the lack of empirical evidence connecting fraud risk to specific safety precursors, fraud risk is not further analysed at the SP or ECR levels in this study.

Fuel management

The reviewed literature provides limited evidence directly linking fuel management to the SEFs considered in this study. It does, however, identify workload as a relevant HF/HP safety precursor for fuel planning and monitoring, as higher task demand can reduce cognitive capacity, increase task saturation, and weaken procedural compliance. The KSI results indicate slightly higher reported use of commander fuel discretion in LCC operations when compared across operator types, although values remain broadly comparable between LCC and network operators. Importantly, the survey does not provide evidence that the use of discretionary fuel is associated with negative managerial responses or adverse consequences, limiting the ability to establish a clear link between fuel-related decision-making and workload-driven pressure. At the safety-outcome level, workload appears as a low-prevalence precursor within ECR reporting compared with others and is more frequently associated with network-carrier occurrences, noting that these findings remain sensitive to the relatively small sample size.

Go-around decisions

The literature identifies **health and lifestyle** factors, particularly accumulated fatigue, stress, and emotional dysregulation, as mechanisms that may impair executive function and bias risk perception, potentially increasing reluctance to initiate a go-around even when stabilisation criteria are not met. However, the KSI results do not provide strong empirical support for this pathway in the surveyed population. Across operator types, perceived pressure to avoid executing a go-around is low (below 10%), and respondents consistently report no perceived negative consequences associated with performing a go-around, indicating that corrective action is not inhibited at a perceptual level. While ECR data show increasing exposure to fatigue precursors over time, stress and complacency remain infrequently reported, suggesting that the mechanisms described in the literature are not prominently reflected in either perception-based indicators or occurrence reporting.

The literature further highlights **work intensity** as a key factor shaping go-around decision-making. Research shows that tight schedules, narrow operational buffers and elevated situational tempo can reduce crew assertiveness, as go-arounds may be perceived as carrying professional or operational consequences, discouraging crews from initiating corrective action even when procedural cues are clear. Repeated exposure to these conditions fosters <u>norms</u> in which continuing an unstable approach becomes implicitly accepted as part of routine operations rather than treated as a deviation requiring correction. At the same time, high task load and time pressure degrade <u>lack of teamwork</u> by weakening shared situational awareness, reducing the crew's ability to respond cohesively during critical phases of flight. This mechanism is reflected in the KSI which captures pilots' concern about potential negative consequences or reprimands following a go-around, directly aligning with the intolerance for operational deviations described in the literature. The results show that such concerns remain low and broadly similar for LCC and network operations. As it has been seen in the other RAs, norms precursor is infrequently reported within the ECR. Additionally, lack of teamwork shows a very similar pattern, having a 0,1% of representativeness among SP-related occurrences.

Generational risk behaviour

Literature evidence indicates that <u>stress</u> is perceived in generational risk behaviour, arising from the combined influence of **health and lifestyle** factors and **resource constraints**. The literature describes how ageing-related physiological strain, cumulative fatigue and psychological vulnerability interact with economic insecurity, particularly among younger cohorts exposed to precarious employment conditions. These dynamics reinforce presenteeism and reduce willingness to declare unfitness for duty, while maladaptive coping strategies further degrade well-being. The KSI results provide only partial support for the pathways described in the literature. When examining contract types across age groups, younger respondents (<30) show a slightly higher exposure to non-permanent or non-direct employment arrangements compared with older cohorts, although the difference remains limited in magnitude. This suggests a modest structural differentiation by age, but not a pronounced generational divide in employment conditions. In contrast, perceptions related to generational work–life balance remain remarkably stable across age groups, with no clear deterioration reported among younger cohorts. While stress emerges recurrently in the literature, often in combination with fatigue, as a core HF/HP precursor arising from socio-economic vulnerability, this prominence is not mirrored in ECR occurrence reporting, where stress-related reports remain consistently low.

The literature also links distraction to generational patterns through **health and lifestyle** mechanisms. Declines in cognitive and psychomotor performance with age, as well as fatigue and substance-based coping strategies observed across age groups, are described as degrading attention and sustained concentration. These effects shape task engagement and situational focus, particularly in demanding operational contexts. The KSI results do not provide empirical support for the literature-described generational pathways linking distraction to health and lifestyle factors. While the survey captures the coexistence of different age profiles within the flight crew population, it does not include measures related to health and lifestyle-mediated mechanisms, such as age-related substance use or coping strategies, that are central to the literature's explanatory framework. As a result, the KSIs cannot substantiate differences in susceptibility to distraction across age groups, and no direct linkage can be established between generational factors and distraction at the perception level. Although distraction appears with moderate representativeness in ECR reporting and is present in some high-severity occurrences, this evidence cannot be attributed to generational health and lifestyle mechanisms based on the available KSI data, highlighting a clear limitation in the ability to validate the literature findings within the scope of this study.

The literature relates lack of awareness to **education** within generational risk behaviour. Research shows that hierarchical norms can suppress safety communication among younger crew members, while overconfidence among more experienced personnel may bias risk perception. Just Culture education is described as a key mechanism to recalibrate these dynamics by reinforcing shared understanding of risk, fatigue and fitness to operate. The KSI results do not indicate generational differences in safety culture perception or reporting behaviours. When examining generational safety culture indicators, perceptions remain stable across age groups, with no evidence of degradation among younger or older cohorts. This suggests that, contrary to the mechanisms described in the literature, hierarchical norms or overconfidence linked to experience do not appear to translate into differentiated perceptions of awareness or safety culture across generations. While lack of awareness remains a low-prevalence precursor in ECR reporting and has decreased since 2019, its presence in a share of high-severity occurrences highlights its relevance at the outcome level. Overall, although the literature emphasises generational education and Just Culture as key moderators of awareness, the KSI evidence does not support a generational effect in perceived safety culture, indicating that these mechanisms are not materially reflected at the perception level in the surveyed population.

Finally, the literature identifies workload as a generationally mediated factor linked to **resource constraints**, suggesting that younger crew members may face higher task demands due to less stable employment conditions and reduced access to mentoring, potentially affecting decision-making over time. However, the KSI results only partially reflect this narrative. While younger cohorts show a slightly higher exposure to non-permanent employment arrangements, no clear generational gradient is observed in work–life balance perceptions, which remain broadly stable across age groups. Moreover, the KSIs do not include indicators capable of directly measuring resource constraints, preventing any empirical assessment of the proposed link between generational workload and constrained operational buffers. Consistent with this, workload does not emerge as a dominant precursor within ECR reporting, where fatigue and lack of communication remain more prevalent. Overall, although workload is emphasised in the literature as a generational risk pathway, the available KSI and ECR evidence does not allow this linkage to be substantiated within the scope of this analysis.

Homebase changes

The literature indicates that fatigue and stress associated with homebase changes arise from the combined influence of **employment conditions** and **health and lifestyle** factors. Forced mobility, temporary base assignments and long commuting distances are described as undermining rest opportunities and social support, leading to cumulative fatigue and increased psychosocial stress, particularly when changes are frequent or implemented with short notice. The KSI results clearly confirm a substantially higher exposure to homebase changes in LCC operations, with at least 40% of respondents reporting one or more homebase changes in the last 12 months, and around half of them experiencing more than one change during that period, compared with a very limited exposure in network operations (below 4%). This supports the relevance of the mobility related mechanisms described in the literature, at least in terms of structural exposure. Network carriers operate at national level with likely only one or few bases to which crew commute to, mainly from within country borders) whereas some LCCs and ACMIs are transnational in nature. Therefore higher exposure to homebase changes is somewhat to be expected when working at an LCC or an ACMI operator.

The literature further links homebase changes to distraction through disrupted sleep, extended commuting and reduced mental resilience. However, within the scope of the KSIs, health and lifestyle impacts cannot be directly measured, and the only observable linkage remains the higher prevalence of homebase changes themselves, rather than downstream cognitive or attentional effects. As such, while the exposure pattern is consistent with the literature, the survey does not allow direct corroboration of distraction related pathways.

As discussed in other Risk Areas where these HF/HP precursors may also emerge, ECR reporting shows a strong and increasing capture of fatigue over time, whereas other precursors such as stress or distraction are reported far less frequently.

Pilot discretion use

The literature shows that fatigue and stress are linked to the repeated use of pilot discretion, affecting crews' **health and lifestyle**. Frequent extensions of duty periods of flight and cabin crew reduce recovery opportunities and increase cumulative fatigue, while the responsibility placed on commanders to decide whether to continue operations under disruption creates additional psychological strain. This is reflected in the KSI results, particularly in LCC operations, which show higher exposure to discretion use, a stronger perception that discretion is used more frequently rather than exceptionally, and longer perceived duty extensions.

The literature identifies pressure as a relevant factor shaping the use of pilot discretion, particularly in environments where refusing duty extensions may be perceived as carrying negative organisational consequences. The KSI results provide differentiated and role-dependent support for this pathway. Among flight crew, LCC operations show a higher proportion of respondents reporting that they are not always consulted when discretion extensions are applied (around 35%), compared with approximately 20% in network operators. While this suggests weaker consultation practices in LCC environments, this indicator alone does not provide strong evidence of explicit or implicit pressure to accept extensions, nor does it allow robust conclusions regarding negative organisational consequences, meaning that alignment with the literature remains limited for this group.

However, a different pattern emerges for cabin crew. In this group, very high proportions of respondents report not being consistently consulted, reaching around 80% in LCC operations and 55% in network operators. This substantially reduced level of consultation indicates a more pronounced limitation in crew involvement in discretion related decision-making and suggests a stronger potential alignment with the literature described pressure mechanisms, particularly in LCC environments.

Finally, the literature indicates that complacency can emerge when pilot discretion becomes embedded in normal operations. Repeated and routine use of discretion weakens its role as an exceptional safeguard and leads crews and organisations to accept extended duties as normal. This mechanism is reflected in the KSI results showing greater scepticism regarding the appropriate use of discretion in LCC environments, alongside higher reported frequency of discretion use. In contrast, network operations report lower frequency, shorter extensions and higher agreement that discretion is used appropriately.

Once more, the pattern intensifies across RAs: fatigue emerges as a prominent and concerning precursor, with a clear footprint in ECR reporting. In contrast, stress, pressure and complacency, although repeatedly identified in the literature as relevant HF/HP mechanisms, show a markedly lower reporting rate in the ECR.

Pilot retirement age

The literature indicates that lack of awareness and workload are linked to pilot retirement age through **health and lifestyle** mechanisms associated with cognitive ageing. Studies show that age-related declines in information processing, working memory and executive function can reduce situational awareness and make the management of high-workload or rapidly changing situations more demanding, particularly outside routine operations. While accumulated experience can compensate in familiar contexts, vulnerabilities become more visible under time pressure or task saturation. The KSI results provide context for these mechanisms by showing that network operations have a relatively older pilot population than LCC. For both precursors, lack of assertiveness and workload, the SPIs show that their representation in the ECR remains comparatively low.

Workforce shortages

The literature consistently links workforce shortages to fatigue and safety degradation through a combination of employment-related, **health and lifestyle**, and **resource-constraint** mechanisms. From an employment perspective, insufficient staffing forces remaining personnel to operate closer to legal and physiological limits, reducing rest and recovery opportunities and fostering presenteeism as a structural response to the lack of reserves. From a health and lifestyle standpoint, sustained understaffing increases workload intensity, accelerates burnout, and degrades overall well-being, while high turnover and the loss of experienced personnel weaken social cohesion, mentoring, and supervisory support. Under resource-constraint conditions, workforce shortages can lead to increased reliance on minimum crew configurations, reduced organisational resilience to disruptions, erosion of institutional knowledge, and diminished supervisory and oversight capacity, with implications extending beyond operators to the wider system.

The KSI results broadly align with these combined pathways when comparing operator types. LCC operations consistently report higher perceived utilisation near legal duty limits, stronger perceptions of staffing shortages, higher workload pressure, and lower average crew tenure, indicating more strained and less resilient staffing conditions. In contrast, network operations report lower perceived strain and longer average crew tenure, reflecting more stable staffing profiles and greater organisational buffers.

For fatigue and workload, their reporting behaviour in the ECR has already been observed in previous RAs. In contrast, lack of resources had not yet appeared linked to any RA. Its representativeness in the ECR is similar to that of workload, in 2024 it was reported in 5.7% of the occurrences associated with SPs. For the rare events that escalated to Tier 1, this precursor was barely present.

ACMI operations

Literature provides support for linking ACMI operations to SEFs, particularly **employment and working conditions and resource constraints**. Despite the lessor retaining full responsibility for the safety of their operations, studies describe how the nature of wet-lease operations, fragmented organisational responsibility between lessor and lessee, and cross-border regulatory arrangements can weaken employment stability and limit the integration of Safety Management Systems. These conditions are associated with cumulative fatigue, reduced psychological detachment from work, and reluctance to report operational hazards.

In the KSI results, within the ACMI operating context, survey responses indicate relevant exposure to non-standard employment arrangements and reduced confidence in safety reporting, alongside moderate levels of perceived workload pressure. Together, these indicators reflect organisational and employment conditions aligned with the mechanisms described in the literature, particularly those related to employment precarity, fragmented oversight and reporting confidence.

However, these pathways cannot be examined at the ECR level. ACMI operations cannot be identified within the ECR dataset, which prevents the analysis of ACMI-related SPs in occurrence data.

Other relevant conclusions

Beyond the general conclusions presented which focus on addressing the study framework and the links between RAs, SPs and SEFs, this section brings together additional conclusions derived from other relevant analyses conducted during the study. These findings do not directly feed into the core SEF–RA–SP framework, but provide complementary conclusions.

Cross-source analysis: Case studies

The cross-source analysis comparing survey-based indicators with operator-reported operational data provides additional confidence in the framework while highlighting the complementary nature of perception-based and factual evidence. Although full case studies could not be implemented, partial datasets from two operators enabled a targeted comparison across several Risk Areas.

For fuel-related practices, higher levels of commander fuel discretion reported by LCC respondents are reflected in higher discretionary fuel uplift observed in operator data, indicating a consistent signal across data sources.

For staffing-related indicators, higher perceived staffing pressure captured through the survey-based KSI WS03 in LCC environments should not be associated with higher standby crew activation rates in operator data. This is evidenced when assessed against published reserve-crew planning literature, the observed activation levels remain contained and do not indicate structural staffing shortages. Variability across roles and periods is largely driven by operational seasonality, with peak demand requiring greater short-term absorption capacity. Overall, the data suggest that staffing buffers remain broadly adequate, even in high-utilisation environments.

These results highlight a potential divergence between perception and reported operational practice: survey data capture how conditions are experienced by personnel, while operator data do not show evidence of sustained understaffing. This difference should be understood as complementary rather than contradictory.

Overall, this exercise serves as a proof of concept. It demonstrates how survey-based indicators can be contextualised and strengthened through operator-reported data when available. With broader and more consistent data provision across operators and business models, this approach could be scaled up to enhance analytical robustness and progressively reduce reliance on perception-based indicators in future Article 89 assessments.

EU pilot profession outlook

Survey responses describe an outlook in which the future supply of qualified pilots in the EU is expected to deteriorate over the next five years. Expectations are largely shaped by factors related to the profession's overall attractiveness and core employment conditions. At the same time, respondents report a strong perception of outward pilot mobility from the EU, although this is not mirrored to the same extent in near-term individual intentions, suggesting that perceived market trends and personal plans do not fully align.

Expectations regarding future pilot supply are predominantly negative. A total of 37% of respondents anticipate a slightly worse situation over the next five years, while a further 25%

expect a significantly worse outcome. By contrast, only around 8% of respondents expect an improvement, with the remainder indicating either stability or uncertainty. These results should, however, be interpreted with some caution, as perceptions regarding the future attractiveness of the profession among individuals already working within it may be subject to perceptual bias and may not fully reflect the views of potential entrants to the profession.

The drivers shaping this outlook concentrate on a small number of core levers. Responses most frequently point to the attractiveness of the profession, followed by working conditions and pay, and by training capacity or the cost of obtaining licences. Perceived outward pilot mobility is widespread across the survey sample. Around 40% of respondents observe pilots leaving the EU frequently, with a further 34% reporting that this occurs occasionally. However, near-term individual intentions to leave Europe are substantially lower: only 13% of respondents state that they are very likely to seek employment outside Europe within the next 12 months, while approximately 40% consider such a move very unlikely.

Signals related to access to the profession and overall attractiveness point to both affordability and sustainability constraints. The most frequently cited barrier for new entrants is the high cost of training and licensing (31%), followed by uncertainty regarding career stability and job security (24%) and a perceived lack of work–life balance (19%). These factors are reflected in a broader perception that the attractiveness of the pilot profession in Europe has declined over the past five years, with 46% of respondents rating it as less attractive and a further 20% as much less attractive, while only around 1% perceive a significant improvement.

These findings suggest that the sustainability of the pilot profession in Europe is increasingly shaped by a limited set of factors, affordability of access, quality of working conditions and perceived long-term attractiveness, which, if not addressed, are likely to translate negative perceptions into tangible supply and retention challenges for the European aviation system.

Survey question grouping

The grouping of survey questions provides a more robust analysis than single-item indicators. Across the composite dimensions analysed, a consistent differentiation emerges by operational model. LCC environments tend to exhibit less favourable perceptions across several dimensions, including mental health, safety culture and reporting, commander’s discretion, and management pressure on safety decisions. These results suggest that perceived operational and organisational strain is more pronounced in LCC contexts and affects several interrelated aspects of the working environment.

Network operators generally display the most favourable outcomes across the same dimensions, indicating comparatively stronger perceptions of psychological well-being, reporting culture and organisational support for safety-related decision-making. ACMI operators typically occupy an intermediate position, although in several dimensions their scores are closer to those observed in LCC environments than to network operations.

Differences between flight crew and cabin crew indicate that these patterns are not uniform across personnel categories. For example, perceived proximity to FTL boundaries display different behaviours. This suggests that exposure to operational pressure and its perceived impact may vary depending on function, even within the same operational model.

Overall, the grouping exercise shows that survey questions can be organised into dimensions that capture shared patterns of perception. This supports the use of indicators as a tool to identify broader socio-operational conditions across the aviation system, while avoiding over-interpretation of single survey items.

Open-response feedback

The open-response feedback provides a qualitative complement to the KSI survey analysis. More than 2,000 respondents submitted open comments, highlighting the issues they considered most relevant. Across these contributions, concerns focus on fatigue and rostering, operational and commercial pressure, employment conditions, and confidence in reporting, with clear differences across operator types.

Fatigue is the most frequently mentioned theme across all operational models, particularly in LCC comments, followed by ACMI and network operations. Respondents describe rosters planned close to limits, insufficient recovery despite formal rest compliance, and cumulative fatigue linked to operational disruption. In LCC environments, fatigue is often directly associated with last-minute changes, standby practices and tight scheduling. Operational and commercial pressure is another recurring theme, especially in LCC feedback. Respondents frequently refer to pressure to maintain punctuality, manage disruptions or complete planned rotations.

Employment-related concerns are raised mainly in ACMI and, to a lesser extent, in LCC. These include contract structures, pay stability, sick-pay arrangements and job security, often linked to mobility requirements in ACMI. Finally, reduced confidence in safety reporting appears primarily in LCC comments. Respondents describe hesitation to report fatigue or operational concerns due to perceived informal consequences.

Overall, the open-response feedback reinforces the patterns identified in the literature review and the quantitative analysis and provides additional context on how operational, organisational and employment-related pressures are experienced across operating environments.

4.2 Lessons learned and recommendations

The development of this study has generated not only a broad evidence base on the socio-economic conditions experienced by safety-critical personnel, but also a clearer understanding of the methodological, structural and operational elements that shape the feasibility and robustness of Article 89 assessments. The lessons learned highlight areas where the analytical process can be strengthened to ensure future iterations benefit from greater consistency, representativeness and depth. The recommendations that follow reflect these insights and outline ways in which the overall framework, rather than specific operational actions, can be reinforced.

Linking Socio-economic factors, Risk areas and Safety precursors through literature review

Lessons learned

The literature review confirmed that there is broad and consistent conceptual support for the existence of relationships between Socio-Economic Factors (SEFs), Risk Areas (RAs) and Safety Precursors (SPs). Across multiple domains, the literature describes plausible mechanisms through which organisational, economic and social conditions may influence human performance, organisational behaviour and, ultimately, safety-relevant outcomes.

However, the review also highlighted important structural limitations. While the available literature is not purely theoretical but contains own data, it is heterogeneous in scope, methodology and purpose, and rarely addresses SEF–RA–SP linkages in an explicit, operational or measurable manner. As a result, establishing structured linkages required interpretative judgement, which inevitably introduces uncertainty and limits reproducibility. In addition, some sources reflect policy positions, advocacy perspectives or sector-specific viewpoints, which cannot be fully controlled through a literature-based approach alone.

A key lesson is therefore that literature review is a necessary but insufficient basis for defining or validating SEF–RA–SP relationships. While it provides a robust conceptual foundation, it cannot, on its own, deliver stable, RA-specific analytical pathways suitable for systematic monitoring or performance assessment. Strengthening these linkages requires moving beyond interpretation toward structured validation and RA-specific operationalisation.

Recommendations

Future development of SEF–RA–SP relationships should follow a more structured, RA-specific and collaborative approach.

First, SEF–RA–SP linkages should be developed and validated separately for each Risk Area, rather than at an aggregated level. For each RA, the relevant SEFs, expected mechanisms and associated

Safety Precursors should be explicitly articulated, documented and justified. This process should lead to the definition of RA-specific analytical pathways, rather than generic mappings.

Second, the literature review could be complemented by a structured expert validation process. A standing expert mechanism, involving operational, human-factors, academic and regulatory expertise, could be used to review the literature collectively, assess its relevance for each RA, and confirm the robustness of the conceptual pathways identified. In this context, the literature would remain the primary evidence base, while the expert process would serve to validate interpretations, incorporate operational insight, and strengthen confidence in the resulting linkages.

Third, the outcome of this process should directly inform the definition and refinement of quantitative KSIs and SPIs. For each RA, the conceptual pathways agreed through expert validation should be translated into clearly defined indicators, with explicit documentation of their scope, assumptions and limitations. This would strengthen transparency, methodological consistency and repeatability across Article 89 cycles.

Case studies

Lessons learned

Case studies were conceived as a complementary analytical instrument to enrich the framework with contextual, organisation-level insight that cannot be captured through surveys or aggregated indicators alone. Their intended role was to explore how socio-economic conditions materialise in real operational environments, to test data feasibility, and to support a more nuanced interpretation of RA-specific mechanisms.

In practice, the execution of case studies was constrained by substantial heterogeneity in data availability, structure and governance across operators. Differences in data definitions, levels of granularity, internal validation processes and confidentiality constraints limited the feasibility of producing methodologically consistent and generalisable case studies within the timeframe of this cycle.

Despite these constraints, the partial datasets provided by a small number of operators demonstrated that relevant factual data do exist at operator level and that operators are willing to engage when appropriate governance, trust and safeguards are in place. These contributions confirmed the analytical value of such data and validated the feasibility of complementing perception-based indicators in future cycles.

In parallel, consideration should be given to the development of a **set of standardised Safety Performance Indicators (SPIs)** to support the continuous monitoring of the relationships between socio-economic factors (SEFs), risk areas (RAs), and safety performance (SP). Such indicators would enable a more systematic and longitudinal assessment of these interactions, complementing periodic analytical exercises with an ongoing monitoring capability.

Recommendations

Future cycles should establish a structured and permanent operator-collaboration mechanism based on a set of standardised Safety Performance Indicators (SPIs) to support the continuous monitoring of the relationships between socio-economic factors (SEFs), risk areas (RAs), and safety performance (SP)., enabling early agreement on data definitions, minimum data requirements, confidentiality safeguards and participation expectations.

Case studies should be targeted to specific RAs, selected based on observed differentiation in KSI results. For those RAs, operator-level data should be used to characterise organisational conditions (e.g. contractual structures, rostering practices, utilisation patterns) in a factual manner, without any benchmarking or performance assessment of individual airlines.

Where possible, case-study data should be analysed in conjunction with survey responses from personnel belonging to the same operators. This combined approach would allow perception-based insights and factual organisational data to be interpreted together, providing a more realistic and operationally grounded understanding of how socio-economic factors influence safety-relevant environments.

Such an approach aligns with collaborative data-sharing frameworks that operate under robust data-governance and data-protection arrangements, such as the D4S programme, and offers a clear pathway for strengthening the empirical basis of the Article 89 framework.

Survey participation, design and alignment

Lessons learned

Surveys proved to be an essential tool for capturing the perceptions, experiences and behavioural dimensions of safety-critical personnel. They provide access to socio-economic and organisational characteristics that cannot be observed through occurrence data or administrative records alone.

At the same time, several limitations were identified. Participation remained uneven across personnel groups, survey length constrained thematic depth, and changes introduced during stakeholder consultation weakened the alignment between survey items and Key Socio-Economic Indicators (KSIs).

Moreover, perception-based data, by definition, capture subjective experiences rather than objective organisational conditions. However, this subjectivity should not lead to discounting or dismissing survey responses as irrelevant; perceptions often reveal meaningful insights into how conditions are interpreted and experienced by personnel.

The key lesson is that surveys are most effective when used as a focused and complementary measurement instrument. One that provides valuable contextual understanding rather than being treated as a standalone proxy for all socio-economic dimensions.

Recommendations

Surveys should continue to be used in future Article 89 cycles, but with a more focused and strategic design.

Survey content should be explicitly prioritised, concentrating on those dimensions that cannot be reliably captured through factual or administrative data, such as reporting confidence, perceived pressure, safety culture and subjective wellbeing. Survey length should be reduced accordingly, favouring depth and clarity over breadth.

Survey design should be modular across cycles, allowing specific Risk Areas to be explored in greater detail over successive iterations, while avoiding respondent fatigue. Core survey items essential for KSI construction should be clearly identified and protected throughout stakeholder consultation.

Finally, survey results should be systematically interpreted alongside other data sources, reinforcing their role as a complementary lens on socio-economic conditions.

Data availability

Lessons learned

The construction of several KSIs was constrained by the limited availability of consistent, accessible and standardised datasets describing organisational and operational conditions. In many cases, the analysis relied primarily on survey data due to the absence of factual information on employment structures, rostering practices or operational arrangements.

At the same time, the study demonstrated, through limited operator-provided data and initial analytical work, that quantitative, factual KSIs are feasible when appropriate data-governance frameworks are in place.

Recommendations

Future iterations of the framework should progressively incorporate factual data describing organisational and operational conditions relevant to socio-economic factors and Risk Areas. This includes, for example, data on employment arrangements, contract types, roster construction, duty patterns and operational utilisation.

A structured assessment of potential data sources should be conducted to identify what information exists, where gaps remain and what level of standardisation is required. Secure, trusted and collaborative data-sharing environments, supported by robust data-governance and data-protection arrangements, provide a viable pathway to enable such data use at system level.

This evolution would significantly strengthen the empirical basis of KSIs, allow more precise RA characterisation, and reduce reliance on perception-only indicators.

Implementation of the SPI framework in the ECR

Lessons learned

1. **Safety Precursors can be operationalised within the ECR, providing a repeatable monitoring layer**

The study demonstrated that it is feasible to translate Safety Precursors into observable signals within ECR occurrence data through a transparent and reproducible mapping approach based on the ECR taxonomy. This creates an initial bridge between human and organisational performance concepts and occurrence-based safety evidence, enabling consistent monitoring of SP-related reporting patterns across time and operational contexts.

2. **A solid and scalable SPI framework is in place**

The SOIs and RTIs defined in this study provide a solid and scalable foundation for SPs monitoring. The framework is modular and can be progressively refined as reporting practices mature and analytical needs evolve.

The inferential analysis shows that it is feasible to move beyond descriptive SPIs and implement an initial multivariable approach that jointly accounts for operator group and operational context. This provides a methodological first step towards more policy-relevant assessment, as it can help explore the study variable isolated from the operational context. The reliability of this approach, however, depends not only on field completeness but also on reporting culture, which directly affects sample coverage and the stability of adjusted associations.

3. **Risk Areas are not consistently observable through occurrence data alone**

Even when narratives are available, they can be heterogeneous and are often written to describe "what happened" rather than to trace upstream organisational or socio-economic drivers. As a result, this limits the ability to directly quantify RA exposure using occurrence data alone and reinforces the need to interpret SP-related indicators as indirect signals of underlying conditions rather than as direct measurements of RAs.

4. **Granularity shapes interpretability and analytical limits**

Analysing SPIs and survey-based KSIs at operator-group level made it possible to identify systemic patterns associated with different operating models. This approach has demonstrated that differentiable socio-economic environments across business models are associated with distinct safety-precursor patterns.

At the same time, group-level analysis limits interpretability. It does not allow distinguishing whether observed patterns reflect broad model-level characteristics or concentration within subsets of individual operators, nor does it allow a precise characterisation of Risk Area exposure profiles.

5. **ECR is a high-potential evidence base, but maturity still constrains analytical capabilities**

ECR enables scalable, occurrence-based analysis of HF/HP-related signals and provides a strong platform for longer-term monitoring. However, as a reporting system that is still evolving in coverage and uptake, current analyses remain constrained by variability in data quality, completeness and reporting consistency. Even so, this kind of studies help demonstrate the value of the system and reinforce the importance of comprehensive, consistent reporting to unlock its full safety-analysis potential.

Recommendations

From lessons 1 and 2 it can be concluded that the SPIs framework provides an immediately usable performance monitoring layer, and can be situated within the EPAS SRM framework, as outlined later. In line with the EPAS logic, it is designed to be iterative: the indicator set, mappings and reporting focus can be progressively refined and extended with expert inputs and as priorities evolve, while preserving a stable baseline for trend tracking. This creates a solid foundation on which more advanced inference can be added over time, as operator tagging and contextual data completeness improve. Moreover, for this advanced inference, while the ECR captures part of the operational conditions, future iterations could be strengthened by integrating additional operational datasets (e.g. METAR and traffic data) to better characterise operating environments and improve adjustment.

At the same time, the lessons show that the robustness of SPI-based analysis depends not only on technical mapping rules but fundamentally on reporting culture and contextual richness (Lessons 1 and 2). Consistent with EPAS SRM principles, strengthening trust, confidence and learning-oriented reporting practices, aligned with Just Culture, is essential to ensure that increased reporting translates into more reliable and decision-relevant safety evidence. In parallel, downstream data-quality improvement activities, including harmonisation, sanitisation and advanced analytical processing within secure governance frameworks, can further enhance the interpretability and reliability of SPI outputs.

To address the limited observability of RAs through occurrence data alone (Lesson 3) and the interpretative constraints associated with operator-group analysis (Lesson 4), future analyses should progressively evolve toward greater analytical granularity. This includes moving from operator-group to operator-level profiling strictly for analytical purposes and RA exposure characterisation, without benchmarking or drawing conclusions at individual airline level. The objective would be to derive more discriminative RA exposure profiles and examine how SPs manifest within those profiles, supporting clearer interpretation of which RAs appear more salient under different operating contexts and which precursors are more consistently associated with those contexts.

Finally, from lesson 5 is highlighted that **reporting culture should be strengthened through the continued promotion of Just Culture, reinforcing confidence and trust so that safety concerns are reported consistently and with adequate contextual detail.**

A. Annexes A: Acronyms and Definitions

The table below presents a list of acronyms used throughout the report.

Table 14: Abbreviations

Acronym	Definition
A4D	Airlines for Dialogue
A4E	Airlines for Europe
ACMI	Aircraft, Crew, Maintenance, and Insurance (wet-lease business model)
AOC / AOCs	Air Operator Certificate(s)
ASR	Annual Safety Review
DaGo	Data Governance framework
D4S	Data4Safety programme
DG MOVE	Directorate-General for Mobility and Transport of the European Commission
EASA	European Union Aviation Safety Agency
ECA	European Cockpit Association
ECCAIRS 2	European Co-ordination centre for Accident and Incident Reporting Systems platform
ECR	European Central Repository
EPAS	European Plan for Aviation Safety
ERA	European Regions Airline Association
ERCS	Common European Risk Classification Scheme
ETF	European Transport Workers’ Federation
EU	European Union
FDP	Flight Duty Period
ICAO	International Civil Aviation Organization
ILO	International Labour Organization
IFR	Instrument Flight Rules

Acronym	Definition
KMO	Kaiser-Meyer-Olkin
KSI / KSIs	Key Socio-economic Indicator(s)
LCC	Low-cost carrier
NAA / NAAs	National Aviation Authority/Authorities
OCC	Operations Control Centre (used as a personnel category)
OTP	On-time performance (used in “OTP pressure” indicator wording)
RA / RAs	Risk Area(s)
RTI / RTIs	Reporting Trend Indicator(s)
SCP	Safety-critical personnel
SEF / SEFs	Socio-economic factor(s)
SIA / SIAs	Safety Investigation Authority/Authorities
SMS	Safety Management System(s)
SO / SOs	Safety outcome(s)
SOI / SOIs	Safety Outcome Indicator(s)
SOP / SOPs	Standard Operating Procedure(s)
SP / SPs	Safety Precursor(s)
SPI / SPIs	Safety Performance Indicator(s)
SRM	Safety Risk Management
SSP	State Safety Programme(s)
TFEU	Treaty on the Functioning of the European Union
VIF / VIFs	Variance Inflation Factor(s)
WHO	World Health Organization

B. Annexes B: Extended methodology

Annex A provides extended methodological material and detailed supporting outputs to complement the main report. It is not intended to function as a standalone reporting section, rather, it adds transparency on how key indicators are constructed and interpreted, and it offers additional detail for readers who wish to understand the analytical steps underpinning the results presented in the core chapters.

The annex is structured around four components. First, it expands the KSI methodology, including a more detailed description of indicator construction and quantification, uncertainty estimation, and the statistical basis used for comparative analysis across groups. Second, it shows the detailed KSI tables for each RA and personnel group, alongside a reading guide explaining how to interpret values, uncertainty, and pairwise group comparisons. Third, it provides the detailed SPI methodology, documenting how SPs are mapped to ECR taxonomy values and how inferential analyses are specified, including variables, controls, and model diagnostics. Finally, it includes additional SPI analyses that further explore relationships between precursors and severity/outcomes.

B.1 Detailed KSI methodology

This section provides additional methodological detail to support the interpretation of the KSI results presented in the main report. It expands on the analytical steps described in Sections 2.4.2 and 2.4.3, offering a more detailed explanation of the construction, quantification and comparative analysis of the KSIs, without introducing new results.

B.1.1 Extended description of KSI construction and quantification

Beyond scale-based inputs, a subset of KSIs is populated using categorical survey questions or combinations of multiple survey inputs. From a construction perspective, two main types of KSIs can be distinguished, depending on how the indicator value is derived.

B.1.1.1 Proportion based KSIs[37]

A first group of KSIs is constructed as proportion-based indicators, where the indicator value represents the share of respondents meeting a predefined condition. This approach applies to KSIs derived from both categorical survey questions and scale-based survey questions.

For scale-based inputs, ordinal responses are first mapped to a condition of interest in accordance with the KSI definition (for example, by identifying respondents selecting values above or below a predefined threshold on the scale). For categorical inputs, one or more response categories are directly defined as satisfying the KSI condition. In both cases, the construction of the indicator relies on the same underlying logic.

[37] Purdue University Northwest. Lecture Notes 8–10: Confidence Intervals for Proportions. https://www.pnw.edu/wp-content/uploads/2020/03/lecturenotes8-10.pdf

Let n denote the number of valid responses within a given analysis group, and let x denote the number of respondents whose answers satisfy the KSI condition after the appropriate mapping step. The KSI value is then computed as:

$$\hat{p} = \frac{x}{n}$$

where $\hat{p}$ represents the estimated proportion of respondents meeting the indicator definition.

For proportion-based KSIs, uncertainty is estimated using standard statistical assumptions for binomial proportions. The objective of the margin of error is to quantify the degree of uncertainty associated with the estimated indicator value, given that it is derived from a finite sample of survey responses rather than from the entire population of interest.

Given an estimated proportion $\hat{p}$ based on n valid responses, the margin of error (ME) at a 95% confidence level is defined as:

$$ME = z_{0.975} \sqrt{\frac{\hat{p}(1-\hat{p})}{n}}$$

where $z_{0.975} = 1.96$ is the critical value of the standard normal distribution corresponding to a two-sided 95% confidence interval where the remaining 5% probability is symmetrically distributed between the lower and upper tails of the normal distribution. The term under the square root represents the estimated standard error of the proportion and captures two key sources of uncertainty. First, uncertainty decreases as the number of valid responses increases, meaning that KSIs based on larger samples are estimated with greater precision. Second, uncertainty depends on the magnitude of the estimated proportion itself, with variability being highest when $\hat{p}$ is close to 0.5 and lower when values are closer to 0 or 1.

The margin of error defines a confidence interval around the estimated KSI value, expressed as $\hat{p} \pm ME$. Under the 95% confidence assumption, this interval can be interpreted as the range within which the true underlying population value would be expected to lie in 95% of repeated samples drawn under the same conditions. The choice of a 95% confidence level reflects a commonly accepted balance between statistical confidence and precision in applied socio-economic and safety-related analyses. Compared to lower confidence levels (e.g. 90%), the 95% level provides increased protection against false positive interpretations of differences, while still maintaining sufficient sensitivity to detect meaningful variations across groups. This choice is consistent with standard practice in survey-based analyses and supports a conservative interpretation of the results[38].

Confidence intervals are used as a supporting tool for result interpretation, particularly when comparing KSIs across groups. Overlapping confidence intervals indicate that observed differences may be partly driven by sampling variability and should therefore be interpreted with caution, while non-overlapping intervals suggest differences that are more robustly supported by the data.

4.2.1.1 Weighted KSIs [39] [40]

A second group of KSIs is constructed as weighted composite indicators. This approach applies to KSIs derived from scale-based survey questions where the full distribution of responses is retained rather than reduced to a binary condition. In these cases, each response category is assigned a predefined numerical weight reflecting its contribution to the underlying socio-economic dimension. The KSI value is calculated as the weighted average of responses, normalised by the total number of valid observations.

Let k denote the number of response categories on the scale. For each category i let n_i be the number of respondents selecting category i, w_i be the numerical weight associated with that category and $N = \sum_{i=1}^{k} n_i$ be the total number of valid responses.

The KSI value is defined as:

$$\hat{\mu} = \frac{\sum_{i=1}^{k} n_i w_i}{N}$$

where $\hat{\mu}$ represents the estimated weighted mean score for the indicator.

For weighted composite KSIs, uncertainty is estimated based on the dispersion of weighted responses around the estimated indicator value. This approach accounts for the variability of responses across scale categories as well as the effective sample size supporting the indicator.

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[38] **European Commission, Directorate-General for Economic and Financial Affairs (DG ECFIN).** *Precision level.* *https://dcf.ec.europa.eu/data-calls/definitions-and-terminology/p/precision-level_en*

[39] **Organisation for Economic Co-operation and Development (OECD)** (2005). *Handbook on Constructing Composite Indicators: Methodology and User Guide.* *https://www.oecd.org/content/dam/oecd/en/publications/reports/2005/08/handbook-on-constructing-composite-indicators_g17a16e3/533411815016.pdf*

[40] **National Institute of Standards and Technology (NIST)**. *Engineering Statistics Handbook – Confidence Intervals.* https://www.itl.nist.gov/div898/handbook/eda/section3/eda352.htm

Let w_j denote the weighted value associated with respondent j and let $\hat{\mu}$ be the estimated weighted mean across N valid responses. The sample variance of the weighted responses is defined as:

$$s^2 = \frac{1}{N-1}\sum_{j=1}^{N}(w_j - \hat{\mu})^2$$

The standard error of the weighted mean is then given by:

$$SE = \frac{s}{\sqrt{N}}$$

The margin of error (ME) at a 95% confidence level is calculated as:

$$ME = z_{0.975} \cdot SE$$

Where $z_{0.975} = 1.96$ corresponds to the critical value of the standard normal distribution for a two-sided 95% confidence interval.

As with proportion-based KSIs, the resulting margin of error defines a confidence interval around the estimated KSI value, expressed as $\hat{\mu} \pm ME$. Wider confidence intervals reflect higher dispersion of responses or smaller sample sizes, while narrower intervals indicate more stable estimates supported by a larger number of observations.

B.1.2 Statistical basis of the comparative analysis across groups [41]

Beyond the descriptive comparison of KSI values and their associated confidence intervals, a formal comparative analysis is conducted to assess whether observed differences between groups are statistically supported. Comparisons are performed on a pairwise basis, allowing two groups to be evaluated at a time while explicitly accounting for differences in sample size and statistical uncertainty.

For each pairwise comparison, three complementary elements are considered: the direct difference, the z-score and the p-value. These elements are interpreted jointly to support a robust assessment of differences across groups.

B.1.2.1 Direct difference

The direct difference represents the absolute difference in the estimated KSI values between two groups. Let $\widehat{p_1}$ and $\widehat{p_2}$ denote the estimated KSI values for group 1 and group 2, respectively. The direct difference is defined as:

[41] Penn State University (n.d.). *STAT 415: Introduction to Mathematical Statistics – Lesson 9.4: Comparing Two Proportions.* https://online.stat.psu.edu/stat415/lesson/9/9.4

$$\Delta = \widehat{p_1} - \widehat{p_2}$$

This measure provides an intuitive indication of both the magnitude and direction of the observed difference. However, on its own, the direct difference does not account for sample size or variability and therefore cannot be used to assess statistical significance. The direct difference is reported for all KSIs, regardless of their construction type.

B.1.2.2 Z-score

For proportion-based KSIs, statistical significance is assessed using a z-test for the difference between two proportions. The purpose of this test is to evaluate whether the observed difference between two group-level proportions is sufficiently large to be attributed to a systematic difference between groups, rather than to random sampling variability.

To assess whether differences between two groups are statistically meaningful, a null hypothesis of no true difference is first assumed. Under this assumption, both groups are considered to share the same underlying proportion, and any observed difference is attributed to sampling variability. Based on this assumption, a pooled proportion is calculated by combining the responses from both groups. This pooled estimate represents the expected proportion in the absence of a real group-level difference and is used as a reference to quantify the variability of the comparison.Let $\widehat{p_1}$ and $\widehat{p_2}$ denote the estimated proportions for group 1 and group 2 and N_1 and N_2 denote the corresponding numbers of valid responses.

- The pooled proportion is defined as:

$$\hat{p}_{pooled} = \frac{\widehat{p_1}N_1 + \widehat{p_2}N_2}{N_1 + N_2}$$

Based on the pooled proportion, the z-score is calculated to measure how large the observed difference between the two group-level proportions is relative to the variability expected under the null hypothesis. The z-score expresses the difference in standard deviation units and provides a standardised measure that accounts for both sample size and proportion variability.

The z-score is defined as:

$$z = \frac{\widehat{p_1} - \widehat{p_2}}{\sqrt{\hat{p}_{pooled} \cdot \left(1 - \hat{p}_{pooled}\right) \cdot \left(\frac{1}{N_1} + \frac{1}{N_2}\right)}}$$

A z-score close to zero indicates that the observed difference is small relative to the expected sampling variability and is therefore consistent with the null hypothesis of no true difference between groups. Larger absolute values of the z-score indicate that the observed difference is less likely to be explained by random variation alone.

B.1.2.3 P-value

The p-value provides a probabilistic measure of the statistical evidence against the null hypothesis of no true difference between the two groups. Specifically, it represents the probability of observing a difference at least as extreme as the one obtained, assuming that the underlying proportions of the two groups are equal.

In this study, p-values are derived from the z-score associated with the difference between two proportions. As differences in either direction are considered relevant, a two-sided test is applied. The p-value is computed as:

$$p = 2\big(1 - \Phi(|z|)\big)$$

Where $\Phi(\cdot)$ denotes the cumulative distribution function of the standard normal distribution and $|z|$ is the absolute value of the z-score.

A significance level of $\alpha = 0.05$ is adopted. Differences associated with p-values below 0.05 are considered statistically significant, indicating sufficient evidence to reject the null hypothesis of no difference between groups. Conversely, p-values equal to or greater than 0.05 indicate that the observed difference cannot be distinguished from random sampling variability with the chosen level of confidence, as there is insufficient statistical evidence to conclude that a systematic difference exists between the groups.

P-values are not interpreted in isolation but in conjunction with the magnitude of the direct difference and the associated confidence intervals.

B.2 Detailed Key Socio-economic indicators analysis

This annex should not be understood as a reporting section on its own. Instead, it is intended to complement the main report by providing additional explanations that build upon the analysis already presented. Its purpose is to support the interpretation of the results, rather than to introduce new findings.

The annex is designed for readers who wish to gain a more detailed understanding of the survey-based analysis, including a more mathematical perspective and a clearer comparison between personnel groups within each RA. In several cases, the results observed for Cabin Crew and Flight Crew are broadly comparable. As a consequence, the structure used to present and explain the results for these groups is also similar.

B.2.1 Reading guide – Tables

For each personnel group within each R, two tables are presented. The first table reports the KSI results by operational group, including the estimated value and associated uncertainty. The second table presents the pairwise comparisons between operator groups, providing information on the statistical significance of the observed differences.

The figure below illustrates how the first table should be read.

Columns group the KSI analysed within the RA.

Each row corresponds to an operational group.

Illustrative

Groups	AC01		
	Total	Matching	ME
ACMI	124	81 (65.32%)	8.38%
Cargo	287	12 (4.18%)	2.32%
LCC	1,234	103 (8.53%)	1.54%
Network	1,531	37 (2.42%)	0.77%
Regional	199	7 (3.52%)	2.56%

Margin of error associated with the KSI estimate.

Total number of survey responses obtained for the group.

Value used in the KSI. Depending on the indicator, this may represent the number of valid responses or another defined reference value. the percentage in brackets shows the share relative to the total.

Figure 62: Illustrative guide to the structure of the KSI results table and its main components.

The figure below illustrates the structure and interpretation of the pairwise comparison table used for the statistical assessment of differences between operator groups. All statistical terms and measures shown in this table are defined and explained in more detail in Section 2.4.3.

Columns group the KSI analysed within the RA.

Each row represents a pair of operational groups being compared.

Illustrative

Pair		AC01 Diff.	AC01 Z-score	AC01 p-val
ACMI	**Cargo**	-61.14%	13.597	0.000
ACMI	**LCC**	-56.98%	17.671	0.000
ACMI	**Network**	-62.91%	26.182	0.000
ACMI	**Regional**	-61.80%	12.134	0.000
Cargo	**LCC**	4.17%	-2.404	0.016
Cargo	**Network**	-1.76%	1.694	0.090
Cargo	**Regional**	-0.66%	0.371	0.711
LCC	**Network**	-5.93%	7.070	0.000
LCC	**Regional**	-4.83%	2.375	0.018
Network	**Regional**	1.10%	-0.928	0.353

Probability that the observed difference could occur by chance under the assumption of no true difference between groups; lower values indicate stronger statistical evidence of a meaningful difference.

Each row represents a pair of operational groups being compared.

Standardised measure of the difference between the two groups, indicating how large the observed difference is relative to the underlying variability.

Figure 63: Structure of the pairwise comparison table for KSI results.

B.2.2 Atypical contracts

B.2.2.1 Flight crew

The analysis of atypical contracts begins by examining two fundamental dimensions: the extent to which crew are not directly employed on permanent airline contracts and the degree to which they are engaged under precarious employment models. Together, these two aspects provide an initial indication of how employment structures vary across operational models and whether non-standard arrangements are concentrated in specific segments. In terms of direct employment, the results show a clear separation across business models. ACMI reports 65.32% of respondents not directly employed on permanent airline contracts (margin of error ±8.38 percentage points), while all other operational models remain in the single digits: cargo 4.18% (±2.32), LCC 8.35% (±1.54), network 2.42% (±0.77), and regional 3.52% (±2.56). This pattern indicates that the reliance on non-direct employment is not evenly distributed across the sector, but instead concentrated in a specific operational environment. The statistical comparisons confirm that ACMI differs sharply from each of these segments (e.g., ACMI versus cargo and ACMI versus network both $p \approx 0$), whereas differences within the low-share cluster are limited. For instance, cargo and network show no statistically significant difference ($p \approx 0.090$), while cargo and LCC show a small but statistically significant gap ($p \approx 0.016$), consistent with the slightly higher value observed for LCC. A similar structure is observed when looking at engagement under precarious employment models. ACMI again reports the highest share, at 42.74% (±8.71), compared with much lower values elsewhere: cargo 1.05% (±1.18), LCC 5.11% (±1.23), network 0.72% (±0.42), and regional 1.51% (±1.69). This suggests that the same operational model that shows high levels of non-direct employment also concentrates the use of more precarious contractual arrangements. Pairwise tests reinforce this structure: ACMI differs significantly from all other operational models ($p \approx 0$ across comparisons), while within the low-share group only some differences are statistically meaningful, such as cargo versus LCC ($p \approx 0.002$), whereas cargo versus network is not significant ($p \approx 0.561$). Taken together, these two indicators point to a consistent concentration of non-standard and precarious employment arrangements in ACMI operations, with LCC higher than cargo, network, and regional but far below ACMI.

Looking next at cross-border contractual arrangements, the differentiation across operational models becomes more pronounced. ACMI and LCC stand out with the highest shares of crew whose contracts are registered outside the airline's primary AOC country, at 57.38% (±8.78) and 64.60% (±2.75) respectively. In contrast, cargo, network, and regional operations report much lower levels, at 19.78% (±4.68) for cargo, 6.95% (±1.29) for network, and 7.65% (±3.72) for regional. This shift indicates that, beyond contract type alone, certain operational models rely more extensively on cross-border employment structures. Despite wider uncertainty around the ACMI estimate, both ACMI and LCC remain clearly separated from the remaining segments. Statistical comparisons support this reading: differences between ACMI and network or regional, as well as between LCC and network or regional, are associated with p-values effectively at zero, while cargo occupies an intermediate position, differing significantly from LCC but less clearly from ACMI.

A closely related picture emerges when examining the alignment between operational base and payroll jurisdiction. Here again, ACMI reports the highest share, with 27.13% (±7.67) of respondents indicating that their payroll jurisdiction differs from their operational base. LCC and cargo show markedly lower but still non-negligible levels, at 3.85% (±1.07) and 3.83% (±2.22) respectively, while network and regional remain very low, at 1.30% (±0.57) and 1.51% (±1.69). This suggests that the concentration of cross-border contracting in ACMI is also reflected in a higher degree of separation between operational activity and payroll arrangements. The statistical tests confirm that ACMI differs significantly from all other operational models ($p \approx 0$ across comparisons). Differences among the low-share segments are generally weak, although some pairwise contrasts, such as cargo versus LCC, reach statistical significance, reflecting small but measurable differences at very low absolute levels. Finally, the departure intention indicator provides a forward-looking perspective on workforce stability. ACMI and LCC again report the highest values, with 27.35% (±8.08) and 23.38% (±2.53) of respondents respectively indicating that it is very likely they will leave their airline in the next 12 months. These levels contrast with substantially lower shares in cargo (6.92% ±3.09), network (6.26% ±1.27), and regional (11.73% ±4.71).

This pattern suggests that the employment structures observed in earlier indicators may be accompanied by higher perceived instability or mobility intentions in certain operational environments. Pairwise comparisons show that ACMI differs significantly from cargo, network, and regional ($p \approx 0$), while LCC also differs strongly from network and cargo ($p \approx 0$). Differences among the lower-intention group are more limited, with some comparisons, such as cargo versus network, not reaching statistical significance. Taken together, the combined reading of contractual structure, jurisdictional alignment, and departure intention reinforces the patterns already identified in the earlier indicators. Cargo, network, and regional operations consistently report low levels across most dimensions, while ACMI concentrates high values across non-direct employment, precarious contracting, cross-border arrangements, payroll mismatches, and stated departure intention. LCC occupies an intermediate but distinct position, characterised in particular by high levels of cross-border registration and elevated departure intention, even where direct employment and payroll mismatch remain comparatively low. This convergence of indicators provides a coherent socio-economic profile that underpins the synthesis presented in the main body of the report.

The tables below present the numerical results of the statistical analysis for the atypical contracts RA. They report the distribution of responses by airline type and the corresponding pairwise comparison statistics used to assess differences between groups.

Table 15: Atypical contracts KSI results – Flight crew.

Groups	AC01			AC02			AC03			AC04			AC05		
	Total	Matching	ME	Total	Matching	ME	Total	Matching	ME	Total	Matching	ME	Total	Matching	ME
ACMI	124	81 (65.32%)	8.38%	124	53 (42.74%)	8.71%	122	70 (57.38%)	8.78%	117	32 (27.35%)	8.08%	129	35 (27.12%	7.67%
Cargo	287	12 (4.18%)	2.32%	287	3 (1.05%)	1.18%	278	55 (19.78%)	4.68%	260	18 (6.92%)	3.09%	287	11 (3.83%)	2.22%
LCC	1,234	103 (8.53%)	1.54%	1,234	63 (5.11%)	1.23%	1,161	750 (64.6%)	2.75%	1,078	252 (23.38%)	2.53%	1,247	48 (3.85%)	1.07%
Network	1,531	37 (2.42%)	0.77%	1,531	11 (0.72%)	0.42%	1,497	104 (6.95%)	1.29%	1,405	88 (6.26%)	1.27%	1,535	20 (1.30%)	0.57%
Regional	199	7 (3.52%)	2.56%	199	3 (1.51%)	1.69%	196	15 (7.65%)	3.72%	179	21 (11.73%)	4.71%	199	3 (1.51%)	1.69%

Table 16: Atypical contracts pairwise comparison – Flight crew

Pair	AC01	AC02	AC03	AC04	AC05

		Diff.	Z-score	p-val	Diff.	Z-score	p-val	Diff.	Z-score	p-val	Diff.	Z-score	p-val	Diff.	Z-score	p-val
ACMI	Cargo	-61.14%	13.597	0.000	-41.70%	11.310	0.000	-37.59%	7.468	0.000	-20.43%	5.410	0.000	-23.30%	7.009	0.000
ACMI	LCC	-56.98%	17.671	0.000	-37.64%	14.294	0.000	7.22%	-1.580	0.114	-3.97%	0.959	0.337	-23.28%	10.574	0.000
ACMI	Network	-62.91%	26.182	0.000	-42.02%	23.343	0.000	-50.43%	17.294	0.000	-21.09%	8.132	0.000	-25.83%	15.761	0.000
ACMI	Regional	-61.80%	12.134	0.000	-41.23%	9.520	0.000	-49.72%	9.743	0.000	-15.62%	3.427	0.001	-25.62%	7.083	0.000
Cargo	LCC	4.17%	-2.404	0.016	4.06%	-3.041	0.002	44.82%	-13.519	0.000	16.45%	-5.934	0.000	0.02%	-0.013	0.990
Cargo	Network	-1.76%	1.694	0.090	-0.33%	0.581	0.561	-12.84%	6.883	0.000	-0.66%	0.400	0.689	-2.53%	3.042	0.002
Cargo	Regional	-0.66%	0.371	0.711	0.46%	-0.454	0.650	-12.13%	3.666	0.000	4.81%	-1.740	0.082	-2.33%	1.507	0.132
LCC	Network	-5.93%	7.070	0.000	-4.39%	7.105	0.000	-57.65%	31.570	0.000	-17.11%	12.295	0.000	-2.55%	4.325	0.000

LCC	Regional	-4.83%	2.375	0.018	-3.60%	2.247	0.025	-56.95%	14.870	0.000	-11.64%	3.499	0.000	-2.34%	1.663	0.096
Network	Regional	1.10%	-0.928	0.353	0.79%	-1.169	0.243	0.71%	-0.363	0.716	5.47%	-2.722	0.006	0.20%	-0.237	0.812

B.2.2.2 Cabin crew

The analysis of atypical contracts for cabin crew follows the same analytical structure as for flight crew, examining how employment arrangements, contractual precarity, cross-border structures, and departure intention vary across operational models. Together, these indicators provide insight into the extent to which non-standard employment practices are present among cabin crew and whether they are concentrated in specific segments of the aviation system.

In terms of direct employment, the results show a clear differentiation across operational models. ACMI reports by far the highest share of cabin crew not directly employed on permanent airline contracts, at 32.56% (margin of error ±14.01 percentage points). In contrast, all other operational models report substantially lower values, with LCC at 7.44% (±1.73), network at 2.68% (±0.96), and regional at 3.41% (±3.79). This indicates that non-direct employment among cabin crew is highly concentrated in ACMI operations. Statistical comparisons confirm this separation, with ACMI differing significantly from LCC, network, and regional operations (p≈0 across comparisons), while differences among the non-ACMI segments are limited and generally not statistically significant.

A similar pattern is observed when examining engagement under precarious employment models. ACMI again reports the highest share, with 27.91% (±13.41) of respondents indicating self-employment, zero-hour, fixed-term, or pay-to-fly arrangements. By contrast, precarious contracting remains marginal in other operational models, with LCC at 1.47% (±0.79), network at 0.28% (±0.31), and regional at 1.14% (±2.21). Pairwise comparisons show that ACMI differs significantly from all other segments (p≈0), whereas differences among LCC, network, and regional operations are not statistically meaningful. Taken together with the direct employment indicator, these findings suggest that both non-direct employment and contractual precarity among cabin crew are structural features of ACMI operations, while remaining limited elsewhere.

Looking next at cross-border contractual arrangements, the differentiation across operational models becomes more pronounced. LCC reports the highest share, with 62.70% (±3.59) of cabin crew having contracts registered outside the airline's primary AOC country, closely followed by ACMI at 50.00% (±15.90). In contrast, regional (16.05% ±7.99) and network (8.07% ±1.72) operations report substantially lower levels. Statistical tests confirm that both ACMI and LCC differ significantly from network and regional operations ($p \approx 0$), while the difference between ACMI and LCC is not statistically significant, reflecting overlapping uncertainty ranges. This indicates that cross-border employment structures for cabin crew are particularly characteristic of ACMI and LCC business models, even where other forms of contractual precarity remain low in LCC.

A related pattern emerges when examining the alignment between operational base and payroll jurisdiction. ACMI again reports the highest share, with 18.18% (±11.40) of respondents indicating a mismatch between payroll jurisdiction and operational base. Other operational models report much lower levels, with LCC at 2.13% (±0.95), network at 2.86% (±0.99), and regional at 1.14% (±2.21). Statistical comparisons show that ACMI differs significantly from all other operational models ($p \approx 0$), while differences among the remaining segments are small and generally not statistically significant. This suggests that, for cabin crew, payroll–base misalignment is primarily concentrated in ACMI operations and closely aligned with the prevalence of cross-border contracting observed earlier.

Finally, the departure intention indicator provides a forward-looking perspective on workforce stability. ACMI and LCC report the highest levels, with 13.51% (±11.02) and 13.15% (±2.39) of respondents respectively indicating that they are very likely to leave their airline in the next 12 months. These values contrast with lower levels reported in network (4.75% ±1.31) and regional (1.23% ±2.40) operations. Pairwise comparisons show that LCC differs significantly from network ($p \approx 0$), while ACMI also differs significantly from network and regional operations ($p \approx 0$). Differences between ACMI and LCC are not statistically significant, reflecting similar point estimates and overlapping margins of error. This pattern suggests that elevated departure intention among cabin crew is associated with operational environments characterised by higher exposure to atypical or cross-border employment arrangements.

Taken together, the combined reading of contractual structure, cross-border registration, payroll alignment, and departure intention reveals a coherent socio-economic profile for cabin crew. ACMI concentrates high values across all indicators, including non-direct employment, contractual precarity, cross-border arrangements, payroll mismatches, and elevated departure intention. LCC occupies a distinct intermediate position, characterised in particular by very high levels of cross-border registration and elevated departure intention, while maintaining relatively low levels of direct contractual precarity. Network and regional operations consistently report low levels across all dimensions, indicating more stable and nationally aligned employment structures for cabin crew. This convergence of indicators mirrors, in part, the patterns observed for flight crew, while also highlighting role-specific differences in how atypical employment practices manifest across operational models.

The tables below present the numerical results of the statistical analysis for the atypical contracts RA. They report the distribution of responses by airline type and the corresponding pairwise comparison statistics used to assess differences between groups.

Table 17: Atypical contracts KSI results – Cabin crew

Groups	AC01			AC02			AC03			AC04			AC05		
	Total	Matching	ME	Total	Matching	ME	Total	Matching	ME	Total	Matching	ME	Total	Matching	ME
ACMI	43	14 (32.56%)	14.01 %	43	12 (27.91%)	13.41%	38	19 (50.00%)	15.90 %	37	5 (13.51%)	11.02 %	44	8 (18.18%)	11.40 %
Cargo	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
LCC	887	66 (7.44%)	1.73%	887	13 (1.47%)	0.79%	697	437 (62.70%)	3.59%	768	101 (13.15%)	2.39%	893	19 (2.13%)	0.95%
Network	1081	29 2.68%)	0.96%	1081	3 (0.28%)	0.31%	966	78 (8.07%)	1.72%	1010	48 (4.75%)	1.31%	1084	31 (2.68%)	0.99%

Regional	88	3 (3.41%)	3.79%	88	1 (1.14%)	2.21%	81	13 (16.05%)	7.99%	81	1 (1.23%)	2.40%	88	1 (1.14%)	2.21%

Table 18: Atypical contracts pairwise comparison – Cabin crew

Pair		AC01			AC02			AC03			AC04			AC05		
		Diff.	Z-score	p-val	Diff.	Z-score	p-val	Diff.	Z-score	p-val	Diff.	Z-score	p-val	Diff.	Z-score	p-val
ACMI	LCC	-25.12%	5.737	0.000	-26.44%	10.470	0.000	12.70%	-1.571	0.116	-0.36%	0.064	0.949	-16.05%	6.215	0.000
ACMI	Network	-29.88%	10.016	0.000	-27.63%	15.484	0.000	-41.93%	8.581	0.000	-8.76%	2.388	0.017	-15.32%	5.453	0.000
ACMI	Regional	-29.15%	4.662	0.000	-26.77%	4.812	0.000	-33.95%	3.894	0.000	-12.28%	2.817	0.005	-17.05%	3.663	0.000
LCC	Network	-4.76%	4.900	0.000	-1.19%	2.920	0.003	-54.62%	23.771	0.000	-8.40%	6.331	0.000	0.73%	-1.032	0.302
LCC	Regional	-4.03%	1.407	0.160	-0.33%	0.248	0.804	-46.65%	8.047	0.000	-11.92%	3.137	0.002	-0.99%	0.628	0.530
Network	Regional	0.73%	-0.402	0.688	0.86%	-1.327	0.185	7.97%	-2.447	0.014	-3.52%	1.471	0.141	-1.72%	0.954	0.340

B.2.3 Commercial pressure

B.2.3.1 Flight crew

The analysis of commercial pressure focuses on how operational and organisational demands translate into perceived workload, roster constraints, and decision-making pressure for flight crew. The indicators examined capture both structural exposure to capacity limits and subjective perceptions of operational pressure, allowing for a comparative assessment across operational models. Together, they provide a multi-dimensional view of how commercial imperatives may shape operational conditions, scheduling practices, and fatigue margins in different segments of the aviation system.

In terms of roster capacity utilisation, the results show moderate but clearly differentiated levels across business models. LCC reports the highest share of respondents operating close to regulatory flight and duty time limits, at 14.80% (±1.98), followed by ACMI at 11.81% (±5.61) and cargo at 11.64% (±3.79). Regional operations report 9.28% (±4.08), while network shows the lowest level, at 5.87% (±1.20). Although the absolute differences between some segments are relatively modest, the pattern indicates that a meaningful proportion of crews operate near their regulatory limits in several operational environments. Statistical comparisons show that ACMI differs significantly from network ($p \approx 0.008$), while differences among cargo, regional, and LCC are less consistently significant, reflecting overlapping margins of error. Overall, these results suggest that exposure to high roster capacity utilisation is more characteristic of ACMI and LCC operations, while remaining comparatively limited in network environments.

A clearer and more pronounced separation emerges when examining short-notice roster changes. ACMI and LCC again report the highest levels, with 24.81% (±7.45) and 25.98% (±2.43) of respondents respectively indicating frequent late-notice changes to their published roster. Cargo follows at 19.86% (±4.62), while regional reports 10.55% (±4.27) and network shows a markedly lower level, at 3.78% (±0.95). The magnitude of these differences is reinforced by the statistical tests, which show strong separation between network and the other operational models, with p-values effectively at zero for comparisons with ACMI and LCC. These findings indicate that roster instability is a recurrent feature in ACMI and LCC environments, and to a lesser extent in cargo operations, whereas network operations are characterised by more predictable and stable roster planning.

Perceived pressure related to on-time performance remains low in absolute terms across all operational models, but some variation is nevertheless observed. Regional reports the highest share, at 2.51% (±2.17), followed by LCC at 2.73% (±0.90) and ACMI at 1.55% (±2.13). Cargo and network report the lowest values, at 1.39% (±1.36) and 0.91% (±0.48) respectively. Most pairwise comparisons do not reach statistical significance, reflecting both the low absolute levels and overlapping margins of error. This suggests that explicit perceptions of OTP pressure compromising safety are reported by a relatively small minority of respondents across all operational models, even in environments where other indicators point to higher commercial pressure. It also highlights that some dimensions of commercial pressure may be experienced indirectly through scheduling and workload rather than being explicitly framed by crews as safety trade-offs.

Finally, the use of commander's discretion provides an additional operational signal of commercial pressure related to scheduling constraints and fatigue margins. LCC reports the highest share, with 49.95% (±2.78) of respondents indicating frequent use of discretion, followed by ACMI at 36.89% (±7.92). Network and regional operations report similar intermediate levels, at 25.30% (±2.13) and 25.59% (±5.64) respectively, while cargo reports the lowest level, at 23.71% (±4.61). Statistical comparisons show strong and consistent differences between LCC and network as well as between LCC and regional operations ($p \approx 0$), and significant differences between cargo and LCC. These results indicate that reliance on commander's discretion is particularly concentrated in LCC operations, with ACMI also showing elevated levels, while network, regional, and cargo operations exhibit more moderate and comparable patterns.

Taken together, the combined reading of roster utilisation, roster stability, perceived OTP pressure, and discretion use points to a differentiated commercial pressure profile across operational models. ACMI and LCC consistently report higher levels across several indicators linked to scheduling pressure, operational flexibility, and fatigue margin management, while network operations show systematically lower levels across all dimensions examined. Cargo and regional generally occupy intermediate positions, combining elevated roster instability with lower levels of other pressure-related indicators.

The tables below present the numerical results of the statistical analysis for the commercial pressure RA. They report the distribution of responses by airline type and the corresponding pairwise comparison statistics used to assess differences between groups.

Table 19: Commercial pressure KSI results – Flight crew

Groups	CP03			CP04			CP05			CP08		
	Total	Matching	ME	Total	Matching	ME	Total	Matching	ME	Total	Matching	ME
ACMI	127	15 (11.81%)	5.61%	129	32 (24.81%)	7.45%	129	2 (1.55%)	2.13%	126	37 (28.97%)	7.92%
Cargo	275	32 (11.64%)	3.79%	287	57 (19.86%)	4.62%	287	4 (1.39%)	1.36%	280	54 (19.11%)	4.61%
LCC	1230	182 (14.8%)	1.98%	1247	324 (25.98%)	2.43%	1247	34 (2.73%)	0.90%	1236	583 (47.17%)	2.78%
Network	1481	87 (5.87%)	1.20%	1535	58 (3.78%)	0.95%	1535	14 (0.91%)	0.48%	1504	349 (23.17%)	2.13%
Regional	194	18 (9.28%)	4.08%	199	21 (10.55%)	4.27%	199	5 (2.51%)	2.17%	193	39 (19.95%)	5.64%

Table 20: Commercial pressure pairwise compariso – Flight crew

Pair	CP03			CP04			CP05			CP08		
	Diff.	Z-score	p-val	Diff.	Z-score	p-val	Diff.	Z-score	p-val	Diff.	Z-score	p-val

ACMI	Cargo	-0.17%	0.051	0.960	-4.95%	1.138	0.255	-0.16%	0.124	0.901	-9.86%	2.240	0.025
ACMI	LCC	2.99%	-0.909	0.363	1.18%	-0.288	0.773	1.18%	-0.797	0.426	18.20%	-3.952	0.000
ACMI	Network	-5.94%	2.634	0.008	-21.03%	10.089	0.000	-0.64%	0.714	0.475	-5.80%	1.489	0.137
ACMI	Regional	-2.53%	0.731	0.465	-14.25%	3.414	0.001	0.96%	-0.589	0.556	-9.02%	1.882	0.060
Cargo	LCC	3.16%	-1.357	0.175	6.12%	-2.126	0.034	1.33%	-1.310	0.190	28.06%	-8.687	0.000
Cargo	Network	-5.76%	3.491	0.000	-16.08%	10.167	0.000	-0.48%	0.757	0.449	4.06%	-1.513	0.130
Cargo	Regional	-2.36%	0.815	0.415	-9.31%	2.731	0.006	1.12%	-0.900	0.368	0.84%	-0.230	0.818
LCC	Network	-8.92%	7.736	0.000	-22.20%	16.897	0.000	-1.81%	3.655	0.000	-24.00%	13.295	0.000
LCC	Regional	-5.52%	2.056	0.040	-15.43%	4.740	0.000	-0.21%	0.173	0.863	-27.22%	7.194	0.000
Network	Regional	3.40%	-1.839	0.066	6.77%	-4.292	0.000	1.60%	-2.041	0.041	-3.22%	1.020	0.308

B.2.3.2 Cabin crew

The analysis of commercial pressure for cabin crew examines how operational and organisational demands translate into scheduling constraints, roster instability, and perceived operational pressure in cabin operations. As for flight crew, the indicators combine objective exposure to workload and roster constraints with subjective perceptions related to operational pressure, allowing for a comparative assessment across operational models. Together, they provide a multi-dimensional view of how commercial imperatives may shape working conditions and fatigue margins for cabin crew in different segments of the aviation system.

In terms of roster capacity utilisation, the results show clear differentiation across business models. LCC reports the highest share, with 20.39% of respondents indicating that they almost always operate close to regulatory limits (±2.68), followed by network at 13.45% (±2.12) and ACMI at 10.00% (±9.30). Regional operations report the lowest level, at 6.49% (±5.50). Although uncertainty around the ACMI estimate is relatively high, statistical comparisons indicate a significant separation between LCC and network operations (p≈0), while differences involving ACMI and regional are less consistently significant. Overall, these results suggest that sustained exposure to high roster utilisation for cabin crew is most characteristic of LCC operations, while remaining more limited in network and regional environments.

A clearer separation emerges when examining short-notice roster changes. ACMI and LCC report the highest levels, with 22.73% (±12.38) and 20.16% (±2.63) of respondents respectively indicating frequent late-notice changes to their published roster. In contrast, network and regional operations report substantially lower levels, at 4.61% (±1.25) and 4.55% (±4.35). Statistical tests reinforce this pattern, showing strong and statistically significant differences between LCC and both network and regional operations (p≈0). These findings indicate that roster instability for cabin crew is concentrated in ACMI and LCC environments, while network and regional operations are characterised by more predictable roster planning.

Perceived pressure related to on-time performance remains low in absolute terms across all operational models, but some variation is nevertheless observed. Cargo is not represented in this sample, while LCC reports the highest share at 7.73% (±1.75), followed by ACMI at 6.82% (±7.45). Network and regional operations report lower values, at 4.61% (±1.25) and 2.27% (±3.11) respectively. Statistical comparisons show significant differences between LCC and network as well as between LCC and regional operations, while differences involving ACMI are less robust due to wide margins of error. As with flight crew, these results suggest that explicit perceptions of OTP pressure compromising safety are reported by a minority of cabin crew, even in environments where other indicators point to higher commercial pressure.

Finally, the use of commander's discretion provides an additional operational signal of commercial pressure related to scheduling constraints and fatigue margins. LCC again reports the highest level, with 40.40% (±3.28) of respondents indicating frequent reliance on discretion, followed by ACMI at 24.32% (±13.82). Network and regional operations report lower levels, at 20.28% (±2.50) and 14.29% (±7.48) respectively. Statistical comparisons show significant differences between LCC and network as well as between LCC and regional operations (p≈0), while differences between ACMI and the other models are less consistently significant due to overlapping uncertainty ranges. This pattern indicates that reliance on operational flexibility mechanisms is particularly pronounced for cabin crew in LCC environments, with ACMI also showing elevated levels.

Taken together, the combined reading of roster utilisation, roster stability, perceived OTP pressure, and discretion use points to a differentiated commercial pressure profile for cabin crew. LCC operations consistently report the highest levels across multiple indicators, particularly those related to roster utilisation, roster instability, and discretion use. ACMI also shows elevated levels, especially in relation to roster instability, though with greater variability. In contrast, network and regional operations systematically report lower levels across most dimensions, indicating more stable and predictable operational environments for cabin crew. This pattern broadly mirrors that observed for flight crew, while highlighting the particularly strong concentration of commercial pressure indicators in LCC cabin crew operations.

The tables below present the numerical results of the statistical analysis for the commercial pressure RA. They report the distribution of responses by airline type and the corresponding pairwise comparison statistics used to assess differences between groups.

Table 21: Commercial pressure KSI results – Cabin crew

Groups	CP03			CP04			CP05			CP08		
	Total	Matching	ME	Total	Matching	ME	Total	Matching	ME	Total	Matching	ME
ACMI	40	4 (10.00%)	9.30%	44	10 (22.73%)	12.38 %	44	3 (6.82%)	7.45%	37	9 (24.32%)	13.82 %

Cargo	-	-	-	-	-	-	-	-	-	-	-	-
LCC	868	177 (20.39%)	2.68%	893	180 (20.16%)	2.63%	893	69 (7.73%)	1.75%	859	347 (40.40%%)	3.28%
Network	996	134 (13.45%)	2.12%	1084	50 (4.61%)	1.25%	1084	50 (4.61%)	1.25%	991	201 (20.28%)	2.50%
Regional	77	5 (6.49%)	5.50%	88	4 (2.27%)	4.35%	88	2 (2.27%)	3.11%	84	12 (14.29%)	7.48%

Table 22: Commercial pressure pairwise comparison – Cabin crew

Pair		CP03			CP04			CP05			CP08		
		Diff.	Z-score	p-val	Diff.	Z-score	p-val	Diff.	Z-score	p-val	Diff.	Z-score	p-val
ACMI	LCC	10.39%	-1.608	0.108	-2.57%	0.396	0.692	0.91%	-0.221	0.825	16.07%	-2.128	0.033
ACMI	Network	3.45%	-0.630	0.528	-18.11%	5.041	0.000	-2.21%	0.678	0.498	-4.04%	0.652	0.515
ACMI	Regional	-3.51%	0.675	0.500	-18.18%	3.147	0.002	-4.55%	1.290	0.197	-10.04%	1.427	0.154
LCC	Network	-6.94%	4.008	0.000	-15.54%	10.688	0.000	-3.11%	2.897	0.004	-20.11%	9.772	0.000

LCC	Regional	-13.90%	2.964	0.003	-15.61%	3.577	0.000	-5.45%	1.884	0.060	-26.11%	4.813	0.000
Network	Regional	-6.96%	1.752	0.080	-0.07%	0.029	0.977	-2.34%	1.025	0.305	-6.00%	1.357	0.175

B.2.4 Crew interoperability

B.2.4.1 Flight crew

The analysis of crew interoperability for flight crew examines two complementary dimensions: the extent to which cross-AOC operations are applied in practice and how clearly roles and procedures are perceived when operating under a different AOC. Together, these indicators provide insight into whether crew interoperability functions as an occasional flexibility tool or as a structurally embedded operating mode.

Exposure to cross-AOC operations shows a very pronounced differentiation across operational models. ACMI stands out clearly, with 50.39% (±8.70) of respondents reporting frequent operations under an AOC different from their primary one. In contrast, cargo (1.77% ±1.54), network (0.13% ±0.18), regional (2.03% ±1.97), and LCC (4.06% ±1.10) report very low levels of exposure. Statistical comparisons confirm that ACMI differs significantly from all other operational models ($p \approx 0$ across comparisons), while differences within the low-exposure group are small and, in most cases, not operationally meaningful. These results indicate that frequent cross-AOC flying is a defining feature of ACMI operations, while remaining marginal elsewhere.

A different pattern emerges when examining perceived procedural clarity. Reports of very unclear roles or procedures when operating under a different AOC remain low across all operational models, but some variation is observed. Cargo and regional report the highest values, at 8.11% (±8.80) and 6.06% (±8.14) respectively, followed by ACMI at 4.88% (±4.66) and network at 3.89% (±2.82). LCC reports the lowest level, at 1.50% (±0.81). While absolute levels remain limited, some pairwise comparisons reach statistical significance, notably between ACMI and LCC and between cargo and LCC, reflecting lower perceived lack of clarity in LCC operations.

Taken together, the combined reading of exposure and perceived clarity highlights a structural distinction across operational models. In ACMI operations, cross-AOC flying is widespread yet associated with relatively moderate levels of perceived procedural confusion, suggesting that interoperability is embedded within established operational frameworks. By contrast, in cargo, network, and regional operations, cross-AOC exposure is rare, but when it does occur, a slightly higher share of respondents report unclear roles or procedures. LCC combines low exposure with high perceived clarity, indicating limited but well-managed interoperability arrangements.

The tables below present the numerical results of the statistical analysis for the crew interoperability RA. They report the distribution of responses by airline type and the corresponding pairwise comparison statistics used to assess differences between groups.

Table 23: Crew interoperability KSI results – Flight crew

Groups	CI01			CI02		
	Total	Matching	ME	Total	Matching	ME
ACMI	127	64 (50.39%)	8.70%	82	4 (4.88%)	4.66%
Cargo	282	5 (1.77%)	1.54%	37	3 (8.11%)	8.80%
LCC	1233	50 (4.06%)	1.10%	868	13 (1.5%)	0.81%
Network	1521	2 (0.13%)	0.18%	180	7 (3.89%)	2.82%
Regional	197	4 (2.03%)	1.97%	33	2 (6.06%)	8.14%

Table 24: Crew interoperability pairwise comparison – Flight crew

Pair	CI01	CI02

		Diff.	Z-score	p-val	Diff.	Z-score	p-val
ACMI	Cargo	-48.62%	12.149	0.000	3.23%	-0.693	0.488
ACMI	LCC	-46.34%	17.943	0.000	-3.38%	2.587	0.010
ACMI	Network	-50.26%	27.753	0.000	-0.99%	0.421	0.674
ACMI	Regional	-48.36%	10.436	0.000	1.18%	-0.275	0.784
Cargo	LCC	2.28%	-1.848	0.065	-6.61%	5.548	0.000
Cargo	Network	-1.64%	4.071	0.000	-4.22%	1.799	0.072
Cargo	Regional	0.26%	-0.204	0.838	-2.05%	0.413	0.680
LCC	Network	-3.92%	7.523	0.000	2.39%	-2.253	0.024
LCC	Regional	-2.02%	1.384	0.166	4.56%	-2.051	0.040
Network	Regional	1.90%	-4.251	0.000	2.17%	-0.635	0.526

B.2.4.2 Cabin crew

The analysis of crew interoperability for cabin crew examines two complementary dimensions: the extent to which cross-AOC operations are applied in practice and how clearly roles and procedures are perceived when operating under a different AOC. Together, these indicators provide insight into whether crew interoperability is used as an occasional flexibility mechanism or constitutes a structurally embedded operating mode for cabin crew.

Exposure to cross-AOC operations shows a very strong differentiation across operational models. ACMI stands out clearly, with 61.90% (±14.69) of respondents reporting frequent operations under an AOC different from their primary one. By contrast, exposure remains negligible in all other operational models, with LCC at 0.81% (±0.59), network at 0.38% (±0.37), and regional at 1.15% (±2.24). Statistical comparisons confirm that ACMI differs significantly from LCC, network, and regional operations ($p \approx 0$ across comparisons), while differences among the non-ACMI models are not statistically significant. These results indicate that frequent cross-AOC deployment of cabin crew is a defining feature of ACMI operations, while remaining marginal in all other segments.

A different and more nuanced pattern emerges when examining perceived procedural clarity. Reports of very unclear roles or procedures when operating under a different AOC remain low across all operational models. Network reports the highest value, at 5.43% (±2.99), followed by ACMI at 3.13% (±6.03) and LCC at 2.84% (±1.52), while regional reports no cases. In absolute terms, these levels remain limited, and statistical comparisons show no robust or systematic differences between non-ACMI operational models. While ACMI differs significantly from network and regional in some pairwise tests, these results should be interpreted with caution given the low absolute values and overlapping margins of error.

Taken together, the combined reading of exposure and perceived clarity highlights a clear structural distinction. In ACMI operations, cross-AOC deployment of cabin crew is widespread, yet reported levels of procedural confusion remain relatively low, suggesting that interoperability is embedded within established and familiar operational frameworks. By contrast, in LCC, network, and regional operations, cross-AOC exposure is rare, and reported clarity issues remain limited and sporadic when such operations occur. Overall, the findings indicate that crew interoperability for cabin crew is structurally embedded in ACMI environments, while remaining occasional and limited in other operational models, with no evidence of widespread procedural clarity concerns outside ACMI operations.

The tables below present the numerical results of the statistical analysis for the crew interoperability RA. They report the distribution of responses by airline type and the corresponding pairwise comparison statistics used to assess differences between groups.

Table 25: Crew interoperability KSI results – Cabin crew

Groups	CI01			CI02		
	Total	Matching	ME	Total	Matching	ME
ACMI	42	26 (61.90%)	14.69%	32	1 (3.13%)	6.03%
Cargo	-	-	-	-	-	-
LCC	869	7 (0.81%)	0.59%	457	13 (2.84%)	1.52%
Network	1063	4 (0.38%)	0.37%	221	12 (5.43%)	2.99%
Regional	87	1 (1.15%)	2.24%	15	0 (0.00%)	0.00%

Table 26: Crew interoperability pairwise comparison – Cabin crew

Pair	CI01			CI02		
	Diff.	Z-score	p-val	Diff.	Z-score	p-val

ACMI	LCC	-61.10%	20.698	0.000	-0.28%	0.104	0.917
ACMI	Network	-61.53%	24.065	0.000	2.30%	-0.625	0.532
ACMI	Regional	-60.76%	7.948	0.000	-3.13%	0.693	0.489
LCC	Network	-0.43%	1.247	0.212	2.59%	-1.902	0.057
LCC	Regional	0.34%	-0.336	0.737	-2.84%	0.663	0.508
Network	Regional	0.77%	-1.054	0.292	-5.43%	0.928	0.354

B.2.5 Fraud risk

B.2.5.1 Flight crew

The analysis of fraud risk examines two complementary dimensions: stakeholder confidence in the system's ability to detect and prevent fraud within licensing and certification processes, and the perceived prevalence of forum shopping across Member States. Together, these indicators provide an initial indication of how respondents assess the integrity and consistency of the regulatory framework, and whether potential vulnerabilities are perceived as isolated or widespread.

In terms of confidence in fraud detection, the reported shares vary across operational models but remain within a relatively narrow band. Cargo reports the highest value at 13.79% (±5.12), followed by LCC at 11.11% (±2.25) and ACMI at 10.00% (±6.20), while network and regional report lower values at 6.94% (±1.69) and 6.40% (±4.29) respectively. Although ACMI's estimate carries a wider margin of error, the overall pattern suggests moderate differences rather than strong segmentation. Statistical comparisons reflect this: ACMI does not differ significantly from cargo or LCC ($p \approx 0.38$ and $p \approx 0.75$), and ACMI versus network or regional also does not reach significance. In contrast, several comparisons involving cargo show statistically significant separation, notably cargo versus network ($p \approx 0.0025$) and cargo versus regional ($p \approx 0.041$), and LCC versus network is also significant ($p \approx 0.0033$). This indicates that while confidence levels are broadly comparable across most operational models, network in particular tends to report lower values than cargo and LCC.

Perceived forum shopping prevalence is markedly higher in absolute terms and shows more limited differentiation across business models. Values cluster around the mid-50% range, with LCC reporting 57.66% (±2.93) and cargo 55.17% (±6.03), followed by network at 53.83% (±2.70) and ACMI at 52.85% (±8.82), while regional reports a lower value at 48.19% (±7.60). Despite the apparent ordering, margins of error overlap substantially, particularly for ACMI and regional, and the pairwise tests confirm that most differences do not reach statistical significance. For example, ACMI does not differ significantly from cargo, LCC, or network ($p \approx 0.67$, $p \approx 0.31$, and $p \approx 0.83$). One of the clearest separations is observed between LCC and regional ($p \approx 0.022$), reflecting the lower perceived prevalence reported in regional operations.

Taken together, the combined reading of these two indicators points to a perception that forum shopping is relatively widespread across operational models, with only limited segmentation and a tendency for regional respondents to report lower prevalence. By contrast, confidence in fraud detection mechanisms is generally maintained across the sector, with differences between operational models remaining moderate. While network respondents tend to report slightly lower confidence than cargo and LCC in some comparisons, and estimates for ACMI are subject to wider uncertainty, there is no indication of a systemic lack of trust in existing detection mechanisms. Overall, the results suggest that perceptions of forum shopping coexist with a broadly sustained confidence in the system's ability to detect and prevent fraud.

The tables below present the numerical results of the statistical analysis for the fraud risk RA. They report the distribution of responses by airline type and the corresponding pairwise comparison statistics used to assess differences between groups.

Table 27: Fraud risks KSI results – Flight crew

Groups	FR01			FR02		
	Total	Matching	ME	Total	Matching	ME
ACMI	90	9 (10.00%)	6.20%	123	65 (52.85%)	8.82%
Cargo	174	24 (13.79%)	5.12%	261	144 (55.17%)	6.03%
LCC	747	83 (11.11%)	2.25%	1096	632 (57.66%)	2.93%
Network	865	60 (6.94%)	1.69%	1306	703 (53.83%)	2.70%
Regional	125	8 (6.4%)	4.29%	166	80 (48.19%)	7.60%

Table 28: Fraud risk pairwise comparison - Flight crew

Pair		FR01			FR02		
		Diff.	Z-score	p-val	Diff.	Z-score	p-val
ACMI	Cargo	3.79%	-0.883	0.377	2.33%	-0.427	0.669
ACMI	LCC	1.11%	-0.318	0.750	4.82%	-1.024	0.306
ACMI	Network	-3.06%	1.068	0.285	0.98%	-0.209	0.834
ACMI	Regional	-3.60%	0.965	0.335	-4.65%	0.782	0.434

Cargo	LCC	-2.68%	0.994	0.320	2.49%	-0.731	0.465
Cargo	Network	-6.86%	3.027	0.002	-1.34%	0.398	0.691
Cargo	Regional	-7.39%	2.040	0.041	-6.98%	1.408	0.159
LCC	Network	-4.17%	2.940	0.003	-3.84%	1.884	0.060
LCC	Regional	-4.71%	1.595	0.111	-9.47%	2.293	0.022
Network	Regional	-0.54%	0.222	0.825	-5.64%	1.371	0.170

B.2.6 Fuel management

B.2.6.1 Flight crew

The analysis of fuel management focuses on the reported use of commander discretion to uplift fuel beyond standard operational requirements. This indicator provides insight into how fuel margins are managed in practice across different operational models.

Reported use of fuel discretion is high across all operational models, though with clear differences in magnitude. LCC reports the highest share, with 79.95% of respondents indicating discretionary fuel uplift (margin of error ±2.22 percentage points). Network follows at 69.12% (±2.31), while regional and cargo report 64.82% (±6.63) and 60.28% (±5.66) respectively. ACMI shows the lowest reported level, at 55.81% (±8.57), although with wider uncertainty due to a smaller sample size.

Statistical comparisons confirm that LCC differs significantly from all other operational models (p≈0 across comparisons), reflecting a substantially higher reported use of fuel discretion. Network also differs significantly from cargo (p≈0.003), while differences between ACMI and cargo or regional do not reach statistical significance.

Overall, the results indicate that discretionary fuel uplift is a widespread operational practice across all business models, with particularly high levels reported in LCC operations.

The tables below present the numerical results of the statistical analysis for the fuel management RA. They report the distribution of responses by airline type and the corresponding pairwise comparison statistics used to assess differences between groups.

Table 29: Fuel management KSI results - Flight crew

Groups	FM01		
	Total	Matching	ME
ACMI	129	72 (55.81%)	8.57%
Cargo	287	173 (60.28%)	5.66%
LCC	1247	997 (79.95%)	2.22%
Network	1535	1061 (69.12%)	2.31%
Regional	199	129 (64.82%)	6.63%

Table 30: Fuel management pairwise comparison - Flight crew

Pair	FM01		
	Diff.	Z-score	p-val

ACMI	Cargo	3.79%	-0.883	0.377
ACMI	LCC	1.11%	-0.318	0.750
ACMI	Network	-3.06%	1.068	0.285
ACMI	Regional	-3.60%	0.965	0.335
Cargo	LCC	-2.68%	0.994	0.320
Cargo	Network	-6.86%	3.027	0.002
Cargo	Regional	-7.39%	2.040	0.041
LCC	Network	-4.17%	2.940	0.003
LCC	Regional	-4.71%	1.595	0.111
Network	Regional	-0.54%	0.222	0.825

B.2.7 Go-around decisions

B.2.7.1 Flight crew

The analysis of go-around decisions examines pilots' perceived pressure to avoid executing go-arounds and concerns about potential negative consequences following their use. Together, these indicators provide insight into whether go-around decisions are experienced as operationally neutral or whether disincentives are perceived in certain operational environments.

In terms of perceived pressure to avoid go-arounds, the results show differentiated levels across operational models. Regional operations report the highest share, with 14.07% of respondents indicating undue pressure (margin of error ±4.83 percentage points), followed by ACMI at 10.85% (±5.37) and LCC at 8.50% (±1.55). Network reports 7.17% (±1.29), while cargo shows the lowest value at 3.14% (±2.02). Despite some overlap in margins of error, the overall pattern suggests that perceived go-around pressure is not evenly distributed across business models.

Statistical comparisons support this differentiation. ACMI differs significantly from cargo ($p \approx 0.0014$), indicating higher perceived pressure in ACMI environments. Cargo also differs significantly from LCC ($p \approx 0.0019$), network ($p \approx 0.011$), and regional ($p \approx 0.000008$), consistently reflecting lower reported pressure. Differences between LCC and network do not reach statistical significance, while regional differs significantly from network ($p \approx 0.0007$). These results indicate that cargo operations form a distinct low-pressure group, while regional and ACMI report comparatively higher perceived pressure.

Looking more specifically at strong concern about negative consequences or reprimands after performing a go-around, reported levels are lower across all operational models. ACMI reports the highest share, with 7.75% (±4.61) of respondents strongly agreeing with this concern. LCC and regional report 3.61% (±1.04) and 3.02% (±2.38) respectively, while network and cargo report lower values at 2.15% (±0.73) and 2.09% (±1.66). Although absolute levels remain limited, the pattern suggests some concentration of strong concern in ACMI environments.

The statistical evidence confirms several meaningful differences. ACMI differs significantly from cargo ($p \approx 0.0055$), LCC ($p \approx 0.022$), and network ($p \approx 0.0001$), while the difference between ACMI and regional is borderline significant ($p \approx 0.052$). Differences among cargo, LCC, network, and regional are generally not significant, reflecting both low absolute levels and overlapping margins of error. This indicates that strong concern about negative consequences is primarily concentrated in ACMI operations, rather than being widespread across the sector.

Taken together, the combined reading of perceived go-around pressure and strong concern about repercussions suggests a nuanced picture. While moderate levels of perceived pressure to avoid go-arounds are reported across several operational models, strong concern about negative consequences remains limited overall and is most pronounced in ACMI environments. Cargo consistently reports the lowest levels across both indicators, while network and LCC occupy intermediate positions. Overall, the findings indicate that perceptions of go-around-related pressure exist across operational models, but are generally moderate in intensity and unevenly distributed, with stronger signals concentrated in specific environments rather than across the system as a whole.

The tables below present the numerical results of the statistical analysis for the go-around decisions RA. They report the distribution of responses by airline type and the corresponding pairwise comparison statistics used to assess differences between groups.

Table 31: Go around decisions KSI results - Flight crew

Groups	GO01, GO02			GO03		
	Total	Matching	ME	Total	Matching	ME
ACMI	129	14 (10.85%)	5.37%	129	10 (7.75%)	4.61%
Cargo	287	9 (3.14%)	2.02%	287	6 (2.09%)	1.66%
LCC	1247	106 (8.50%)	1.55%	1247	45 (3.61%)	1.04%
Network	1535	110 (7.17%)	1.29%	1535	33 (2.15%)	0.73%
Regional	199	28 (14.07%)	4.83%	199	6 (3.02%)	2.38%

Table 32: Go around pairwise comparison - Flight crew

Pair	GO01, GO02			GO03		
	Diff.	Z-score	p-val	Diff.	Z-score	p-val

ACMI	Cargo	-7.72%	3.185	0.001	-5.66%	2.777	0.005
ACMI	LCC	-2.35%	0.901	0.367	-4.14%	2.287	0.022
ACMI	Network	-3.69%	1.531	0.126	-5.60%	3.852	0.000
ACMI	Regional	3.22%	-0.852	0.394	-4.74%	1.945	0.052
Cargo	LCC	5.36%	-3.112	0.002	1.52%	-1.293	0.196
Cargo	Network	4.03%	-2.536	0.011	0.06%	-0.064	0.949
Cargo	Regional	10.93%	-4.470	0.000	0.92%	-0.646	0.518
LCC	Network	-1.33%	1.308	0.191	-1.46%	2.318	0.020
LCC	Regional	5.57%	-2.516	0.012	-0.59%	0.422	0.673
Network	Regional	6.90%	-3.386	0.001	0.87%	-0.775	0.439

B.2.8 Generational risk behaviour

B.2.8.1 Flight crew

The analysis of generational risk behaviour examines how socio-economic and safety-relevant indicators vary across age cohorts, focusing on contractual vulnerability, work–life balance dissatisfaction, and perceptions related to safety culture. Age information was collected using predefined bands rather than continuous values. As a result, all indicators are analysed at cohort level, and numerical interpretations rely on group proportions rather than individual ages. For analytical consistency, the “under 21” cohort is not used for substantive interpretation, as it contains only three responses and is associated with very high margins of error, making any comparison statistically unreliable.

The first dimension assesses whether exposure to potentially vulnerable contractual arrangements differs by age group. A clear age gradient emerges. The 21–30 cohort reports 6.4% (±2.11) of respondents under potentially vulnerable contractual conditions. This figure remains similar for 31–40, at 6.5% (±1.36), before declining steadily in older cohorts: 4.5% (±1.26) in 41–50, 3.9% (±1.39) in 51–60, and 2.03% (±2.27) among those 60 or older. While some adjacent cohorts show overlapping margins of error, several pairwise comparisons confirm that the downward trend is not purely descriptive. The difference between 21–30 and 51–60 reaches statistical significance ($p \approx 0.045$), as do comparisons between 31–40 and 41–50 ($p \approx 0.043$) and 31–40 and 51–60 ($p \approx 0.015$). By contrast, differences among older cohorts, such as 41–50 versus 51–60 or 51–60 versus 60 or older, are not statistically significant, reflecting both smaller absolute gaps and wider uncertainty. Overall, this indicator shows that contractual vulnerability is disproportionately concentrated in younger and early mid-career cohorts and decreases progressively with age.

The second dimension examines generational differences in reported work–life balance dissatisfaction, proxied by intention to leave. Unlike contractual vulnerability, the pattern here does not follow a monotonic age decline. The 21–30 cohort reports 9.0% (±2.46), which increases to 12.1% (±1.79) in 31–40 and 12.9% (±2.02) in 41–50. Levels remain broadly similar for 51–60, at 11.5% (±2.29), before increasing again in the 60 or older group to 13.3% (±5.44). Statistical comparisons indicate that the most robust separation occurs between 21–30 and 41–50 ($p \approx 0.024$), suggesting that dissatisfaction increases once pilots move beyond the youngest cohort. Differences among the mid-career and late-career cohorts are generally not statistically significant, largely due to overlapping confidence intervals. This results in a plateau-type pattern rather than a clear generational divide, indicating that dissatisfaction with work–life balance becomes more prevalent after early career stages and remains elevated thereafter.

Perceptions related to safety culture, including trust in reporting systems and perceived commercial pressure, show a more compressed distribution across age groups. Reported values range from 5.8% (±2.00) in 21–30, to 7.5% (±1.45) in 31–40, 7.1% (±1.54) in 41–50, 6.0% (±1.71) in 51–60, and 5.3% (±3.60) in 60 or older. Although some individual pairwise comparisons reach statistical significance, such as 31–40 versus 41–50 ($p \approx 0.043$) and 31–40 versus 51–60 ($p \approx 0.015$), the absolute differences remain small, typically below two percentage points. The overall pattern suggests limited generational segmentation in safety culture perception, with broadly comparable levels across age cohorts once sampling uncertainty is taken into account.

The age composition of respondents by airline type provides important structural context for these findings. Excluding the under-21 group, low-cost carriers show a distinctly younger profile, with 42.82% of respondents in the 31–40 cohort and 16.44% in 21–30, and a relatively small share in 51–60 (11.39%). In contrast, network and cargo operators display older age distributions, with 51–60 accounting for 25.21% and 27.53% respectively, and a higher share of pilots 60 or older in network operations (5.54%). Regional airlines occupy an intermediate position, combining a strong 31–40 cohort (36.18%) with a non-negligible presence in older age bands. These structural differences imply that generational effects observed at aggregate level may interact with airline business models and employment practices.

Taken together, the combined reading of the indicators highlights three distinct generational patterns. First, contractual vulnerability is clearly concentrated in younger cohorts, with a statistically supported decline as age increases. Second, work–life balance dissatisfaction increases after the youngest cohort and remains elevated across mid- and late-career stages, rather than being confined to early career pilots. Third, safety culture perceptions show limited generational differentiation, with relatively homogeneous responses across age groups. Given that age was collected in bands and that the youngest cohort contains very few observations, these results should be interpreted with caution, particularly when comparing adjacent age groups.

The tables below present the numerical results of the statistical analysis for the generational risk behaviour RA. They report the distribution of responses by airline type and the corresponding pairwise comparison statistics used to assess differences between groups.

Table 33: Age groups - Flight crew

Age groups	GR01, GR02				
	ACMI	Cargo	LCC	Network	Regional

21-30	13 (10.08%)	32 (11.15%)	205 (16.48%)	186 (12.12%)	32 (16.08%)
31-40	37 (28.68%)	76 (26.48%)	534 (42.93%)	438 (28.53%)	72 (26.18%)
41-50	40 (31.01%)	89 (31.01%)	334 (26.85%)	439 (28.60%)	53 (26.63%)
51-60	34 (26.36%)	79 (27.53%)	142 (11.41%)	387 (25.21%)	33 (16.58%)
60 or older	5 (26.36%)	11 (3.83%)	29 (2.33%)	85 (5.54%)	9 (4.52%)
Total	129	287	1244	1535	199

Table 34: Generational risk behaviour KSI results - Flight crew

Groups	GR03			GR04			GR05		
	Total	Matching	ME	Total	Matching	ME	Total	Matching	ME
21-30	516	33 (6.40%)	2.11%	521	47 (9.02%)	2.46%	521	30 (5.76%)	2.00%
31-40	1263	82 (6.49%)	1.36%	1276	155 (12.15%)	1.79%	1276	96 (7.52%)	1.45%
41-50	1055	48 (4.55%)	1.26%	1062	137 (12.90%)	2.02%	1062	75 (7.06%)	1.54%

51-60	742	29 (3.91%)	1.39%	745	86 (11.54%)	2.29%	745	45 (6.04%)	1.71%
60 or older	148	3 (2.03%)	2.27%	150	20 (13.33%)	5.44%	150	8 (5.33%)	3.60%

Table 35: Generational risk behaviour pairwise comparison - Flight crew

Pair		GR03			GR04			GR05		
		Diff.	Z-score	p-val	Diff.	Z-score	p-val	Diff.	Z-score	p-val
21-30	31-40	-0.10%	-0.076	0.940	-3.13%	-1.904	0.057	-1.77%	-1.330	0.184
21-30	41-50	1.85%	1.554	0.120	-3.88%	-2.263	0.024	-1.30%	-0.980	0.327
21-30	51-60	2.49%	2.004	0.045	-2.52%	-1.440	0.150	-0.28%	-0.209	0.834
21-30	60 or older	4.37%	1.137	0.255	-4.31%	-1.552	0.121	0.42%	0.198	0.843
31-40	41-50	1.94%	2.024	0.043	-0.75%	-0.548	0.584	0.46%	0.427	0.670
31-40	51-60	2.58%	2.443	0.015	0.60%	0.404	0.686	1.48%	1.263	0.207
31-40	60 or older	4.47%	1.231	0.218	-1.19%	-0.419	0.675	2.19%	0.976	0.329

41-50	51-60	0.64%	0.661	0.509	1.36%	0.863	0.388	1.02%	0.859	0.390
41-50	60 or older	2.52%	0.354	0.724	-0.43%	-0.148	0.882	1.73%	0.785	0.433
51-60	60 or older	1.88%	0.000	1.000	-1.79%	-0.619	0.536	0.71%	0.335	0.738

B.2.8.2 Cabin crew

The analysis of generational risk behaviour for cabin crew examines how socio-economic and safety-relevant indicators vary across age cohorts, with a focus on contractual vulnerability, work–life balance dissatisfaction, and perceptions related to safety culture. Age information was collected using predefined bands rather than continuous values. Consequently, all indicators are analysed at cohort level, and interpretations rely on group proportions rather than individual ages. For analytical consistency, the “under 21” cohort is not used for substantive interpretation, as it contains a very limited number of responses and is associated with high margins of error, making meaningful comparisons unreliable.

The first dimension assesses whether exposure to potentially vulnerable contractual arrangements differs by age group. A clear and monotonic age gradient emerges. The 21–30 cohort reports the highest level, with 9.1% (±2.47) of respondents without permanent direct employment contracts. This share declines markedly in subsequent cohorts, to 3.1% (±1.34) in 31–40 and 2.3% (±1.20) in 41–50, before reaching very low levels in older cohorts, at 0.7% (±0.81) in 51–60 and 0.0% among those 60 or older. Several pairwise comparisons confirm that this downward trend is statistically robust. Differences between 21–30 and 31–40, 41–50, and 51–60 are all statistically significant (p≈0 across comparisons), while differences among the older cohorts are not significant, reflecting both small absolute differences and lower exposure overall. This pattern indicates that contractual vulnerability among cabin crew is strongly concentrated in early career stages and decreases steadily with age.

The second dimension examines generational differences in work–life balance dissatisfaction. Unlike contractual vulnerability, dissatisfaction does not follow a clear monotonic age decline. Reported dissatisfaction increases sharply from the youngest substantive cohort, rising from 17.1%

(±3.21) in 21–30 to 17.3% (±2.91) in 31–40 and 18.2% (±3.08) in 41–50. Levels remain broadly similar in the 51–60 cohort, at 16.5% (±3.56), before declining in the oldest group, to 6.3% (±4.89) among respondents aged 60 or older. Statistical tests indicate significant differences between 21–30 and all older cohorts except 31–40, while differences among the mid-career cohorts are generally not statistically significant. This produces a plateau-type pattern, suggesting that work–life balance dissatisfaction emerges after the youngest cohort and remains elevated throughout mid-career stages before declining at later career stages.

Perceptions related to safety culture also show clear generational variation, though with a different profile. The 21–30 cohort reports the highest level, with 22.6% (±3.56) of respondents strongly disagreeing that they can report their own mistakes without negative consequences. This share declines progressively with age, to 17.9% (±2.95) in 31–40, 11.8% (±2.57) in 41–50, 8.1% (±2.62) in 51–60, and 7.4% (±5.25) in the 60 or older cohort. Several pairwise comparisons confirm that these differences are statistically meaningful, particularly between 21–30 and 41–50, 51–60, and 60 or older ($p \approx 0$). The results indicate that perceptions of constrained reporting culture are disproportionately concentrated among younger cabin crew and diminish steadily with age.

The age composition of respondents by airline type provides important structural context for these findings. Excluding the under-21 cohort, LCC cabin crew show a distinctly younger age profile, with high concentrations in the 21–30 and 31–40 cohorts. In contrast, network and regional operators display older age distributions, with a larger share of respondents in the 41–50 and 51–60 cohorts, and a non-negligible proportion aged 60 or older. These structural differences suggest that observed generational patterns may interact with airline business models and employment practices.

Taken together, the combined reading of the indicators highlights three key generational patterns for cabin crew. First, contractual vulnerability is strongly concentrated in younger cohorts and declines sharply with age, more pronouncedly than observed for flight crew. Second, work–life balance dissatisfaction increases after early career stages and remains elevated across mid-career cohorts, before declining in later career stages. Third, safety culture perceptions show a clear age gradient, with younger cabin crew reporting significantly higher constraints on reporting than older colleagues. As with flight crew, these findings should be interpreted with caution given the use of age bands and the limited size of the youngest cohort, but they nevertheless point to early career stages as a critical period of heightened socio-economic and safety-related vulnerability for cabin crew.

The tables below present the numerical results of the statistical analysis for the generational risk behaviour RA. They report the distribution of responses by airline type and the corresponding pairwise comparison statistics used to assess differences between groups.

Table 36: Age groups – Cabin crew

Age groups	GR01, GR02				
	ACMI	Cargo	LCC	Network	Regional
21-30	15 (34.09%)	-	289 (32.66%)	143 (13.23%)	20 (22.99%)
31-40	12 (27.27%)	-	324 (36.61%)	241 (22.29%)	18 (20.69%)
41-50	12 (27.27%)	-	224 (25.31%)	302 (27.94%)	28 (32.18%)
51-60	5 (11.36%)	-	46 (5.20%)	325 (30.06%)	17 (19.54%)
60 or older	0 (0.00%)	-	2 (0.23%)	70 (6.48%)	4 (4.60%)
Total	44	-	885	1081	87

Table 37: Generational risk behaviour KSI results - Cabin crew

Groups	GR03			GR04			GR05		
	Total	Matching	ME	Total	Matching	ME	Total	Matching	ME
21-30	525	48 (9.14%)	2.47%	531	91 (17.14%)	3.21%	531	120 (22.60%)	3.56%
31-40	643	20 (3.11%)	1.34%	648	112 (17.28%)	2.91%	648	116 (17.90%)	2.95%
41-50	603	14 (2.32%)	1.20%	604	110 (18.21%)	3.08%	604	71 (11.75%)	2.57%
51-60	417	3 (0.72%)	0.81%	418	69 (16.51%)	3.56%	418	34 (8.13%)	2.62%
60 or older	95	0 (0.0%)	0.00%	95	6 (6.32%)	4.89%	95	7 (7.37%)	5.25%

Table 38: Generational risk behaviour pairwise comparison - Cabin crew

Pair		GR03			GR04			GR05		
		Diff.	Z-score	p-val	Diff.	Z-score	p-val	Diff.	Z-score	p-val
21-30	31-40	6.03%	4.380	0.000	-0.15%	-0.1	0.9	4.70%	2.006	0.045
21-30	41-50	6.82%	5.014	0.000	-1.07%	-0.5	0.6	10.84%	4.872	0.000

21-30	51-60	8.42%	5.675	0.000	0.63%	0.3	0.8	14.46%	6.000	0.000
21-30	60 or older	9.14%	2.809	0.005	10.82%	2.7	0.0	15.23%	3.400	0.001
31-40	41-50	0.79%	0.854	0.393	-0.93%	-0.4	0.7	6.15%	3.049	0.002
31-40	51-60	2.39%	2.610	0.009	0.78%	0.3	0.7	9.77%	4.477	0.000
31-40	60 or older	3.11%	1.318	0.188	10.97%	2.7	0.0	10.53%	2.580	0.010
41-50	51-60	1.60%	1.965	0.049	1.70%	0.7	0.5	3.62%	1.874	0.061
41-50	60 or older	2.32%	1.012	0.312	11.90%	2.9	0.0	4.39%	1.262	0.207
51-60	60 or older	0.72%	0.000	1.000	10.19%	2.5	0.0	0.77%	0.248	0.804

B.2.9 Homebase changes

B.2.9.1 Flight crew

The analysis of homebase changes begins by examining how widespread relocations are across operational models. It should be noted at the outset that, while HC01 is based on a wider sample, the indicators related to relocation intensity, reporting behaviour, and notice periods (HC02, HC03, and HC04) rely on smaller sub-samples of crew who have actually experienced a homebase change. In ACMI, cargo, and regional operations in particular, the number of affected respondents is limited, which implies wider margins of error and requires that the results for these indicators be interpreted with caution.

In terms of overall exposure, the results show a highly uneven distribution of homebase changes across operational models. ACMI and LCC operators stand out with the highest proportions of crew reporting a homebase change, at 36.43% (±8.30) and 39.05% (±2.71) respectively. In the case of ACMI operators, this pattern appears broadly consistent with the operational flexibility and short-term deployment characteristics inherent to the ACMI business model, where crews are more frequently reassigned across operational bases depending on leasing demand and seasonal requirements. For LCCs, the comparatively high prevalence of homebase changes may also partly reflect the scale and geographic distribution of their operations within the EEA market, including extensive cross-border networks and dynamic base allocation practices associated with rapid market adaptation and expansion.

In contrast, cargo and network operations report comparatively low levels of relocation, at 2.79% (±1.90) and 3.45% (±0.91), while regional operations occupy an intermediate position at 15.58% (±6.69). Statistical comparisons confirm that these contrasts are robust: differences between ACMI and cargo, ACMI and network, as well as between LCC and both cargo and network, are strongly significant, with p-values effectively at zero. By comparison, the difference between ACMI and LCC is not statistically significant, indicating that both operational models are characterised by similarly high exposure to homebase changes, albeit potentially driven by different operational and market dynamics. Furthermore, an increased number of home bases could facilitate closer proximity to aircrew's place of living and limit the etnnt of their commute to the place of employment (home base).

Looking next at the intensity of relocations among affected crew, the share of relocated personnel reporting more than one homebase change is highest in ACMI, at 68.09%, followed by cargo at 62.50%. LCC, network, and regional report lower but still substantial levels, ranging from approximately 40% to 48%. Given the small number of relocated respondents in ACMI, cargo, and regional operations, these results should be interpreted as indicative rather than definitive. Nevertheless, several pairwise comparisons remain statistically meaningful, particularly between

ACMI and LCC or network, suggesting that repeated relocations may be more common once crew are affected in certain operational environments.

The perceived willingness of relocated crew to submit voluntary safety reports shows further variation across operational models, again acknowledging the limitation related to limited sub-sample sizes in ACMI, cargo, and regional operations. LCC reports the highest share of relocated crew indicating that they feel willing or very willing to report safety issues, at 48.46% (±4.44). ACMI follows at 34.04% (±13.55), while network and regional report lower values, at 26.42% (±11.87) and 22.58% (±14.72) respectively. Cargo reports no respondents indicating willingness to report. However, this result is based on a very small number of relocated crew and should therefore be treated with particular caution. Despite these limitations, the overall pattern suggests meaningful differences in how relocated crew perceive the reporting environment across business models. Finally, the timing of relocation decisions highlights additional structural differences. The share of crew reporting that they received less than 14 days' notice before a mandatory homebase change is highest in ACMI, at 40.00% (±16.23). Cargo, LCC, network, and regional report lower and broadly similar levels, ranging from around 11% to 16%. As with the previous indicators, the ACMI result is based on a limited number of relocated respondents and should be interpreted cautiously.

Nonetheless, statistical omparisons indicate that ACMI differs significantly from the other operational models, whereas differences among the remaining groups are generally not statistically significant. Taken together, the four indicators provide a coherent picture of homebase change dynamics while also highlighting important methodological constraints. ACMI and LCC concentrate the highest exposure to relocations but differ in how these relocations are structured and perceived. ACMI combines high relocation rates with indications of repeated moves, lower perceived reporting willingness, and a higher incidence of short-notice relocations, albeit with greater uncertainty due to smaller samples. LCC, while similarly exposed in terms of overall relocation prevalence, shows lower repetition intensity, higher reporting willingness, and fewer short-notice relocations. Cargo, network, and regional operations consistently report lower relocation exposure, with regional occupying an intermediate position across several dimensions. The tables below present the numerical results of the statistical analysis for the homebase changes RA. They report the distribution of responses by airline type and the corresponding pairwise comparison statistics used to assess differences between groups.

Table 39: Homebase changes KSI results - Flight crew.

Groups	HC01			HC02			HC03			HC04		
	Total	Matching	ME	Total	Matching	ME	Total	Matching	ME	Total	Matching	ME
ACMI	129	47 (36.43%)	8.30%	47	32 (68.09%)	13.33 %	47	16 (34.04%)	13.55 %	35	14 (40.00%)	16.23 %
Cargo	287	8 (2.79%)	1.90%	8	5 (62.50%)	33.35 %	8	0 (0.00%)	32.84 %	19	3 (15.79%)	16.40 %
LCC	1,247	487 (39.05%)	2.71%	487	235 (48.25%)	4.44%	487	236 (48.46%)	4.44%	751	94 (12.52%)	2.37%
Network	1,535	53 (3.45%)	0.91%	53	21 (39.62%)	13.17 %	53	14 (26.42%)	11.87 %	152	17 (11.18%)	5.01%
Regional	199	31 (15.58%)	5.04%	31	13 (41.94%)	17.37 %	31	7 (22.58%)	14.72 %	51	7 (13.73%)	9.44%

Table 40: Homebase changes pairwise comparison - Flight crew

Pair	HC01			HC02			HC03			HC04		
	Diff.	Z-score	p-val	Diff.	Z-score	p-val	Diff.	Z-score	p-val	Diff.	Z-score	p-val

ACMI	Cargo	-33.65%	9.371	0.000	-5.59%	0.311	0.756	-34.04%	1.960	0.050	-24.21%	1.829	0.067
ACMI	LCC	2.62%	-0.581	0.561	-19.83%	4.010	0.000	14.42%	-1.891	0.059	-27.48%	4.616	0.000
ACMI	Network	-32.98%	15.138	0.000	-28.46%	3.558	0.000	-7.63%	0.831	0.406	-28.82%	4.133	0.000
ACMI	Regional	-20.86%	4.334	0.000	-26.15%	2.708	0.007	-11.46%	1.086	0.277	-26.27%	2.786	0.005
Cargo	LCC	36.27%	-11.849	0.000	-14.25%	3.838	0.000	48.46%	-2.722	0.006	-3.27%	0.425	0.671
Cargo	Network	0.67%	-0.575	0.565	-22.88%	3.110	0.002	26.42%	-1.656	0.098	-4.61%	0.589	0.556
Cargo	Regional	12.79%	-5.104	0.000	-20.56%	2.225	0.026	22.58%	-1.484	0.138	-2.06%	0.219	0.826
LCC	Network	-35.60%	23.611	0.000	-8.63%	1.232	0.218	-22.04%	3.057	0.002	-1.33%	0.456	0.648
LCC	Regional	-23.48%	6.414	0.000	-6.32%	0.696	0.487	-25.88%	2.800	0.005	1.21%	-0.252	0.801

Network	Regional	12.13%	-7.496	0.000	2.31%	-0.261	0.794	-3.83%	0.392	0.695	2.54%	-0.486	0.627

B.2.9.2 Cabin crew

The analysis of homebase changes for cabin crew begins by examining how widespread relocations are across operational models. As for flight crew, it should be noted at the outset that while HC01 is based on the full cabin crew sample, the indicators related to relocation intensity, reporting behaviour, and notice periods (HC02, HC03, HC04) rely on smaller sub-samples of crew who have actually experienced a homebase change. In ACMI and regional operations in particular, the number of affected respondents is limited, implying wider margins of error and requiring cautious interpretation for these indicators. In terms of overall exposure, the results show a highly uneven distribution of homebase changes across operational models. ACMI and LCC report the highest relocation prevalence, at 38.64% (±14.39) and 29.68% (±3.00) respectively, while network reports much lower levels at 6.55% (±1.47). Regional occupies an intermediate position at 15.91% (±7.64). Statistical comparisons confirm that ACMI differs significantly from both network and regional ($p \approx 0$ and $p \approx 0.004$ respectively), while LCC also differs strongly from network ($p \approx 0$) and from regional ($p \approx 0.006$). By contrast, the difference between ACMI and LCC is not statistically significant, indicating that both business models are characterised by relatively high exposure to relocations among cabin crew.

Looking next at the intensity of relocations among affected crew, the share of relocated personnel experiencing more than one homebase change is highest in ACMI at 88.24% (±15.32). Other operational models show notably lower levels, with network at 49.30% (±11.63), LCC at 43.77% (±5.97), and regional at 35.71% (±25.10). Despite uncertainty driven by small affected samples in ACMI and regional, pairwise tests indicate that ACMI differs significantly from LCC, network, and regional ($p \approx 0$ across comparisons). These results suggest that, once relocations occur, repeated moves are particularly common in ACMI cabin crew operations, while remaining closer to “one-off” relocations in the other models.

The perceived willingness to submit voluntary safety reports among relocated crew shows further variation across operational models, again acknowledging limitations due to small sub-sample sizes. Among relocated cabin crew, the share reporting reduced comfort with voluntary reporting is highest in ACMI at 47.06% (±23.73), followed by LCC at 43.77% (±5.97) and network at 33.80% (±11.00), while regional reports

21.43% (±26.15). Differences between ACMI and the other models are not consistently statistically significant, reflecting overlapping margins of error. Nonetheless, the overall distribution suggests that relocation may be associated with reduced perceived reporting comfort in some operational environments, particularly where relocations are more frequent. Finally, relocation notice period compliance highlights additional differences in how relocations are managed. The share of relocated cabin crew reporting less than 14 days' notice before a mandatory homebase change is highest in ACMI at 46.67% (±25.25), compared with 23.21% (±7.82) in network, 18.18% (±16.12) in regional, and 15.23% (±3.49) in LCC. Statistical comparisons indicate that ACMI differs significantly from LCC ($p \approx 0.001$) and from network (borderline significance, $p \approx 0.052$), while LCC differs significantly from network ($p \approx 0.046$). Given the limited relocated sub-sample sizes for ACMI and regional, these results should be interpreted cautiously, but they suggest that short-notice relocations are more characteristic of ACMI, whereas LCC reports comparatively lower levels.

Taken together, the four indicators provide a coherent picture of homebase change dynamics for cabin crew while also highlighting key methodological constraints. ACMI and LCC concentrate the highest exposure to relocations, but the structure of relocations differs markedly. ACMI combines high relocation prevalence with very high repetition intensity and a higher incidence of short-notice relocations, alongside indications of reduced reporting comfort among relocated crew, although with greater uncertainty due to small affected samples. LCC, while also highly exposed in prevalence terms, shows substantially lower repetition intensity and fewer short-notice relocations. Network and regional operations report lower exposure overall, with regional occupying an intermediate position but subject to wider uncertainty. Overall, the results suggest that workforce mobility among cabin crew is concentrated in specific business models and is associated with differing relocation practices and reporting perceptions across the sector.

The tables below present the numerical results of the statistical analysis for the homebase changes RA. They report the distribution of responses by airline type and the corresponding pairwise comparison statistics used to assess differences between groups.

Table 41: Homebase changes KSI results - Cabin crew.

Groups	HC01	HC02	HC03	HC04

	Total	Matching	ME	Total	Matching	ME	Total	Matching	ME	Total	Matching	ME
ACMI	44	17 (38.64%)	14.39%	17	15 (88.24%)	15.32%	17	8 (47.06%)	23.73%	15	7 (46.67%)	25.25%
Cargo	-	-	-	-	-	-	-	-	-	-	-	-
LCC	893	265 (29.68%)	3.19%	265	116 (43.77%)	3.88%	265	116 (43.77%)	6.01%	407	62 (15.23%)	4.85%
Network	1084	71 (6.55%)	2.90%	71	35 (43.77%)	7.49%	71	24 (33.80%)	11.61%	112	26 (23.21%)	9.24%
Regional	88	14 (15.91%)	10.17%	14	5 (15.23%)	16.88%	14	3 (21.43%)	26.15%	22	4 (18.18%)	20.85%

Table 42: Homebase changes pairwise comparison - Cabin crew

Pair		HC01			HC02			HC03			HC04		
		Diff.	Z-score	p-val	Diff.	Z-score	p-val	Diff.	Z-score	p-val	Diff.	Z-score	p-val
ACMI	LCC	-8.96%	1.265	0.206	-44.46%	5.462	0.000	-3.29%	0.265	0.791	-31.43%	3.233	0.001
ACMI	Network	-32.09%	7.780	0.000	-38.94%	4.233	0.000	-13.26%	1.021	0.307	-23.45%	1.945	0.052

ACMI	Regional	-22.73%	2.904	0.004	-52.52%	3.983	0.000	-25.63%	1.484	0.138	-28.48%	1.861	0.063
LCC	Network	-23.13%	13.624	0.000	5.52%	-0.902	0.367	-9.97%	1.513	0.130	7.98%	-1.993	0.046
LCC	Regional	-13.77%	2.731	0.006	-8.06%	0.603	0.546	-22.35%	1.648	0.099	2.95%	-0.373	0.709
Network	Regional	9.36%	-3.256	0.001	-13.58%	1.010	0.312	-12.37%	0.909	0.363	-5.03%	0.518	0.605

B.2.10 Pilot discretion use

B.2.10.1 Flight crew

The analysis of pilot discretion use begins by examining two fundamental dimensions: how widespread the experience is among flight crew and whether its use is perceived as frequent rather than exceptional. Together, these two aspects provide an initial indication of whether commander's discretion is functioning as an occasional safety safeguard or whether it may already be drifting towards a more structural role in operations.

In terms of prevalence, the figure shows that being affected by the use of commander's discretion is a common experience across all operational models. Even in the lowest-exposure segments, such as cargo and network, roughly two thirds of pilots report having been affected at some point. However, clear differences emerge between business models. LCC operations stand out with close to 90% of respondents reporting exposure, a result supported by a very narrow margin of error (around ±1.6 percentage points) due to the large number of responses. ACMI also shows a high prevalence (around 86%), although with a wider margin of error (approximately ±6 points), which reflects greater uncertainty around the exact level but not the overall magnitude. By contrast, cargo and network cluster around 64%, while regional sits between these groups at just under 70%.

These patterns are reinforced by the statistical comparisons. Differences between groups that appear far apart in the figure, such as LCC versus network or ACMI versus cargo, are associated with very small p-values (well below 0.001), indicating that the observed gaps are unlikely to be due to random variation. Conversely, groups that appear similar in the chart, most notably cargo and network, also show no statistically significant difference ($p \approx 0.90$). The coherence between the visual results, margins of error, and p-values supports the conclusion that exposure to discretion is genuinely higher in LCC and ACMI environments.

Looking beyond exposure to the perceived frequency of use, the contrast between operational models becomes more pronounced. Here, the analysis moves closer to the question of normalisation. In LCC operations, around one third of pilots perceive discretion as being used frequently, a level that is substantially higher than in any other segment. ACMI again occupies an intermediate position, with close to one quarter of respondents reporting frequent use, although this estimate carries a larger margin of error (around ±7 points). In contrast, cargo, network, and regional all remain close to 10%, forming a clearly distinct low-frequency group.

The supporting statistical tests confirm this structure. LCC differs significantly from cargo, network, and regional, with p-values effectively at zero, and even the difference between LCC and ACMI remains statistically significant ($p \approx 0.02$). By comparison, differences within the low-frequency cluster are not significant, for example, network versus regional shows virtually no separation ($p \approx 0.98$). This reinforces the interpretation that the high-frequency perception in LCC (and, to a lesser extent, ACMI) is a structural feature rather than a product of sampling noise.

At this stage, the combined reading of prevalence and frequency already suggests an important divergence. In cargo, network, and regional operations, discretion appears to be widely encountered but still largely perceived as an exceptional measure. In LCC, and partially in ACMI, high exposure is accompanied by a much stronger sense that discretion is used regularly.

In terms of the perceived average duration of discretion, a clear gradient emerges across operational models. ACMI and LCC crews report the longest extensions on average, with values of around 54 minutes in ACMI and 47 minutes in LCC, compared with shorter extensions in network (around 43 minutes) and regional operations (approximately 39 minutes). Cargo sits between these groups at roughly 45 minutes. While some of these differences are moderate in absolute terms, the statistical comparisons show that several are meaningful: for example, ACMI reports significantly longer extensions than network and regional (both with p-values well below 0.01), and cargo extensions are significantly shorter than those reported in LCC ($p \approx 0$). These results suggest that in the environments where discretion is more prevalent and more frequently perceived as routine, it is also associated with longer duty extensions, reinforcing the idea that discretion may be carrying a heavier operational load in those contexts.

The perception of whether discretion is used appropriately adds a further qualitative layer. Here, LCC stands out again, with close to half of respondents expressing disagreement that discretion is applied appropriately. This contrasts sharply with cargo and network, where roughly one in five pilots hold this view, and with regional operations, which show similarly lower levels of dissatisfaction. ACMI lies between these extremes, with around 29% questioning the appropriateness of use. The statistical evidence supports this separation: differences between LCC and network or LCC and cargo are strongly significant (p-values well below 0.001), whereas comparisons among cargo, network, and regional are generally not significant. This pattern aligns closely with PD01 and PD02, indicating that higher exposure and higher frequency are accompanied by greater scepticism regarding appropriateness, particularly in LCC environments.

Finally, the crew consultation indicator sheds light on how discretion decisions are made in practice. A substantial share of pilots report that they are not systematically consulted about their level of alertness when an FDP extension is decided. This issue is most pronounced in ACMI and LCC, where roughly 35–36% of respondents indicate a lack of consistent consultation, compared with about 21% in network and 27% in regional operations. Cargo again sits close to ACMI and LCC at around 34%. Several of these differences are statistically significant, for example, ACMI versus network shows a strong separation ($p \approx 0.0001$), while others are less clear-cut, reflecting overlapping margins of error. Nonetheless, the overall picture suggests that in the same operational environments where discretion is more frequent and longer in duration, crew involvement in the decision-making process is less consistently perceived.

Taken together, PD03, PD04, and PD05 deepen the picture established by prevalence and frequency. In cargo, network, and regional operations, discretion tends to involve shorter extensions, lower levels of perceived inappropriate use, and more consistent consultation, broadly aligning with an interpretation of discretion as an exceptional tool. In contrast, LCC and to some extent ACMI combines higher frequency, longer extensions, greater dissatisfaction with appropriateness, and weaker consultation signals. This convergence of indicators strengthens the hypothesis that, in these environments, discretion may be under pressure to perform a systemic role, a hypothesis that will be further tested when considering reporting confidence and the broader organisational context in the following section.

The tables below present the numerical results of the statistical analysis for the pilot discretion use RA. They report the distribution of responses by airline type and the corresponding pairwise comparison statistics used to assess differences between groups.

Table 43: Pilot discretion use KSI results - Flight crew

Groups	PD01			PD02			PD03			PD04			PD05		
	Total	Matching	ME	Total	Matching	ME	Total	Matching[42]	ME	Total	Matching	ME	Total	Matching	ME
ACMI	128	110 (85.94%)	6.02 %	127	30 (23.63%)	7.39%	120	54.25	5.73	126	37 (29.97%)	7.92%	127	45 (35.43%)	8.32%
Cargo	280	179 (63.93%)	5.62 %	275	24 (8.73%)	3.34%	252	45.00	4.16	280	54 19.11%)	4.61%	259	89 (34.36%)	5.78%
LCC	1,243	1,123 (90.35%)	1.64 %	1240	420 (33.87%)	2.63%	1099	46.80	1.57	1236	583 (47.17%)	2.78%	1214	442 (36.41%)	2.71%

[42] This column refers to the average duration, as calculated for this KSI and explained in Annex C.4.

Network	1,514	974 (64.33%)	2.41 %	1507	157 (10.42%)	1.54%	1381	43.37	1.71	1504	349 (23.17%)	2.13%	1423	294 (20.66%)	2.10%
Regional	197	137 (69.54%)	6.43 %	193	20 (10.36%)	4.30%	175	39.26	4.49	193	39 (19.95%)	5.64%	177	48 (27.12%)	6.55%

Table 44: Pilot discretion use pairwise comparison - Flight crew

Pair		PD01			PD02			PD03			PD04			PD05		
		Diff.	Z-score	p-val	Diff.	Z-score	p-val	Diff.	Z-score	p-val	Diff.	Z-score	p-val	Diff.	Z-score	p-val
ACMI	Cargo	-22.01%	4.538	0.000	-14.89%	4.071	0.000	-9.25	-	-	-9.86%	2.213	0.027	-1.07%	0.208	0.836
ACMI	LCC	4.41%	-1.578	0.114	10.25%	-2.349	0.019	-7.45	-	-	18.20%	-3.908	0.000	0.98%	-0.217	0.828
ACMI	Network	-21.60%	4.955	0.000	-13.20%	4.504	0.000	-10.88	-	-	-5.80%	1.472	0.141	-14.77%	3.859	0.000
ACMI	Regional	-16.39%	3.381	0.001	-13.26%	3.202	0.001	-14.99	-	-	-9.02%	1.857	0.063	-8.31%	1.552	0.121
Cargo	LCC	26.42%	-11.338	0.000	25.14%	-8.354	0.000	1.80	-	-	28.06%	-8.591	0.000	2.05%	-0.622	0.534

Cargo	Network	0.40%	-0.130	0.897	1.69%	-0.860	0.390	-1.63	-	-	4.06%	-1.495	0.135	-13.70%	4.837	0.000
Cargo	Regional	5.61%	-1.277	0.202	1.64%	-0.599	0.549	-5.74	-	-	0.84%	-0.227	0.820	-7.24%	1.600	0.110
LCC	Network	-26.01%	15.927	0.000	-23.45%	15.023	0.000	-3.43	-	-	-24.00%	13.195	0.000	-15.75%	8.986	0.000
LCC	Regional	-20.80%	8.203	0.000	-23.51%	6.587	0.000	-7.54	-	-	-27.22%	7.094	0.000	-9.29%	2.417	0.016
Network	Regional	5.21%	-1.442	0.149	-0.06%	0.024	0.981	-4.11	-	-	-3.22%	1.005	0.315	6.46%	-1.977	0.048

B.2.10.2 Cabin crew

The analysis of pilot discretion use for cabin crew begins by examining two fundamental dimensions: how widespread the experience is and whether discretion is perceived as being used frequently rather than as an exceptional measure. Together, these aspects provide an initial indication of whether commander's discretion functions primarily as an occasional safeguard or whether it may be drifting towards a more structural operational buffer. It should be noted that commander's discretion is a flight-deck prerogative; for cabin crew, the indicators therefore capture exposure to, and perceptions of, discretion use and related practices.

In terms of prevalence (PD01), being affected by the use of commander's discretion is common across operational models, but shows clear differentiation. LCC reports the highest exposure, at 89.93% (±1.99), indicating that nearly all cabin crew respondents in this segment have been affected. ACMI and network report similar mid-high levels, at 65.91% (±14.01) and 66.41% (±2.88) respectively, while regional reports the lowest prevalence, at 50.00% (±10.57). Pairwise comparisons confirm that LCC differs significantly from ACMI ($p \approx 0.000001$) and that LCC is also strongly separated from network and regional ($p \approx 0$ in the corresponding tests), whereas ACMI and network are not meaningfully different in prevalence terms ($p \approx 0.95$). Overall, these results suggest that exposure to discretion is particularly widespread for cabin crew in LCC operations, while remaining substantial but less universal in ACMI and network environments.

Looking beyond exposure to perceived frequency (PD02), the contrast between operational models becomes more pronounced and moves closer to the question of normalisation. LCC again stands out, with 37.46% (±3.20) of respondents perceiving discretion as used frequently. ACMI reports a lower but still elevated level, at 20.51% (±12.67), while network and regional report much lower values, at 9.25% (±1.77) and 2.47% (±3.38) respectively. Statistical comparisons support this structure: LCC differs strongly from network and regional ($p \approx 0$), and ACMI differs significantly from LCC ($p \approx 0.023$) as well as from network and regional ($p \approx 0.013$ and $p \approx 0.0007$). Differences within the low-frequency group (network versus regional) are weaker and less structurally informative. Taken together, these findings indicate that in LCC, and to a lesser extent ACMI, cabin crew are substantially more likely to perceive discretion as a recurrent operational feature rather than an exceptional measure.

At this stage, the combined reading of prevalence and frequency already suggests a divergence across operational models. In network and regional operations, discretion appears to be experienced by a majority of cabin crew but remains largely perceived as exceptional. In LCC, very high exposure is paired with a much stronger perception of frequent use, pointing to potential normalisation. ACMI occupies an intermediate position, with high exposure but greater uncertainty around the frequency estimate due to smaller sample size.

In terms of the perceived average duration of discretion (PD03), a moderate gradient is observed across operational models. Cabin crew report the longest typical extensions in LCC at 58.34 minutes (±2.48) and ACMI at 46.36 minutes (±9.26), compared with network at 54.06 minutes (±2.04) and regional at 43.81 minutes (±7.96). While these differences are not always large in absolute terms, they indicate that in the segments where discretion is perceived as more frequent, particularly LCC, extensions are also reported as longer on average, reinforcing the interpretation of discretion as carrying a heavier operational load.

Perceptions of appropriate use provide an additional qualitative signal. LCC reports the highest share of cabin crew disagreeing that discretion is used appropriately, at 40.40% (±3.28). ACMI reports 24.32% (±13.82), while network and regional report lower levels, at 20.28% (±2.50) and 14.29% (±7.48) respectively. Statistical comparisons show strong separation between LCC and both network and regional (p≈0), and a borderline difference between ACMI and LCC (p≈0.050). This pattern is consistent with the frequency results, suggesting that environments where discretion is perceived as more recurrent are also associated with greater scepticism regarding appropriate use.

Finally, the crew consultation indicator sheds light on decision-making practices around FDP extensions as experienced by cabin crew. A substantial share report that they are not consulted about their level of alertness every time a discretion decision is made. Levels are highest in LCC at 80.07% (±2.65) and ACMI at 70.00% (±14.20), compared with 55.00% (±3.07) in network and 48.00% (±11.31) in regional operations. Statistical tests confirm strong differences between LCC and both network and regional (p≈0), while the ACMI comparisons are directionally similar but less consistently significant due to wider uncertainty. Overall, these results suggest that perceived consultation is weakest in the same operational environments where discretion is most frequently reported.

Taken together, the combined reading of PD01–PD05 points to a differentiated discretion-use profile for cabin crew across operational models. LCC combines very high exposure with the highest perceived frequency, longer extensions, greater disagreement about appropriate use, and the weakest consultation signals, consistent with potential normalisation of discretion as an operational buffer. ACMI shows elevated frequency and weaker consultation, but with wider uncertainty. In contrast, network and regional operations show lower perceived frequency, lower disagreement about appropriateness, and comparatively stronger consultation, aligning more closely with discretion functioning as an exceptional tool rather than a routine planning mechanism.

The tables below present the numerical results of the statistical analysis for the pilot discretion use RA. They report the distribution of responses by airline type and the corresponding pairwise comparison statistics used to assess differences between groups.

Table 45: Pilot discretion use KSI results - Cabin crew

Groups	PD01			PD02			PD03			PD04			PD05		
	Total	Matching	ME	Total	Matching	ME	Total	Matching [43]	ME	Total	Matching	ME	Total	Matching	ME
ACMI	44	29 (65.91%	14.01 %	39	8 (20.51%)	12.67 %	33	46.36	9.26	37	9 (24.32%)	13.82 %	40	28 (70.00%)	14.20 %
Cargo	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
LCC	874	786 (89.93%)	1.99%	881	330 (37.46%)	3.20%	762	54.06	2.04	859	347 (40.40%)	3.28%	873	699 (80.07%)	2.65%
Network	1030	684 (66.41%)	2.88%	1027	95 (9.25%)	1.77%	850	58.34	2.48	991	201 (20.28%)	2.50%	1009	555 (55.00%)	3.07%
Regional	86	43 (50.00%)	10.57 %	81	2 (2.47%)	3.38%	63	43.81	7.96	84	12 (14.29%)	7.48%	75	36 (48.00%)	11.31 %

Table 46: Pilot discretion use pairwise comparison - Flight crew

	PD01	PD02	PD03	PD04	PD05

[43] This column refers to the average duration, as calculated for this KSI and explained in Annex C.3.

Pair		Diff.	Z-score	p-val	Diff.	Z-score	p-val	Diff.	Z-score	p-val	Diff.	Z-score	p-val	Diff.	Z-score	p-val
ACMI	LCC	24.02%	-4.926	0.000	16.94%	-2.276	0.023	7.69	-	-	16.07%	-1.956	0.050	10.07%	-1.546	0.122
ACMI	Network	0.50%	-0.069	0.945	-11.26%	2.470	0.013	11.98	-	-	-4.04%	0.599	0.549	-15.00%	1.872	0.061
ACMI	Regional	-15.91%	1.727	0.084	-18.04%	3.397	0.001	-2.55	-	-	-10.04%	1.343	0.179	-22.00%	2.262	0.024
LCC	Network	-23.52%	12.193	0.000	-28.21%	14.744	0.000	4.29	-	-	-20.11%	9.449	0.000	-25.06%	11.500	0.000
LCC	Regional	-39.93%	10.293	0.000	-34.99%	6.338	0.000	-10.25	-	-	-26.11%	4.704	0.000	-32.07%	6.385	0.000
Network	Regional	-16.41%	3.068	0.002	-6.78%	2.079	0.038	-14.53	-	-	-6.00%	1.324	0.186	-7.00%	1.175	0.240

B.2.11 Pilot retirement age

B.2.11.1 Flight crew

The analysis of pilot retirement age examines the demographic structure of the pilot workforce and the extent to which age-related concentration may generate near-term retirement exposure across operational models. It should be noted at the outset that age information was collected using predefined age bands rather than exact ages. For analytical purposes, the midpoint of each age band has been used to approximate individual ages when calculating weighted averages and medians. This approach provides a consistent basis for comparison across operational models but necessarily simplifies within-band variation. As a result, the age-related indicators should be interpreted with a degree of caution, particularly when considering small differences between groups.

In terms of the overall age profile, the weighted average age shows a high degree of convergence across most operational models, with a clear exception in LCC operations. ACMI, cargo, and network report very similar weighted average ages, at 44.01 years (±1.80), 44.12 (±1.22), and 43.82 (±0.55) respectively, indicating a broadly mature workforce with limited variation around the mid-forties. Regional operations report a somewhat lower average age at 41.21 (±1.50), suggesting a slightly younger profile but still within a comparable range. By contrast, LCC operations stand out with a markedly lower weighted average age of 39.46 (±0.54), a difference that is both statistically significant and consistent across comparisons with all other operational models.

This pattern is reinforced when considering the median age indicator. In ACMI, cargo, network, and regional operations, the median age band corresponds to 45.50, indicating that at least half of pilots fall within or above the 41–50 age cohort. In LCC operations, by contrast, the median age band is 35.50, pointing to a substantially younger central cohort. The coherence between the weighted average and median indicators strengthens the interpretation that LCC pilots are, on average, younger, while the remaining operational models share a broadly similar age structure clustered around the mid-forties.

Looking beyond the central tendency to the upper tail of the age distribution, the retirement wave projection provides a forward-looking view of potential near-term exits from the workforce. Defined as the share of pilots older than 65 years, this indicator remains relatively low across all operational models, but with meaningful variation. Network operations report the highest value at 5.54% (±1.14), followed by regional at 4.52% (±2.89). ACMI and cargo report similar and slightly lower levels, at 3.88% (±3.33) and 3.83% (±2.22) respectively, while LCC again reports the lowest share, at 2.33% (±0.84).

Statistical comparisons indicate that most differences involving ACMI, cargo, and regional are not statistically significant, reflecting both the low absolute values and the simplification inherent in the band-based age approximation. The clearest separation emerges between LCC and network operations, where the difference is statistically significant (p≈0.00002), confirming a higher concentration of pilots beyond retirement age in network operations compared with the younger LCC workforce. Differences between network and regional operations are not statistically significant, and the contrast between LCC and regional does not reach conventional significance thresholds (p≈0.07), consistent with wider uncertainty around the regional estimate.

Taken together, the combined reading of PR01, PR02, and PR03 suggests a broadly mature pilot workforce across ACMI, cargo, network, and regional operations, with limited differentiation in central age profiles among these models. LCC operations consistently display a younger demographic structure, reflected in both lower weighted average age and a lower median age band. At the same time, the share of pilots already beyond 65 years of age remains limited across all segments. Given the use of age bands and midpoint assumptions, these results should be viewed as indicative rather than precise, particularly when interpreting marginal differences across operational models.

The tables below present the numerical results of the statistical analysis for the pilot retirement age RA. They report the distribution of responses by airline type and the corresponding pairwise comparison statistics used to assess differences between groups.

Table 47: Pilot retirement age KSI results - Flight crew

Groups	PR01			PR02			PR03		
	Total	Matching	ME	Total	Matching	ME	Total	Matching	ME
ACMI	129	44.01	1.80	129	45.50	4.50	129	5 (3.88%)	3.33%
Cargo	287	44.12	1.22	287	45.50	4.50	287	11 (3.83%)	2.22%
LCC	1247	39.46	0.54	1247	35.50	4.50	1247	29 (2.33%)	0.84%
Network	1535	43.82	0.55	1535	45.50	4.50	1535	85 (5.54%)	1.14%

Regional	199	41.21	1.50	199	45.50	4.50	199	9 (4.52%)	2.89%

Table 48: Pilot retirement age pairwise comparison - Flight crew

Pair		PR01			PR02			PR03		
		Diff.	Z-score	p-val	Diff.	Z-score	p-val	Diff.	Z-score	p-val
ACMI	Cargo	0.11	-	-	0.00	-	-	-0.04%	0.021	0.983
ACMI	LCC	-4.55	-	-	-10.00	-	-	-1.55%	1.080	0.280
ACMI	Network	-0.18	-	-	0.00	-	-	1.66%	-0.801	0.423
ACMI	Regional	-2.80	-	-	0.00	-	-	0.65%	-0.283	0.777
Cargo	LCC	-4.66	-	-	-10.00	-	-	-1.51%	1.445	0.149
Cargo	Network	-0.30	-	-	0.00	-	-	1.70%	-1.186	0.235
Cargo	Regional	-2.92	-	-	0.00	-	-	0.69%	-0.376	0.707
LCC	Network	4.36	-	-	10.00	-	-	3.21%	-4.250	0.000
LCC	Regional	1.75	-	-	10.00	-	-	2.20%	-1.799	0.072
Network	Regional	-2.62	-	-	0.00	-	-	-1.01%	0.595	0.552

B.2.12 Workforce shortages

B.2.12.1 Flight crew

The analysis of workforce strain and staffing shortages combines multiple indicators capturing both perceived workload intensity and structural aspects of workforce stability. The focus is on understanding whether operational demand is perceived as consistently high relative to available staffing resources, and whether these perceptions align with indicators such as crew tenure.

The perceived high utilisation rate offers a first indication of sustained workload pressure. LCC and ACMI report the highest shares of crew indicating that they operate consistently above their legal duty limits, at 36.21% (±2.68) and 30.40% (±8.06) respectively. Regional operations follow at 24.37% (±5.99), while cargo and network report markedly lower levels, at 19.61% (±4.63) and 17.71% (±1.92). Statistical comparisons reinforce this separation. LCC differs strongly from network ($p \approx 0$), and also from regional ($p \approx 0.0012$), while the contrast between network and regional is statistically significant ($p \approx 0.0236$). ACMI also differs from network ($p \approx 0.00047$). By contrast, ACMI and LCC are not statistically distinguishable ($p \approx 0.197$), consistent with overlapping margins of error and similarly elevated utilisation levels.

Perceived staffing shortages add a complementary perspective by capturing whether available personnel are viewed as sufficient to manage daily workload safely and effectively. LCC again stands out, with 32.53% (±2.70) of respondents reporting staffing shortages, compared with 23.08% (±7.63) in ACMI, 22.53% (±5.15) in cargo, and 21.93% (±5.93) in regional. Network operations report a substantially lower share at 10.98% (±1.64). The statistical evidence confirms that network is clearly separated from the higher-shortage group: ACMI differs significantly from network ($p \approx 0.000065$), and cargo also differs strongly from network ($p \approx 0$). LCC shows the strongest separation from network ($p \approx 0$). In contrast, ACMI and regional are not significantly different ($p \approx 0.811$), and cargo and regional are likewise not significantly different ($p \approx 0.878$), indicating that much of the differentiation is driven by the lower network value and the higher LCC value.

Average crew tenure provides a structural context for interpreting these perceptions. LCC reports the lowest average tenure, at 14.46 years (±0.50), while cargo and network report higher values, at 19.79 (±1.19) and 19.46 (±0.54) respectively. ACMI and regional sit between these groups at 18.02 (±1.88) and 16.37 (±1.39). This distribution is consistent with the perception-based indicators, in the sense that the operational model with the highest perceived utilisation and understaffing (LCC) also shows the lowest tenure, whereas network combines lower perceived strain with higher tenure. Differences in tenure between LCC and the longer-tenure operational models are large in absolute terms and exceed the associated margins of error, indicating a robust separation in workforce stability.

Taken together, the combined reading of perceived utilisation, perceived staffing shortages, and crew tenure provides a coherent picture of workforce strain across operational models. LCC operations consistently exhibit the strongest signals of sustained workload pressure and staffing stress, supported by statistically significant separations from network across both perceived utilisation and staffing shortage indicators ($p \approx 0$ in both cases). ACMI also shows elevated perceived utilisation and higher staffing shortage perceptions compared with network ($p \approx 0.00047$ and $p \approx 0.000065$), though with wider margins of error. Cargo and regional tend to sit closer to ACMI on staffing shortage perceptions but without statistically strong separations between them, while network remains the distinct low-strain group. Overall, the results indicate that perceived workforce strain is not evenly distributed across the sector, but concentrated in specific operational environments, particularly LCC and to a lesser extent ACMI operations.

The tables below present the numerical results of the statistical analysis for the workforce shortages RA. They report the distribution of responses by airline type and the corresponding pairwise comparison statistics used to assess differences between groups.

Table 49: Workforce shortages KSI results - Flight crew

Groups	WS02			WS03			WS04		
	Total	Matching	ME	Total	Matching	ME	Total	Matching	ME
ACMI	125	38 (30.40%)	8.06%	117	27 (23.08%)	7.63%	129	-	1.88
Cargo	283	56 (19.61%)	4.63%	253	57 (22.53%)	5.15%	287	-	1.19
LCC	1236	448 (36.21%)	2.68%	1159	377 (32.53%)	2.70%	1247	-	0.50

Network	1516	269 (17.71%)	1.92%	1403	154 (10.98%)	1.64%	1535	-	0.54
Regional	197	48 (24.37%)	5.99%	187	41 (21.93%)	5.93%	199	-	1.39

Table 50: Workforce shortages pairwise comparisons - Flight crew

Pair		WS02			WS03			WS04		
		Diff.	Z-score	p-val	Diff.	Z-score	p-val	Diff.	Z-score	p-val
ACMI	Cargo	-10.79%	2.390	0.017	-0.55%	0.117	0.907	1.77	-	-
ACMI	LCC	5.81%	-1.291	0.197	9.45%	-2.159	0.031	-3.56	-	-
ACMI	Network	-12.69%	3.499	0.000	-12.10%	3.994	0.000	1.44	-	-
ACMI	Regional	-6.03%	1.193	0.233	-1.15%	0.239	0.811	-1.65	-	-
Cargo	LCC	16.59%	-5.351	0.000	10.00%	-3.273	0.001	-5.32	-	-
Cargo	Network	-1.90%	0.764	0.445	-11.55%	5.286	0.000	-0.32	-	-
Cargo	Regional	4.75%	-1.246	0.213	-0.60%	0.154	0.878	-3.41	-	-

LCC	Network	-18.49%	11.000	0.000	-21.55%	13.547	0.000	5.00	-	-
LCC	Regional	-11.84%	3.245	0.001	-10.60%	2.918	0.004	1.91	-	-
Network	Regional	6.65%	-2.264	0.024	10.95%	-4.319	0.000	-3.09	-	-

B.2.12.2 Cabin crew

The analysis of workforce strain and staffing shortages for cabin crew combines indicators capturing perceived workload intensity and structural aspects of workforce stability. The focus is on understanding whether operational demand is perceived as consistently high relative to available staffing resources, and whether these perceptions align with indicators such as average crew tenure.

Perceived high utilisation (WS02) provides a first indication of sustained workload pressure. LCC reports the highest share, with 48.98% (±3.30) of respondents strongly agreeing that they operate consistently near their legal duty limits. Network follows at 37.25% (±2.93), while ACMI reports 32.93% (±14.39) and regional 26.44% (±9.27). Statistical comparisons show a strong separation between LCC and network ($p \approx 0$), and between LCC and regional ($p \approx 0.000058$). The difference between ACMI and LCC is statistically significant but weaker ($p \approx 0.044$), while ACMI does not differ significantly from network or regional ($p \approx 0.57$ and $p \approx 0.45$), reflecting wider uncertainty in ACMI due to the smaller sample size. Overall, these results indicate that sustained utilisation pressure is most characteristic of LCC cabin crew operations, with network also reporting relatively elevated levels.

Perceived staffing shortages provide a complementary perspective on whether available staffing is viewed as sufficient to manage daily workload safely and effectively. LCC again reports the highest share, at 39.43% (±3.29). ACMI reports 24.39% (±13.15), with network and regional at similar levels, 23.57% (±2.61) and 18.07% (±8.28) respectively. Statistical tests reinforce the distinctiveness of LCC: LCC differs strongly from network (p≈0) and from regional (p≈0.000122). By contrast, differences between ACMI and network or regional are not statistically significant (p≈0.90 and p≈0.41), consistent with overlapping margins of error. This suggests that perceived understaffing among cabin crew is most pronounced in LCC operations, while the remaining operational models cluster at a lower and relatively comparable level.

Average crew tenure (WS04) provides structural context for interpreting these perceptions. LCC reports the lowest average tenure, at 10.52 years (±0.51), while network reports the highest at 19.36 (±0.65). Regional reports 15.51 (±2.18) and ACMI 12.11 (±2.65). The separation between LCC and network is large in absolute terms and substantially exceeds the associated margins of error, indicating a robust difference in workforce stability. This pattern is broadly consistent with the perception-based indicators, in the sense that the operational model reporting the strongest signals of sustained utilisation and staffing stress (LCC) also shows the lowest tenure, while network combines comparatively high utilisation perceptions with much higher tenure, suggesting a more stable workforce structure despite elevated workload perceptions.

Taken together, the combined reading of perceived utilisation, perceived staffing shortages, and tenure provides a coherent picture of workforce strain across operational models for cabin crew. LCC operations consistently exhibit the strongest signals of sustained workload pressure and staffing stress, supported by statistically significant separations from network and regional across both perception indicators. Network reports elevated utilisation pressure but substantially higher tenure and lower staffing shortage perceptions than LCC, indicating a different workforce strain profile. ACMI and regional generally occupy intermediate positions, though interpretation for ACMI is constrained by wider uncertainty. Overall, the results indicate that perceived workforce strain among cabin crew is not evenly distributed across the sector, but concentrated most clearly in LCC operations, with network showing selectively elevated workload pressure under more stable tenure conditions.

The tables below present the numerical results of the statistical analysis for the workforce shortages RA. They report the distribution of responses by airline type and the corresponding pairwise comparison statistics used to assess differences between groups.

Table 51: Workforce shortages KSI results - Cabin crew

Groups	WS02	WS03	WS04

	Total	Matching	ME	Total	Matching	ME	Total	Matching	ME
ACMI	41	13.5 (32.95%)	14.39%	41	10 (24.39%)	13.15%	44	12.11	2.65491
Cargo	-	-	-	-	-	-	-	-	-
LCC	883	432.5 (48.98%)	3.30%	847	334 (39.43%)	3.29%	893	10.52	0.512065
Network	1047	390 (37.25%)	2.93%	1014	239 (23.57%)	2.61%	1084	19.36	0.647202
Regional	87	23 (26.44%)	9.27%	83	15 (18.07%)	8.28%	88	15.51	2.183806

Table 52: Workforce shortages pairwise comparisons - Flight crew

Pair		WS02			WS03			WS04		
		Diff.	Z-score	p-val	Diff.	Z-score	p-val	Diff.	Z-score	p-val
ACMI	LCC	16.05%	-2.011	0.044	15.04%	-1.931	0.053	-1.59	-	-
ACMI	Network	4.32%	-0.562	0.574	-0.82%	0.121	0.903	7.24	-	-
ACMI	Regional	-6.49%	0.759	0.448	-6.32%	0.825	0.409	3.39	-	-

LCC	Network	-11.73%	5.192	0.000	-15.86%	7.455	0.000	8.83	-	-
LCC	Regional	-22.54%	4.020	0.000	-21.36%	3.841	0.000	4.98	-	-
Network	Regional	-10.81%	2.014	0.044	-5.50%	1.143	0.253	-3.85	-	-

B.3 Detailed SPI methodology

B.3.1 Mapping of safety precursors to ECR taxonomy values

This appendix documents the mapping between SPs and the ECCAIRS 2 taxonomy used to identify relevant occurrences in the ECR for the purposes of this analysis.

The mapping is based on the *Event* entity of the taxonomy, which captures all the events associated with the occurrence. In particular, the taxonomy elements used in the mapping are drawn from the *Event type* attribute across different taxonomy levels.

In the context of the Annual Safety Review (ASR) 2021, the analysis relied on the high-level "Personnel" event type (level 1) to characterise the presence of human factors and human performance in reported occurrences. This category aggregates a set of generic values and does not support attribution to specific operational SPs

For the purposes of the present study, the taxonomy was therefore explored at a more granular level. All relevant sub-levels within the "Personnel", "Operational" and "Organisational" values were reviewed and mapped to specific SPs respectively. Generic values that could not be meaningfully attributed to any precursor were excluded from the mapping.

Table 53 lists the specific *Event type* values, across different taxonomy levels, that are used to identify occurrences associated with each SP.

Table 53: Mapping of each Safety Precursors with the corresponding ECR taxonomy values

Safety Precursor	Event Type			
	Level 1	Level 2	Level 3	Level 4
Lack of communication	Personnel	Personnel Task Performance Events	Personnel Communication Events	Accuracy of Communication Complexity of Communication Crew/Duty Changeover Interpretation/Understanding Lack of Communication Language/Accent Non Standard Phraseology Speech Rate/Tone

	Operational	Aircraft Flight Operations	Flight Crew Communications Events	Communications by Flight crew with ANS Flight Crew Callsign Confusion Flight Crew Hearback Flight Crew Interpretation of Communications Flight Crew Response to Communications Flight Crew Use of Headsets Incorrect Position or Time Report Readback by Incorrect Aircraft Readback Correct - Incorrect Action Readback Incomplete - Correct Aircraft Readback Incorrect - Correct Aircraft
		Air Navigation Services	ATM Staff Communication	Ambiguous Transmission ATM Personnel Hearback ATM Personnel Readback Callsign Confusion Inappropriate Information Given
Distraction	Personnel	Situational Awareness and Sensory Events	Personnel Attention and Vigilance Events	Distraction - Job Related Distraction - Non Job Related
Lack of resources	Organisational	Regulatory	Personnel Regulatory Events	Crew or Staff Below Regulatory Requirement Crew or Staff not Licensed for Activity
			Flight Operations Regulatory	Regulatory Information Provision
			ATM Regulaton Devation	ATM Equipment Deviation

			Aircraft related regulatory event/issue	Aircraft Not Equipped or Certified for Approach Aircraft Not Equipped or Certified for Operation Aircraft Not RVSM Equipped
		Organisational Management	Flight Operational Management	Flight Crew CRM Flight Crew Staffing and Scheduling
Stress	Personnel	Situational Awareness and Sensory Events	Personnel Mental and Emotional States	Stress Anxiety/Panic
Complacency	Personnel	Situational Awareness and Sensory Events	Personnel Mental and Emotional States	Boredom Lack of Confidence/Over-Confidence
Lack of teamwork	Organisational	Organisational Management	Aerodrome Operational Management	Aerodrome Leadership and Supervision Aerodrome Roles and Responsibilities
			ATM Operational Management	ATM Leadership and Supervision ATM Roles and Responsibilities
			Flight Operational Management	Flight Operations Leadership and Supervision Flight Operations Roles and Responsibilities
Pressure	Personnel	Personnel Task Performance Events	Task Management Events	External Pressure Time Pressure
	Organisational	Regulatory	Flight Operations Regulatory Events	Operation in Violation of Aerdrome Curfew
Lack of awareness	Personnel	Situational Awareness and Sensory Events	Personnel Perception Events	Expectations/Assumptions Geographic Dissorientation (lost) Identification/Recognition

				Lack of Individual Risk Perception Misjudge Perception of Auditory Information Perception of Visual Information Spatial Disorientation Understanding/Comprehension
Lack of knowledge	Personnel	Experience and Knowledge Events	Knlowedge Events	Aeronautical Knowledge Knowledge of Equipment or Aircraft Knowledge of Geographic Area Knowledge of Meteorological Conditions Knowledge of Procedures Knowledge of Regulations Reading/Language Comprehension
			Qualifications and Experience Events	Qualifications Recent Proficiency/Experience Total Experience
			Training of Personnel Events	Initial Instruction or Training Mentoring Recent Instruction or Training Recurrent/OJT Instruction or Training Total Instruction or Training Training on Equipment or Aircraft Type of Instruction or Training
Fatigue	Personnel	Physiological Events	Personnel Alertness and Fatigue Events	Fatigue Acclimatisation Circadian Disruption

Norms	Personnel	Personnel Task Performance Events	Personnel Non Conformance Events	Routine Individual Non-Conformance Routine Team Non-Conformance Situation Induced Individual Non-Conformance Situation Induced Team Non-Conformance
Workload	Personnel		Task Management Events	Fluctuating Workload Post-Peak Workload Task Allocation Underload Unfamiliar or Unusual Task
	Organisational	Regulatory	Personnel Regulatory Events	Duty Time Exceeded Duty Time Extension Rest Time Less than Required

B.3.2 Inferential analysis of Safety Precursors and safety outcomes

B.3.2.1 Analytical sample and data preparation

B.3.2.1.1 Variables and controls

This appendix documents the operationalisation of key variables used in the inferential analysis, including the ECR attributes referenced. Variables are implemented as binary indicators to support consistent interpretation and stable estimation, reflecting the discrete structure and completeness constraints of ECR reporting fields.

Table 54 and Table 55 summarise the study variables and operational controls respectively of the regression models, specifying the aspect captured, the corresponding variable, and the coding rule used to derive each measure from ECR fields.

The reference category defines the baseline against which regression effects are interpreted and, by definition, corresponds to the value 0. For categorical controls, one category is selected as this baseline and is not included as a separate indicator in the regression, so that estimated coefficients represent differences relative to the reference condition. For example, for *flight phase*, *cruise* is used as the reference, and the estimated coefficients for the remaining phases represent changes relative to cruise.

For both, study variables and the operational covariates, where ECR fields include missing values, unknown, or other non-interpretable values, they are treated as missing and excluded from the regression estimation. In addition to the attribute hierarchies defined in the coding rules, some ECR attributes may record multiple values for a single occurrence, in such cases, predefined selection rules are applied to retain one consistent value for analysis.

Table 54: Definition of the study varibales of the regression

Aspect	Study Variable	Reference category	Coding rule
Operator Group	LCC	Network carries	*Operator* attribute was used to identify the operating airline, and operators were subsequently classified into operator groups using the Cirium-based classification provided by EASA
SP-related occurrence	SP-related	Non-SP related occurrence	*Event Type* attribute implementing the taxonomy-based mapping methodology described in Annex B.3.1

Table 55: Definition of operational control covariates within the ECR

Operational aspect	Operational control covariates	Reference category	Coding rule
Night	Night	Daytime	If *Local Time* available: (1) Night = 1 if 22:00–05:59; else 0[44] If *UTC date*, *UTC time* and *State Area* available: (2) Extract local time and apply (1) If *Light conditions* available:

[44] Flight-time bands are defined for the purposes of this study as an analytical grouping for interpretability and do not represent a standardised external definition.

			(3) Night = 1 if reported as *Night/ dark* or *Night/moonlight;* else 0
Weather	Weather	Weather not relevant	If *Weather* relevant available: (1) Weather = 1 if *Yes;* else 0 If *Event Type L3* available: (2) Weather = 1 if contains *Weather and Environmental Encounters*; else 0
	FP Ground		If *Flight Phase* or *Phase level 2* or *Detection Phase* available (sequential order): (1) FP Ground = 1 if reported as *Standing*, *Tow*, or *Taxi*; else 0
Flight Phase	FP Take-off	FP Cruise	If *Flight Phase* or *Phase level 2* or *Detection Phase* available (sequential order): (1) FP Take-off = 1 if reported as *Take-off*, or *Climb*; else 0
	FP Landing		If *Flight Phase* or *Phase level 2* or *Detection Phase* available (sequential order): (1) FP Landing = 1 if reported as *Approach*, or *Descent,* or *Landing,* or *Manoeuvring,* or *Hovering*; else 0
Haul Category	HC short HC medium	HC long	Calculation of the distance between *Last Departure Point L2* and *Planned Destination L2* using the Great Distance Circle • (1) HC short = 1 if 'distance' < 1,500 km[45] • Calculation of the distance between *Last Departure Point L2*

[45] International Air Transport Association (IATA), "Connectivity and network evolution", IATA Economics, 2025, classification applied (very short-haul < 500 km, short-haul 500 –1,500 km, medium-haul 1,500–4,000 km, long-haul > 4,000 km), available at: https://www.iata.org/en/iata-repository/publications/economic-reports/connectivity-and-network-evolution/ (accessed January 2026)

- and *Planned Destination L2* using the Great Distance Circle
- (1) HC medium = 1 if 1,500 ≤ 'distance' < 4000 km[45]

B.3.2.2 Model specifications

B.3.2.2.1 Preliminary analysis

Pearson correlation

Pairwise correlations are used as an initial screening tool to identify candidate covariates that convey highly overlapping information and may therefore reduce interpretability when included jointly. For two continuous variables X and Y, linear association is quantified using the Pearson correlation coefficient:

$$r_{XY} = \frac{Cov(X,Y)}{\sigma_X \sigma_Y}$$

where $r_{XY} \in [-1,1]$ with values close to +1 indicating strong positive association, values close to -1 indicating strong negative association, and values near 0 indicating limited linear association.

For binary variables, association is assessed using the Phi coefficient, which is equivalent to Pearson's correlation computed on 0/1 indicators. Using the $2x2$ contingency table with counts *a, b, c, d,* Phi is:

$$\varphi = \frac{ad - bc}{\sqrt{(a+b)(c+d)(a+c)(b+d)}}$$

In this study, correlations are reviewed primarily to flag potential redundancy. As an operational rule, pairs with $|\varphi| \geq 0.7$ are treated as strongly correlated and are examined to determine whether one variable should be excluded, consolidated, or retained based on conceptual relevance and completeness. This threshold is applied as a practical rule to identify potentially redundant variables, it is not intended as a formal statistical decision threshold.

Variance inflation factors

Variance Inflation Factors (VIFs) are used to assess multicollinearity among the covariates included in the regression models. High multicollinearity can inflate uncertainty and reduce the stability and interpretability of estimated effects.

Formally, for each covariate X_j, the VIF quantifies how much the variance of its estimated coefficient is inflated due to linear dependence with the remaining covariates. It is defined as:

$$VIF_j = \frac{1}{1 - R_j^2}$$

where R_j^2 is obtained from regressing X_j on the other covariates included in the model. A VIF of 1 indicates no inflation, while larger values indicate increasing multicollinearity and reduced precision of the corresponding coefficient estimates. As a practical diagnostic rule, VIF values close to 1 indicate negligible multicollinearity. Values above 5 are commonly treated as potentially concerning and warrant review, while values below 2 are generally considered low and unlikely to affect the stability or interpretability of estimates.

B.3.2.2.2 Bivariate analysis

In the bivariate analysis, associations between operator group and each binary outcome are summarised using unadjusted odds ratios (ORs) computed directly from the corresponding 2×2 contingency table. Let a denote the number of events in the group of interest, b non-events in that group, c events in the reference group, and d non-events in the reference group. The unadjusted OR is the cross-product ratio:

$$OR = \frac{a/b}{c/d}$$

In line with the approach used in Annex B.1.1.1, uncertainty is reported using 95% confidence intervals based on the log-OR scale with 1.96 as the two-sided critical value.

$$CI_{95} = \left[\exp\left(\ln(OR) - 1.96SE(\ln(OR))\right), \exp\left(\ln(OR) + 1.96SE(\ln(OR))\right)\right]$$

With SE being the Standard Error:

$$SE(\ln(OR)) = \sqrt{\frac{1}{a} + \frac{1}{b} + \frac{1}{c} + \frac{1}{d}}$$

B.3.2.2.3 Logistic regression

<u>Generic logistic regression specification</u>

Let Y_i denote a binary outcome for occurrence i, taking value 1 when the condition of interest is met and 0 otherwise. Logistic regression models the conditional probability of the outcome as:

$$\Pr(Y_i = 1|X_i) = \frac{1}{1 + \exp(-\eta_i)}$$

with linear predictor

$$\eta_i = \beta_0 + X_i^{\mathrm{T}} \beta$$

Equivalently, the model can be written in log-odds form:

$$\log\left(\frac{\Pr(Y_i = 1|X_i)}{1 - \Pr(Y_i = 1|X_i)}\right) = \beta_0 + X_i^{\mathrm{T}}\beta$$

where X_i includes the explanatory variables and control covariates defined in Annex B.3.2.1.

<u>Association between SPs and operator groups</u>

A separate model is estimated for each SP, p. The outcome is:

$$Y_p = \begin{cases} 1 & \text{if occurrence } i \text{ is related to } p \\ 0 & \text{otherwise} \end{cases}$$

The model is specified as:

$$\log\left(\frac{\Pr(Y_i = 1|X_i)}{1 - \Pr(Y_i = 1|X_i)}\right)_p = \beta_{0_p} + \beta_{1_p} LCC_i + \gamma_{i_p}^{\mathrm{T}} Z_i$$

$$Z_i = \{Night, Weather, Flight\ Phase, Haul\}$$

Here, $\gamma_i^{\mathrm{T}} Z_i$ represents the combined contribution of the operational controls. For flight phase and haul, Z_i includes a set of category indicators corresponding to the levels defined in Table 55, relative to a reference category.

<u>Association between severity and SPs</u>

A single logistic regression model is estimated. The outcome is defined as:

$$Y_p = \begin{cases} 1 & \text{if occurrence } i \text{ is classified as Tier 1 severity} \\ 0 & \text{if occurrence i is classified as Tier 2 severity} \end{cases}$$

The model is specified as:

$$\log\left(\frac{\Pr(Y_i = 1|X_i)}{1 - \Pr(Y_i = 1|X_i)}\right) = \beta_0 + \beta_1 SP_i + \beta_2 LCC_i + \gamma_i^{\mathrm{T}} Z_i$$

$$Z_i = \{Night, Weather, Flight\ Phase, Haul\}$$

Here, $\gamma_i^{\mathrm{T}} Z_i$ represents the equal combined contribution of the operational controls as in the previous models.

<u>Odds ratio and interpretation</u>

Logistic regression coefficients are estimated on the log-odds scale and are therefore not directly interpretable in probability units. For reporting, results are presented as odds ratios (ORs), obtained by exponentiating the estimated coefficients:

$$OR_k = \exp(\hat{\beta}_k)$$

An odds ratio compares the odds of the outcome under two conditions that differ by one unit in the covariate of interest, holding all other variables constant. For binary indicators, the OR compares the odds when the indicator equals 1 relative to 0, which corresponds to the reference category. For categorical controls, ORs for each category are interpreted relative to the selected reference category.

An OR above 1 indicates higher odds of the outcome relative to the reference condition, while an OR below 1 indicates lower odds. For example, an OR of 1.30 indicates 30% higher odds relative to the reference, whereas an OR of 0.80 indicates 20% lower odds, conditional on the controls included in the model.

In line with the approach used in Annex B.1.1.1, uncertainty is reported using **95% confidence intervals (CIs)** for odds ratios with 1.96 as the two-sided critical value. This is obtained by exponentiating the confidence limits of the corresponding coefficient estimate:

$$CI_{95} = \left[\exp\left(\hat{\beta}_k - 1.96SE(\hat{\beta}_k)\right), \exp\left(\hat{\beta}_k + 1.96SE(\hat{\beta}_k)\right)\right]$$

Where $SE(\hat{\beta}_k)$ denotes the standard error of $\hat{\beta}_k$. Confidence intervals that exclude 1 provide stronger evidence that the association differs from the reference condition, while intervals that include 1 indicate that the estimated association is not distinguishable from the reference at the 95% confidence level.

Predicted probabilities

While odds ratios provide a convenient measure of relative association, predicted probabilities are reported to support interpretation in probability terms. Predicted probabilities translate the estimated log-odds from the logistic model into an estimated likelihood of the outcome under a defined set of covariate values.

For a given occurrence profile X, the predicted probability is computed as:

$$\hat{p} = \Pr(Y = 1|X) = \frac{1}{1 + \exp\left(-(\hat{\beta}_0 + \mathrm{X}^{\mathrm{T}}\hat{\beta})\right)}$$

Predicted probabilities should be read as **model-based estimates conditional on the specified scenario**, holding the remaining covariates at the chosen reference levels or fixed values. They are therefore useful to illustrate how the estimated likelihood of the outcome changes between groups under comparable operating conditions. Predicted probabilities are reported relative to a clearly defined baseline profile that sets the reference categories for categorical controls and the value 0 for binary indicators.

The baseline scenario for the association between the SPs and the operator groups is defined as:

- Study variables:
  - Network carrier (LCC=0)
- Operating conditions:
  - Daytime (Night=0)
  - Weather not relevant (Weather=0)
  - Flight phase cruise (FP ground/take-off/landing = 0)
  - Long haul (Haul short/medium = 0)

The baseline scenario for the association between severity and SPs is defined as:

- Study variables:
  - Non-SP-related occurrence (SP-related=0)
  - Network carrier (LCC=0)
- Operating conditions:
  - Daytime (Night=0)
  - Weather not relevant (Weather=0)
  - Flight phase cruise (FP ground/take-off/landing = 0)
  - Long haul (Haul short/medium = 0)

Regression output and model diagnostics

To support transparent interpretation, regression outputs are reported using standard statistics that describe the estimated association, its uncertainty, and overall model fit and discrimination.

- **Coefficient ($\hat{\beta}$):** Represents the change in the log-odds of the outcome associated with a one-unit increase in the covariate, holding other variables constant. Positive coefficients correspond to higher predicted probabilities of the outcome, while negative coefficients correspond to lower probabilities.
- **Standard Error (SE):** Quantifies the sampling uncertainty associated with the coefficient estimate. Larger standard errors indicate lower precision and typically result in wider confidence intervals for the estimated effect.
- **z-statistic (z):** Standardised measure of the coefficient, computed as:

$$z = \frac{\hat{\beta}}{SE(\hat{\beta})}$$

The z-statistic in the regression framework serves an analogous purpose as in Annex B.1.2.2 by testing whether an estimated coefficient differs from zero. Therefore, it indicates how large the estimated effect is relative to its sampling uncertainty.

- **p-value:** Evaluates the null hypothesis that the coefficient equals zero. Smaller p-values indicate stronger evidence against the null hypothesis, suggesting that the estimated association is unlikely to arise from random sampling variation alone, conditional on the model specification.
- **Pseudo-R^2:** Summary measure of model fit for logistic regression based on improvement relative to a null model. It is useful for comparing specifications, but it does not have the same interpretation as the R^2 in linear regression and should be read as an indicative fit metric rather than a share of variance explained.
- **AUC (Area Under the ROC Curve):** Measures the model's ability to discriminate between outcomes. In this setting, AUC values are expected to be moderate, as the models are specified for interpretability and rely on a parsimonious set of organisational and operational covariates. For the precursor-tagging models, AUCs in the 0.60–0.75 range are typically consistent with meaningful discrimination, while for the Tier 1 severity model, where outcomes are rare, AUCs are commonly closer to 0.55–0.70.

These models are specified to support coefficient interpretation rather than predictive optimisation. Accordingly, diagnostics such as the AUC are reported as a basic check that the specification discriminates beyond chance and provides a credible basis for interpreting the estimated associations, rather than as targets for maximising predictive accuracy.

B.4 Additional SPIs analysis

B.4.1 Inferential analysis of safety precursors and safety outcomes

B.4.1.1 Association between safety precursors and safety outcomes

B.4.1.1.1 Preliminary analysis

Multicollinearity diagnostics

To ensure the robustness of the data first it was ensured that for each set of categorical indicators, a reference category was defined to avoid redundant dummy specifications and ensure that categories are interpreted relative to a consistent baseline.

Pairwise Pearson correlations were then examined among the model predictors to screen for potential multicollinearity. The resulting correlation matrix is reported in Table 56. Cells in light red indicate predictor pairs with |φ| ≥ 0.700, flagged for potential redundancy, while cells in light green denote correlations below this threshold, suggesting lower risk of multicollinearity. The diagonal cells in grey simply represent the correlation of each variable with itself.

As it can be observed, all correlations remain below this threshold. The highest values arise among the haul-length indicators, but they still fall below the screening threshold. Consequently, the risk of multicollinearity is considered low, and all predictors are retained in the regression model.

Table 56: Pearson correlation matrix

	LCC	Night	Weather	FP Ground	FP Take-off	FP Landing	HC short	HC medium
LCC	1.000	-0.156	0.049	0.001	0.064	0.126	0.149	0.175
Night	-0.156	1.000	-0.032	-0.027	-0.057	0.015	-0.079	-0.026
Weather	0.049	-0.032	1.000	-0.131	-0.038	0.195	0.032	0.005
FP Ground	0.001	0.027	-0.131	1.000	-0.233	-0.472	0.007	-0.018
FP Take-off	0.064	-0.057	-0.038	-0.233	1.000	-0.220	0.069	-0.015
FP Landing	0.126	0.015	0.195	-0.472	-0.220	1.000	0.133	0.004
HC short	0.149	-0.079	0.032	0.007	0.069	0.133	1.000	-0.619
HC medium	0.175	-0.026	0.005	-0.018	-0.015	0.004	-0.619	1.000

|φ| < 0.700 |φ| ≥ 0.700

Finally, multicollinearity was assessed using factor level variance inflation factors (VIF), which identify redundancy that may arise from combinations of predictors rather than from pairwise overlap alone. Table 57 reports these diagnostics: a VIF of 1 indicates no variance inflation, and its reciprocal (1/VIF) is the tolerance. The results show low VIFs (maximum = 1.91 for HC short; mean = 1.45), indicating that predictors contribute nonoverlapping information in aggregate and that adjusted estimates are stable and interpretable.

It is therefore concluded that multicollinearity is unlikely to bias or destabilise the results reported here.

Table 57: Variance Inflation Factors (VIF)

	VIF	1/VIF

LCC	1.20	0.84
Night	1.04	0.97
Weather	1.04	0.96
FP Ground	1.57	0.64
FP Take Off	1.29	0.77
FP Landing	1.66	0.60
HC Short	1.91	0.52
HC Medium	1.86	0.54
Mean VIF	1.45	

B.4.1.2 Multivariate analysis results

To assess the stability of the estimated association with operator group, the regression models were estimated under a series of alternative specifications. Controls were introduced sequentially and, in complementary checks, subsets of operational covariates were removed to evaluate how sensitive the LCC coefficient was to reasonable changes in adjustment.

Across these specifications, the magnitude of the LCC estimate varies as expected when accounting for different aspects of operational context, but its direction and overall interpretation remain consistent for most precursors. The main exceptions are pressure and distraction, where low precursor prevalence in the analytic sample implies fewer positive cases and, consequently, more sensitivity to changes in control variables.

The detailed results are reported in Table 58-Table 64. Each table corresponds to a separate logistic regression model estimated for a single SP, where the dependent variable is the presence of that precursor in the occurrence.

Table 58: Logistic regression results for "Lack of communication"

	Coefficient	Std. Error	z	p-value
LCC	0.195	0.050	3.870	<0.001
Night	-0.615	0.067	-9.116	<0.001
Weather	-0.343	0.106	-3.229	0.001

FP Ground	-0.098	0.056	-1.731	0.083
FP Take Off	-0.788	0.101	-7.769	<0.001
FP Landing	-0.557	0.066	-8.484	<0.001
HC Short	0.264	0.066	3.995	<0.001
HC Medium	0.023	0.073	0.311	0.756
N	102,203			
Pseudo-R^2	0.015			
AUC	0.612			

Table 59: Logistic regression results for "Distraction"

	Coefficient	Std. Error	z	p-value
LCC	0.010	0.133	0.073	0.942
Night	0.190	0.167	-1.141	0.254
Weather	0.124	0.258	0.481	0.630
FP Ground	0.632	0.177	3.564	<0.001
FP Take Off	0.293	0.240	1.220	0.223
FP Landing	-0.320	0.211	-1.518	0.129
HC Short	1.232	0.222	5.539	<0.001
HC Medium	0.336	0.259	1.301	0.193
N	102,203			
Pseudo-R^2	0.029			
AUC	0.68			

Table 60: Logistic regression results for "Pressure"

	Coefficient	Std. Error	z	p-value

LCC	0.157	0.232	0.677	0.498
Night	-0.129	0.281	-0.458	0.647
Weather	-0.302	0.469	-0.644	0.520
FP Ground	-0.308	0.284	-1.082	0.279
FP Take Off	-0.275	0.396	-0.695	0.487
FP Landing	-0.370	0.294	-1.258	0.208
HC Short	1.384	0.448	3.087	0.002
HC Medium	1.267	0.465	2.722	0.006
N	102,203			
Pseudo-R^2	0.013			
AUC	0.61			

Table 61: Logistic regression results for "Lack of awareness"

	Coefficient	Std. Error	z	p-value
LCC	0.355	0.115	3.083	0.002
Night	-0.592	0.159	-3.712	<0.001
Weather	0.232	0.198	1.171	0.242
FP Ground	1.296	0.180	7.187	<0.001
FP Take Off	0.244	0.265	0.923	0.356
FP Landing	0.553	0.196	2.818	0.005
HC Short	0.779	0.178	4.365	<0.001
HC Medium	0.238	0.201	1.181	0.238
N	102,203			
Pseudo-R^2	0.036			
AUC	0.692			

Table 62: Logistic regression results for "Lack of knowledge"

	Coefficient	Std. Error	z	p-value
LCC	0.354	0.106	3.330	0.001
Night	-0.639	0.147	-4.349	<0.001
Weather	-0.145	0.198	-0.731	0.465
FP Ground	1.465	0.181	8.118	<0.001
FP Take Off	0.136	0.281	0.485	0.628
FP Landing	1.068	0.189	5.659	<0.001
HC Short	0.665	0.170	3.912	<0.001
HC Medium	0.617	0.181	3.411	0.001
N	102,203			
Pseudo-R^2	0.037			
AUC	0.690			

Table 63: Logistic regression results for "Fatigue"

	Coefficient	Std. Error	z	p-value
LCC	-0.391	0.041	-10.103	<0.001
Night	0.399	0.037	10.802	<0.001
Weather	-1.367	0.125	10.962	<0.001
FP Ground	-2.430	0.052	-46.551	<0.001
FP Take Off	-4.937	0.117	-25.028	<0.001
FP Landing	-2.932	0.070	-42.035	<0.001
HC Short	0.534	0.044	12.153	<0.001
HC Medium	0.214	0.047	4.551	<0.001
N	102,203			

Pseudo-R^2	0.184
AUC	0.822

Table 64: Logistic regression results for "Workload"

	Coefficient	Std. Error	z	p-value
LCC	-0.422	0.146	-2.899	0.004
Night	0.486	0.134	3.634	<0.001
Weather	1.640	0.166	9.882	<0.001
FP Ground	0.797	0.148	5.401	<0.001
FP Take Off	-1.364	0.466	-2.928	0.003
FP Landing	-1.075	0.231	-4.652	<0.001
HC Short	-0.384	0.151	-2.540	0.011
HC Medium	-0.585	0.183	-3.204	0.001
N	102,203			
Pseudo-R^2	0.064			
AUC	0.732			

B.4.2 Association between severity and Safety Precursors

B.4.2.1 Preliminary analysis

Multicollinearity diagnostics

For this regression study, the SP-related indicator, that indicates if the occurrence is associated with a SP or not, is included in the predictor set. Therefore, multicollinearity studies are repeated for the new set.

Table 65 reports the Pearson correlation matrix, the inclusion of the SP-related indicator does not introduce any notable additional overlap, with all the correlations remaining below the screening threshold, with the highest values still observed within the haul-length indicators.

Table 65: Pearson correlation matrix

	SP related	LCC	Night	Weather	FP Ground	FP Take-off	FP Landing	HC short	HC medium
SP related	1.000	-0.042	0.013	-0.038	-0.036	-0.058	-0.104	-0.004	-0.015
LCC	-0.042	1.000	-0.156	0.049	0.001	0.064	0.126	0.149	0.175
Night	0.013	-0.156	1.000	-0.032	-0.027	-0.057	0.015	-0.079	-0.026
Weather	-0.038	0.049	-0.032	1.000	-0.131	-0.038	0.195	0.032	0.005
FP Ground	-0.036	0.001	0.027	-0.131	1.000	-0.233	-0.472	0.007	-0.018
FP Take-off	-0.058	0.064	-0.057	-0.038	-0.233	1.000	-0.220	0.069	-0.015
FP Landing	-0.104	0.126	0.015	0.195	-0.472	-0.220	1.000	0.133	0.004
HC short	-0.004	0.149	-0.079	0.032	0.007	0.069	0.133	1.000	-0.619
HC medium	-0.015	0.175	-0.026	0.005	-0.018	-0.015	0.004	-0.619	1.000

$|\varphi| < 0.700$ $|\varphi| \geq 0.700$

VIFs were also recomputed after adding the SP-related indicator to the predictor set, reported in Table 66. Overall, VIF values remain low and close to 1, indicating limited multivariate dependence among predictors. The highest VIFs continue to be observed for the categorical indicator blocks (flight phase and haul length), as expected, but remain well below thresholds. Therefore, including SP-related variable does not materially increase VIF values, suggesting that it does not introduce additional multicollinearity in the multivariable specification.

Table 66: Variance Inflation Factors (VIFs)

	VIF	1/VIF
SP related	1.04	0.96
LCC	1.20	0.84
Night	1.04	0.97
Weather	1.04	0.96
FP Ground	1.61	0.62
FP Take Off	1.32	0.76

FP Landing	1.71	0.59
HC Short	1.92	0.52
HC Medium	1.86	0.54
Mean VIF	1.41	

B.4.2.2 Multivariate analysis results

To assess the stability of the results, the models were complementary computed under a series of alternative specifications. Operational covariates were added and removed in plausible subsets, and the inclusion of the two key indicators, SP-related and LCC, was also varied to assess how sensitive the main associations were to reasonable changes in specification. Across these checks, effect magnitudes change as expected with different levels of adjustment, but the overall direction and interpretation of the main associations remain consistent.

Table 67 reports the primary specification, which includes the full set of operational covariates and serves as the main reference model for the analysis.

Table 67: Logistic regression results for "Severity"

	Coefficient	Std. Error	z	p-value
SP-related	0.884	0.252	3.510	<0.001
LCC	0.595	0.197	3.015	0.003
Night	-0.566	0.251	-2.258	0.024
Weather	0.415	0.275	1.509	0.131
FP Ground	-0.160	0.241	-0.664	0.507
FP Take Off	0.018	0.335	0.054	0.957
FP Landing	0.176	0.237	0.745	0.456
HC Short	-0.443	0.239	-1.853	0.064
HC Medium	-0.271	0.254	-1.065	0.287
N	102,203			
Pseudo-R^2				0.016

C. Annexes C: Background and reference material

Annex B compiles the background and reference material that supports the analytical framework used in the study. While the main report summarises the most relevant conceptual links and empirical results, this annex provides the supporting evidence base in greater depth, consolidating key sources and definitions that inform the selection of socio-economic dimensions, the interpretation of safety-critical roles, and the operationalisation of survey-based indicators.

The annex is organised into three parts. First, literature review on SEFs is presented, documenting how employment conditions, work intensity, resource constraints, health and lifestyle, and training/Just Culture have been discussed in prior research as potential drivers of operational risk. Then, it focuses on SCP, reviewing literature relevant to the roles included in the scope of the study and the mechanisms through which working conditions and organisational context may affect safety-related performance. Finally, Section 7.3 provides reference material on KSIs, including definitions and measurement considerations that support the construction and interpretation of the indicators used in the empirical analysis.

C.1 Literature review on S-E factors

This annex summarises the results of the literature review, providing a synthesis of existing research on the relationship between SEFs and aviation safety.

In addition to the classification by SEF and associated RA, each entry in the table includes three elements to support interpretation:

- Main outcomes: A summary of the source's main findings regarding the relationship between socio-economic conditions and aviation safety.
- Key outcomes: A concise takeaway highlighting the source's most relevant contribution to understanding how SEFs influence safety performance.
- Level of consideration within the project: This field indicates the degree to which the source is considered relevant for the objectives of the analysis. The three levels of classification used are:
- Considered: The source provides direct evidence on the relationship between socio-economic conditions and aviation safety.
- Partially considered: The source offers relevant insights, but its scope is limited or only indirectly related to the project's analytical focus.
- Not considered: The source is of limited applicability for the analysis of SEFs and has not been integrated into the evidence base.

The following table summarises the literature reviewed to analyse the link between SEFs and aviation safety.

Table 68: Literature review towards the link between socio-economic factors and aviation safety.

Source	Associated main socio-economic factor	Associated main risk areas	Main outcomes	Key outcomes	Level of consideration within the project
Ford, J., Henderson, R., & O'Hare, D. (2013). ***Barriers to intra-aircraft communication and safety: The perspective of the flight attendants***. The International Journal of Aviation Psychology, 23(4), 368–387. https://doi.org/10.1080/10508414.2013.834167	Employment and working conditions	• Crew interoperability	The document presents evidence that organisational and operational differences between pilots and flight attendants such as segregated preflight briefings, differential terms and conditions, and restricted access due to the locked flight deck door create barriers to communication and teamwork, potentially compromising aviation safety. These barriers have been linked to past accidents, including the Kegworth and Dryden crashes, where ineffective intra-crew communication was a contributing factor. The study identifies communication hindrances as safety risks and supports joint Crew Resource Management (CRM) training as a mitigation strategy.	Communication barriers due to organisational asymmetry.	Considered – Highlights critical communication gaps
Chen, C.-F., & Chen, S.-C. (2014). ***Investigating the effects of job demands and job resources on cabin crew***	Work intensity, flexibility, and uncertainty	• Atypical contracts	The document presents evidence that high job demands, such as emotional labour and work overload, negatively affect cabin crew members' in-role safety behaviour, extra-role safety behaviour, and upward safety communication. Conversely, job resources including job	Workload impacts safety behaviour; job	Considered – Strong link between workload,

***safety behaviours*.** Tourism Management, 41, 45–52. https://doi.org/10.1016/j.tourman.2013.08.009			autonomy and professional development are positively associated with this safety behaviour. Furthermore, job resources significantly moderate the negative impact of job demands on safety behaviour, buffering their detrimental effects.	resources buffer effect.	resources and safety behaviour.
Ford, J., O'Hare, D., & Henderson, R. (2014). **Flight attendant and pilot perceptions of inflight events.** *International Journal of Human Factors and Ergonomics*, 3(1), 1–14. https://doi.org/10.1504/IJHFE.2014.062545	Employment and working conditions	• Crew interoperability	The document presents evidence that differences in perceived roles and responsibilities between flight attendants and pilots may contribute to communication breakdowns during in-flight events. These breakdowns are linked to interpersonal, organisational, and regulatory factors such as status hierarchies, duty-hour rules, and differing training practices. Despite the implementation of CRM training, reluctance to speak up due to team climate concerns or divergent risk perceptions persists, representing a potential safety risk in high-stress situations.	Hierarchies impair crew communication.	Considered – Reveals structural causes of communication breakdowns.
Ford, J., Henderson, R., & O'Hare, D. (2014**). The effects of Crew Resource Management (CRM) training on flight attendants' safety attitudes.** *Journal of Safety Research*, 48, 49 – 56.	Employment and working conditions	• Skills and training gaps	The document presents evidence that CRM training for flight attendants significantly improves safety attitudes, particularly regarding teamwork, communication, and understanding of crew roles. Analysis of pre and post training data from over 500 flight attendants revealed statistically improvements in nearly half of the questionnaire items, especially those related to perceptions of pilot collaboration and safety culture. CRM training was also shown to be more effective for senior, short-haul, and more experienced crew members. These	CRM boosts communication and teamwork.	Partially considered – Focuses on mitigation rather than identifying safety degradation.

https://doi.org/10.1016/j.jsr.2013.11.003			findings support the integration of CRM as a critical component in enhancing flight attendant safety behaviour and minimizing communication related safety risks.		
Brown, L. J., Schoutens, A. M. C., Whitehurst, G., Booker, T., Davis, T., Losinski, S., & Diehl, R. (2014). **The Effect of Blue Light Therapy on Flight CrewMembers Behavioural Alertness.** SSRN. https://doi.org/10.2139/ssrn.2402409	Health and lifestyle	• Atypical contracts	The document presents evidence that exposure to short-wavelength blue light (460–465 nm) significantly improves behavioural alertness in both pilots and flight attendants. The intervention led to statistically significant reductions in subjective sleepiness (KSS), subjective fatigue (SP), and psychomotor lapses (PVT), with 39.1% of the variance in alertness explained by time (pre/post intervention) and 49.4% explained by crew position (pilot/flight attendant). The study confirms blue light as an effective non-pharmacological countermeasure to reduce fatigue-related risks in aviation settings. Unlike previous studies, this one show how improving a socio-economic factor improves aviation safety	Blue light improves alertness.	Partially considered – Focuses on solutions rather than identifying underlying risks.
McLean, C. L., Weed, D. B., Paskoff, L. N., Ruppel, D. J., & McLean, G. A. (2017). ***Cabin Crew Fire Training Needs Analysis.*** Office of Aerospace Medicine, Federal Aviation Administration.	Education in the context of just culture	• Skills and training gaps	The document presents evidence that deficiencies in the realism, consistency, and frequency of cabin crew firefighting training pose risks to aviation safety. Survey responses from U.S. cabin crew and instructors revealed inadequate preparation for multiple simultaneous fires, limited hands-on training for hidden fire scenarios, and inconsistent use of protective breathing equipment and communication procedures. The report concludes that most crew members desire more realistic and frequent	Training gaps increase safety risk.	Considered – Directly links training deficits to emergency response capacity.

Technical Report DOT/FAA/AM-17/11.			practical training, including varied scenarios, role assignments, and team coordination under realistic cabin conditions. The findings support recommendations for standardized training practices to mitigate safety risks in fire emergencies.		
Omholt, M. L., Tveito, T. H., & Ihlebæk, C. (2017). **Subjective health complaints, work-related stress and self-efficacy in Norwegian aircrew.** *Occupational Medicine*, 67(2), 135–142. https://doi.org/10.1093/occmed/kqw127	Health and lifestyle	• Atypical contracts • Generational risk behaviour	The document presents evidence that high levels of work-related stress are significantly associated with increased subjective health complaints (SHCs) among Norwegian aircrew. Both cockpit and cabin crew reported high prevalence of SHCs such as tiredness, sleep problems, low back pain, and gastrointestinal issues with cabin crew consistently reporting more complaints than cockpit crew. The study also found that self-efficacy partly moderated the relationship between work-related stress and psychological complaints, and between stress and musculoskeletal complaints among cockpit crew. These findings indicate that work-related stress is a key factor influencing aircrew health outcomes.	Stress correlates with health complaints.	Considered – Shows strong association between stress and reduced operational fitness.
Mumtaz, S. H. (2017). Analysis of mental health issues and its implications on cabin crew at Emirates Airlines. Middle	Health and lifestyle	• Atypical contracts • Generational risk behaviour	The document presents evidence that cabin crew at Emirates Airlines are exposed to several occupational stressors contributing to mental health issues, including irregular sleep patterns, long duty hours, homesickness, job insecurity, and restrictive corporate policies. These conditions were associated with reported anxiety, depression, and emotional exhaustion. The study highlights the lack of psychological support and perceived	Mental health impacted by poor support.	Considered – Links working conditions to mental health and safety performance.

Tennessee State University.			lack of empathy from management as exacerbating factors. It recommends the implementation of structured mental health support systems, confidential reporting mechanisms, and improved organizational communication to mitigate the negative mental health outcomes among cabin crew.		
Yoo, K.-I., & Kim, M.-K. (2018). **A Study on Minimum Cabin Crew Requirements for Korean Low-Cost Air Carriers.** *The Korean Journal of Air and Space Law*, 33(2), 291–314. https://doi.org/10.31691/KASL33.2.9	Employment and working conditions	• Workforce shortages • Commercial pressure	The document presents evidence that the current minimum cabin crew requirements for Korean low-cost carriers based only on passenger seat count may have a safety risk due to increased workload and fatigue. The study highlights that low-cost carriers operate with the minimum number of required crew, often resulting in unstaffed emergency exits and inability to respond effectively if a crew member becomes incapacitated. It recommends that cabin crew fatigue and workload be formally considered in regulatory provisions, suggesting amendments to ICAO Annex 6 and Korean national regulations to improve cabin safety during emergencies.	Minimum staffing increases risk.	Partially considered – Highlights a potential risk from lean crew operations
Schiffinger, M., & Braun, S. M. (2020). The impact of social and temporal job demands and resources on emotional exhaustion and turnover intention among flight attendants.	Work intensity, flexibility, and uncertainty	• Commercial pressure • Homebase changes	The document presents evidence that scheduling dissatisfaction, time pressure, and surface acting significantly increase emotional exhaustion and turnover intention among flight attendants. The study identifies scheduling satisfaction as the most influential predictor of both emotional exhaustion and turnover intention, suggesting that better alignment of work schedules with employee preferences can enhance retention and reduce	Poor scheduling drives exhaustion.	Considered – Strong link between fatigue, burnout, and safety culture

Journal of Human Resources in Hospitality & Tourism, 19(2), 196–219. https://doi.org/10.1080/15332845.2020.1702867			burnout. Temporal job demands and perceived lack of organizational support were also found to be key contributors to staff depletion and intention to leave. These findings underscore the importance of managing human resources conditions, particularly scheduling and workload in the context of safety and workforce stability.		
Van den Berg, M. J., Signal, T. L., & Gander, P. H. (2020). Fatigue risk management for cabin crew: The importance of company support and sufficient rest for work–life balance—a qualitative study. *Industrial Health*, 58(1), 2–14. https://doi.org/10.2486/indhealth.2018-0233	Work intensity, flexibility, and uncertainty	• Workforce shortages • Pilot discretion use	The document presents evidence that cabin crew fatigue, especially in ultra-long-range (ULR) operations is significantly affected by insufficient rest, irregular scheduling, high workload, lack of company support, and limited fatigue management training. Fatigue was found to impact both personal health and safety-related performance, including alertness during safety tasks. Participants reported that current rest periods and roster design do not allow adequate recovery or work-life balance, leading to chronic fatigue and safety concerns. The study recommends prioritizing fatigue management training, improving scheduling practices, and increasing organizational support to reduce fatigue-related risks.	Fatigue linked to poor scheduling and lack of support.	Considered – Clear evidence of chronic fatigue as safety risk
Elwezza, M. M., Elbadry, M., & Talaat, N. (2020). **The impact of cabin crew work stress on costs.** *Journal of the Faculty of Tourism and*	Health and lifestyle	• Generational risk behaviour	The document presents evidence that work-related stress among cabin crew may negatively affect safety performance by increasing the likelihood of human error during flight operations. Survey results indicate that stress can impair concentration and decision-making, which are critical for ensuring cabin safety. Although the study	Stress reduces alertness and decision-making.	Considered – Identifies psychological load as a direct safety threat

Hotels, University of Sadat City, 4(2/2), 81–92.			primarily addresses economic impacts, it also notes that stress-induced errors have safety implications, highlighting the importance of managing crew stress to maintain operational safety.		
Görlich, Y., & Stadelmann, D. (2020). **Mental Health of Flying Cabin Crews: Depression, Anxiety, and Stress Before and During the COVID-19 Pandemic.** *Frontiers in Psychology*, 11, 581496. https://doi.org/10.3389/fpsyg.2020.581496	Health and lifestyle	• Atypical contracts • Generational risk behaviour	The document presents evidence that labour disruptions and job insecurity during the COVID-19 pandemic led to a substantial increase in symptoms of depression, anxiety, and stress among cabin crews. Clinically significant levels of these symptoms rose from 8% to 23% for depression, 6% to 14% for anxiety, and 8% to 24% for stress. The study identifies that subjective working conditions and existential fears correlate with these outcomes. While not measuring safety events directly, the findings suggest that such psychological load represent a latent safety risk by impairing cognitive and emotional functioning, especially in high-stakes operational environments.	Mental health deterioration as latent risk.	Considered – Links pandemic-related instability to latent safety risk
Mulay, R., Gangwal, A., Shyam, A., & Sancheti, P. (2019**). Prevalence and risk factors for**	Health and lifestyle	• Generational risk behaviour	The document presents evidence that 82% of flight attendants experience work-related musculoskeletal disorders (WRMSDs), particularly in the feet, lower back, and neck. Key risk factors include prolonged standing,	Physical strain reduces fitness to operate.	Considered – Identifies operational limitations linked

work-related musculoskeletal disorders in flight attendants. *International Journal of Community Medicine and Public Health*, 6, 2456. https://doi.org/10.18203/2394-6040.ijcmph20192304			wearing high heels, irregular working hours, confined working environments, and mental stress. These conditions lead to muscle fatigue, restricted movement, and pain that can compromise physical performance during flights. Over half of respondents missed work due to these disorders, and 42% sought medical consultation. While not directly measuring safety incidents, the study suggests that physical discomfort and restricted mobility could impair the ability to perform safety duties effectively.		to crew health that can degrade safety performance.
Wen, C., Nicholas, C., Clarke-Errey, S., Howard, M., Trinder, J., & Jordan, A. (2021). **Health risks and potential predictors of fatigue and sleepiness in airline cabin crew.** International Journal of Environmental Research and Public Health, 18(1), 13. https://doi.org/10.3390/ijerph18010013	Health and lifestyle	• Generational risk behaviour • Homebase changes	The document presents evidence that fatigue, sleepiness, shift work disorder (SWD), insomnia, and depression are highly prevalent among airline cabin crew and significantly linked to work-related factors such as number of duty days per week, consecutive workdays, route type (especially international), flight delays, and commuting time. Notably, 78.2% of respondents reported fatigue impairing their safety-related performance, and 34.8% admitted to falling asleep during critical flight phases. These findings suggest that operational scheduling and inadequate rest contribute to increased safety risks due to fatigue-related impairment.	Fatigue and poor rest impair performance.	Considered – Directly links operational conditions to degraded safety performance.

Park, J., & Hyun, S. S. (2021). Influence of airline cabin crew members' rapport-building behaviours and empathy toward colleagues on team performance, organizational atmosphere, and irregularity. International Journal of Environmental Research and Public Health, 18(12), 6417. https://doi.org/10.3390/ijerph18126417	Employment and working conditions	• Crew interoperability •	The document presents evidence that rapport-building behaviours and empathy among airline cabin crew positively influence team performance and organisational atmosphere while significantly reducing reported irregularities, including operational errors and lapses. The study demonstrates that greater empathy fostered through behaviours such as attentive interaction, humour, courtesy, and information sharing correlates with improved safety-related performance. Specifically, 230 surveyed crew members reported fewer mistakes and higher satisfaction in teams where empathy and communication were strong. These findings support incorporating interpersonal behaviour and team cohesion into airline safety and human resource practices. Unlike previous studies, this one show how improving a socio-economic factor improves aviation safety	Empathy and cohesion reduce errors.	Partially considered – Highlights a mitigating factor, not a negative safety impact.
Grout, A., & Leggat, P. A. (2021**). Cabin crew health and fitness-to-fly: Opportunities for re-evaluation amid COVID-19.** Travel Medicine and Infectious Disease, 40, 101973.	Resource constraints and labour market dynamics	• Skills and training gaps	The document presents evidence that current fitness-to-fly assessments for cabin crew do not sufficiently address operational health risks such as fatigue, infectious disease exposure, and mental health conditions. It highlights that cabin crew often report for duty while unwell, partly due to fear of disciplinary action or disruption to schedules. This behaviour may pose safety risks during flight operations. The study recommends harmonising fitness-to-fly criteria across jurisdictions, improving self-assessment tools, and including pandemic-related risks to	Unfit crew may fly due to fear of consequences.	Considered – Identifies systematic gaps that increase safety risk.

https://doi.org/10.1016/j.tmaid.2021.101973			ensure cabin crew are medically and operationally fit for duty.		
Kim, J., Yu, M., & Hyun, S. S. (2022). **Study on factors that influence human errors: Focused on cabin crew.** International Journal of Environmental Research and Public Health, 19(9), 5696. https://doi.org/10.3390/ijerph19095696	Health and lifestyle	• Generational risk behaviour	The document presents evidence that physical fatigue, psychological stress, and complacency significantly increase the likelihood of human errors among cabin crew. The study found that fatigue impairs attention and communication, stress leads to unstable behaviour, and complacency, defined as excessive confidence or lack of motivation, was the strongest predictor of error. These human errors are directly linked to flight safety risks during operations. Distraction and hurrying under time pressure did not show significant effects. The findings emphasize the need to manage work conditions and psychological states to reduce error-related safety risks.	Fatigue, stress, and complacency drive human error in cabin crew.	Considered – Links psychological strain to increased operational error risk. ●
Lindsey, W. N. (2022). Strategies for reducing occupational stress on cabin crewmembers in the airline industry (Doctoral dissertation). Walden University.	Health and lifestyle	• Generational risk behaviour	The document presents evidence that occupational stress among cabin crew members negatively affects aviation safety by impairing alertness, increasing fatigue, and contributing to human error. The study identifies specific stressors such as irregular schedules, reserve duties, inflight emergencies, and exposure to air rage as factors that compromise cognitive performance and the ability to execute safety protocols. Airline leaders reported implementing strategies such as inflight training, communication systems, and employee support resources to mitigate stress. These measures aim to maintain	Occupational stress degrades alertness and safety performance.	Considered – Reinforces need for stress mitigation to safeguard operational safety. ●

			mental alertness and operational performance in safety-critical situations.		
Kim, H., Yu, M., & Hyun, S. S. (2022). **Strategies to improve work attitude and mental health of problem employees: Focusing on airline cabin crew.** International Journal of Environmental Research and Public Health, 19(2), 768. https://doi.org/10.3390/ijerph19020768	Health and lifestyle	• Generational risk behaviour	The document presents evidence that negative work attitudes among cabin crew, often linked to low job confidence or inadequate task alignment, can impair mental health and reduce job performance. The study demonstrates that targeted strategies such as assigning duties based on ability, fostering core confidence, and applying mentoring systems, significantly improve mental health and job performance through improved work attitudes. While not directly measuring safety events, the study highlights that poorly managed psychological conditions and attitudes in flight environments may affect safe service delivery, underscoring the need for structured psychological support and individualized personnel management.	Poor work attitudes and low confidence undermine crew mental health.	Considered – Underscores link between psychological support and performance reliability in flight. ●
Roderick, A. D. (2023). The Impact of Flight on Cabin Crew Wellness: A Literature Review (Senior Honors Thesis). Liberty University.	Health and lifestyle	• Generational risk behaviour	The document presents evidence that cabin crew are exposed to a range of occupational health risks, including radiation, circadian rhythm disruption, musculoskeletal strain, and sleep disorders that may impair wellness and contribute to fatigue, stress, anxiety, and depression. The literature reviewed indicates that mental health deterioration due to work-related stress and irregular schedules is significantly more prevalent among cabin crew than in the general population, with up to 40% reporting substantial risk of major depressive disorder	Chronic fatigue and stress impair mental health and cabin safety.	Considered – Reveals elevated fatigue and mental health risks linked to crew schedules.

			and 78% reporting fatigue to a degree that compromises safety. The review concludes that unmanaged psychological strain and fatigue represents a potential safety risk in flight operations, supporting calls for improved regulation, reporting systems, and support programs.		
Wen, C. C. Y., Cherian, D., Schenker, M. T., & Jordan, A. S. (2023). **Fatigue and sleep in airline cabin crew: A scoping review.** International Journal of Environmental Research and Public Health, 20(3), 2652. https://doi.org/10.3390/ijerph20032652	Health and lifestyle	• Workforce shortages	The document presents evidence that fatigue, sleepiness, and poor sleep quality are highly prevalent among airline cabin crew and are significantly associated with operational factors such as early start times, consecutive workdays, long duty hours, and eastward transmeridian flights. These conditions were linked to reduced alertness, impaired psychomotor performance, and increased risk of safety-critical errors, especially on inbound flights and during commutes home. Despite regulatory fatigue training requirements, the review found that cabin crew often lack effective fatigue management support, and fatigue-related performance degradation remains underreported. These findings highlight fatigue as a critical safety risk in ultra-long-range and irregular flight operations.	Irregular schedules and long duties drive fatigue and underreported risks.	Considered – Confirms systemic fatigue and underreporting risks in cabin operations.
van den Berg, M. J., Zaslona, J. L., Muller, D. P., Wu, L., Hughes, M., Johnston, B., Dyer, C., Drane, M., & Signal,	Health and lifestyle	• Pilot discretion use	The document presents evidence that ultra-long range (ULR) operations represent a significant fatigue-related safety risks for cabin crew, particularly during the top-of-descent phase. The study shows that higher fatigue and sleepiness levels at top of descent are associated with	ULR operations cause high fatigue levels	Considered – Highlights operational fatigue risks

T. L. (2023). **Managing cabin crew fatigue during ultra-long range operations.** Frontiers in Environmental Health, 2, 1329206. https://doi.org/10.3389/fenvh.2023.1329206			reduced in-flight sleep, longer periods of wakefulness, and increased perceived workload. Despite pre-flight preparation and scheduled bunk rest, 71% of crew reported fatigue levels ≥5 and 59% reported sleepiness levels ≥7 after landing, which are thresholds linked to performance impairment. These findings confirm the need to optimize rest break timing, enhance fatigue risk management training, and protect post-trip recovery periods to maintain safety margins.	impairing safety.	despite mitigation efforts. ●
Hong, R. M., Hsu, C. Y., & Hsu, C. J. (2023). Exploring relationships between health-related lifestyle habits and fatigue among flight attendants and trainees. WORK, 74(4), 1361–1369. https://doi.org/10.3233/WOR-211355	Health and lifestyle	• Generational risk behaviour	The document presents evidence that fatigue among flight attendants is significantly associated with poor health-related lifestyle habits such as irregular sleep patterns, insufficient sleep duration, unbalanced diet, lack of relaxation techniques, sedentary leisure time, and infrequent physical exercise. These factors were shown to increase the probability of fatigue, which has been previously linked to impaired alertness and degraded performance in safety duties. The study emphasizes that maintaining a healthy lifestyle is critical for reducing fatigue and supporting safe performance in flight operations.	Poor lifestyle habits increase fatigue and impair safety performance.	Considered – Strong link between lifestyle factors, fatigue, and safety duties. ●
Burdon, J., Budnik, L. T., Baur, X., Hageman, G., Howard, C. V., Roig, J., Coxon, L., Furlong, C. E., Gee, D., Loraine, T.,	Health and lifestyle	• Generational risk behaviour	The document presents extensive evidence linking chronic and acute exposure to thermally degraded engine oil, hydraulic fluid fumes, and associated ultrafine particles in aircraft cabins to a wide range of adverse health effects in aircrew. These include neurological,	Chronic exposure to contaminated	Considered – Demonstrates link between occupational

Terry, A. V. Jr., Midavaine, J., Petersen, H., Bron, D., Soskolne, C. L., & Michaelis, S. (2023). **Health consequences of exposure to aircraft contaminated air and fume events: A narrative review and medical protocol for the investigation of exposed aircrew and passengers.** Environmental Health, 22, Article 43. https://doi.org/10.1186/s12940-023-00964-9			respiratory, cardiological, and neurobehavioral disorders. The report identifies repeated low-dose exposure as a characteristic of modern aircraft operation and suggests that cumulative exposure over time increases vulnerability to acute incidents. The literature review cites multiple studies associating these exposures with measurable biomarker changes, neuroimaging findings, clinical symptoms, and increased rates of neurodegenerative diseases among aircrew. The paper concludes that a causal link is supported between exposure to cabin air contamination and long-term adverse health outcomes and outlines a structured medical protocol for diagnosis and documentation.	cabin air harms crew health.	environment and long-term health risks. ●
European Commission. (2015). **European Corporate Just Culture Declaration. Signed in Brussels on 1st October 2015.** Endorsed by major European aviation organizations, including EASA, ECA,	Education in the context of just culture	• Skills and training gaps	The document presents evidence that a Just Culture framework is essential for ensuring aviation safety, particularly through protecting staff from adverse consequences when reporting safety-related incidents. It explicitly states that socio-organisational conditions, such as mutual trust, support during external procedures, and protection under Regulation (EU) No. 376/2014, are necessary to enable staff to report occurrences without fear, thus reducing risk. The declaration highlights that	Trust and protection are essential for safety reporting.	Considered – Highlights cultural enablers of risk reporting and system learning.

CANSO, ACI Europe, and others.			factors like organisational responsibility, training, systemic influences, and avoidance of blame culture are key to improving SOs.		●
European Commission: Directorate-General for Mobility and Transport, Ricardo, Molina, C., Levin, S., Castillo, L., et al. (2019)**. *Study on employment and working conditions of aircrews in the EU internal aviation market – Final report*.** Publications Office of the European Union. https://doi.org/10.2832/37654	Employment and working conditions	• Atypical contracts • ACMI operations	The document presents evidence that atypical employment models, such as agency contracts, self-employment, and pay-to-fly schemes, may negatively affect aircrew working conditions and weaken safety culture. The study identifies that such arrangements are associated with increased fatigue, reduced job security, limited access to union support, and lower willingness to report safety risks. It highlights concerns regarding legal ambiguity in employment relationships, which may hinder the effective application of social and labour protections. The report references EASA findings indicating that certain employment models can impair safety culture, and it recommends systematic monitoring of fatigue, sickness absence, and safety reporting across employment types.	Atypical models reduce job security and erode safety reporting.	Considered – Highlights structural link between employment model and safety reporting behaviour. ●
Reader, T. W., Parand, A., & Kirwan, B. (2016). *European pilots' perceptions of safety culture in European aviation*. Future Sky Safety, Deliverable D5.4, Project P5: Resolving	Work intensity, flexibility and uncertainty	• Atypical contracts • Commercial pressure	The document presents evidence that pilots working under atypical employment contracts, such as self-employed, zero-hour, fixed-term, or pay-to-fly arrangements report significantly more negative perceptions of safety culture compared to those with permanent contracts. These negative perceptions extend to critical dimensions such as fatigue management, organisational support, management commitment to	Atypical contracts weaken safety culture and fatigue management.	Considered – Highlights contract-linked erosion of safety culture

the Organisational Accident. London School of Economics and Political Science (LSE), EUROCONTROL.			safety, and availability of staff and equipment. Moreover, pilots in low-cost and cargo airlines also perceive a lower safety culture compared to those in network carriers. These findings suggest that work intensity and employment insecurity may undermine key aspects of safety culture, which is a recognized proxy for operational safety risk.		and risk reporting. ●
EASA, Eurocontrol, FAA, NLR, Thales, Aeroporto di Bologna, & AESA. (2021). *Safety issue report – Skills and knowledge degradation due to lack of recent practice* (V2.0 – 04 August 2021). EASA Together4Safety.	Resource constraints and labour market dynamics	• Skills and training gaps • Workforce shortages	The document presents evidence that reduced operational activity during the COVID-19 pandemic has led to significant degradation of skills and knowledge among aviation personnel, including flight crews, ATCOs, cabin crew, maintenance engineers, and ground handlers. This degradation, driven by temporary workforce reductions, reduced training access, and staffing shortages, has been associated with increased cognitive load, performance limitations, and a higher likelihood of slips, lapses, or errors, thereby increasing safety risks. The report highlights the need for targeted retraining, updated procedures, and reinforced safety culture as critical measures to mitigate these risks during the return to normal operations.	Skill degradation from reduced activity increases safety risk.	Considered – Strong link between reduced training, staffing gaps, and SOs ●
EASA. (2021). *Review of aviation safety issues arising from the COVID-19 pandemic* (Version 2 – April 2021). European	Resource constraints and labour market dynamics	• Skills and training gaps	The document presents evidence that work intensity, employment instability, degraded training conditions, and uncertainty caused by the COVID-19 pandemic have led to increased aviation safety risks. Identified issues include skills and knowledge degradation due to lack of practice,	Pandemic-induced instability degraded human and	Considered – Strong link between degraded

Union Aviation Safety Agency (EASA).		• Workforce shortages • Commercial pressure	reduced oversight and regulatory capacity, increased fatigue among personnel due to extended or irregular working conditions, disrupted teamwork, and a general decrease in wellbeing. Financial constraints further exacerbated risks by reducing operational personnel and degrading infrastructure maintenance. These socio-economic conditions have affected human performance and organisational effectiveness, increasing the likelihood of safety-related incidents.	organisational performance.	conditions and operational safety risks.
Bureau d'Enquêtes et d'Analyses pour la sécurité de l'aviation civile (BEA). (2016). *Accident on 24 March 2015 at Prads-Haute-Bléone to the Airbus A320-211 registered D-AIPX operated by Germanwings* *– Final Report*. Ministère de l'Écologie, du Développement durable et de l'Énergie, France.	Health and lifestyle	• Atypical contracts • Generational risk behaviour	The report presents evidence that fear of professional consequences, financial insecurity, and limitations in the medical certification system, particularly concerning mental health, can prevent pilots from reporting decreased fitness to fly, posing a serious safety risk. Specifically, the co-pilot's concern over loss of licence and associated income, combined with a waiver that hindered his access to additional insurance, contributed to his concealment of a severe mental disorder. This condition ultimately led to the deliberate crash of the aircraft. The investigation also highlights systemic deficiencies in the reporting of mental health issues by private physicians due to confidentiality laws, and the lack of effective oversight or early detection mechanisms within airlines and aviation medical frameworks. Eleven safety recommendations were issued to mitigate these risks, including promoting pilot support programmes and	Job insecurity and stigma obstruct mental health disclosure.	Considered – Highlights critical mental health vulnerabilities tied to employment insecurity.

			addressing the psychological impacts of job insecurity and confidentiality.		
European Commission & European Union Aviation Safety Agency (EASA). (2015). ***Report of the Task Force on the Germanwings Flight 9525 to the European Commission* (16 July 2015).** European Commission & EASA.	Health and lifestyle	• Atypical contracts • Generational risk behaviour	The document presents evidence that psychosocial stressors, work environment factors, and variable employment arrangements may contribute to aviation safety risks through their effect on pilot mental health. The Task Force explicitly recognizes that fatigue, work-related stress, and private or workplace problems can lead to temporary or permanent mental health issues if unaddressed. It further concludes that the fear of stigma or professional consequences may dissuade pilots from seeking support. To mitigate these risks, the report recommends the implementation of non-punitive pilot support and reporting systems integrated within airline Safety Management Systems. These systems should account for different contract types and organisation sizes to encourage early intervention and maintain safety. The need for trust, confidentiality, and regulatory support is emphasized as critical to effectiveness.	Mental health risks increase under stigma and precarious conditions.	Considered – Reveals structural causes of communication breakdowns and reporting gaps. ●
European Union Aviation Safety Agency (EASA). (s. f.**). *Flight time limitation – Temporary exemptions under Article 7.11*.**	Health and lifestyle	• Pilot discretion use • Commercial pressure	The document presents evidence that temporary exemptions from Flight Time Limitation (FTL) regulations during the COVID-19 crisis, such as extended FDPs, reduced rest, and use of in-flight rest facilities at outstations, pose fatigue-related safety risks. It identifies multiple scenarios in which operational pressure and increased flexibility could elevate the probability of	Operational flexibility increases fatigue-related safety risks.	Considered – Strong link between flexibility, fatigue, and

European Union Aviation Safety Agency.		• Homebase changes	fatigue-induced incidents. The guidelines establish that such exemptions must be accompanied by operator-specific risk assessments and enhanced fatigue mitigation strategies. These include rest requirements, use of augmented crew, and monitoring of fatigue data. The document emphasizes that cumulative fatigue risks must not be exempted and that all mitigations must be actively assessed by National Competent Authorities.		safety behaviour.
European Parliament & Council of the European Union. (2018). ***Regulation (EU) 2018/1139 on common rules in civil aviation and establishing EASA*.** Official Journal of the European Union, L 212, 1–122.	Education in the context of just culture	• Skills and training gaps • Atypical contracts	The document presents evidence from a regulatory framework that incorporates safety management principles, including safety reporting and the proactive identification of risks. It explicitly mentions the requirement for Member States to establish State Safety Programmes (SSPs), which include planning actions to mitigate identified safety risks, and outlines the role of the European Plan for Aviation Safety in setting the Union's safety performance levels. While the Regulation refers broadly to oversight and safety-related responsibilities of personnel (e.g., aircrew, ATM/ANS personnel), and highlights that certification, training, and duty time limitations may be regulated, it does not explicitly link socio-economic factors such as work intensity, employment type, or uncertainty to SOs	Regulatory framework promotes proactive risk reporting.	Partially considered – Framework supports safety management, but lacks explicit socio-economic linkage.

European Union Aviation Safety Agency (EASA). (2023). Final Certification Memorandum ref. CM-SA-002 Issue 02: Flight Crew Human Factors Assumptions in Aircraft and System Safety Assessments (Applicable to large aeroplanes). European Union Aviation Safety Agency.	Work intensity, flexibility and uncertainty	• Commercial pressure	The document presents evidence that assumptions made about flight crew behaviour during system failure conditions can influence the classification of such failures and related safety objectives. It highlights the safety risks posed by a mismatch between assumed and actual human behaviour under operational conditions. The Certification Memorandum mandates a structured Human Factors assessment process to validate such assumptions, considering cognitive workload, fatigue, stress, environmental factors, and the variability of individual crew responses. It recommends the use of simulator testing and scenario-based evaluations to detect deviations in crew performance, particularly under conditions of high workload or reduced clarity of system alerts, which are forms of operational intensity and uncertainty.	Mismatch between behavioural assumptions and actual crew performance affects safety.	Considered – Highlights how operational stress affects flight crew reliability. ●
International Civil Aviation Organization (ICAO). (2006). *Circular 240-AN/144: Human Factors Investigation Digest* (complement to ICAO Doc 6920). ICAO.	Work intensity, flexibility and uncertainty	• Commercial pressure • Skills and training gaps	The document presents evidence that work conditions such as tight schedules, crew pairing policies, workload saturation, stress, and organizational decisions significantly influence human performance and contribute to aviation accidents. Using the "Anytown" accident scenario and James Reason's model, the circular identifies how latent failures, such as fatigue from long duty periods, inadequate training, and operational pressure, can create unsafe acts at the front line, leading to accidents. The document emphasizes that these latent factors often result from management or regulatory	Workload and organisational stressors degrade human performance.	Considered – Strong link between workload, resources and safety behaviour. ●

			decisions and must be examined systematically in investigations to uncover the root causes of human error and prevent recurrence.		
Kurniawan, M., Sutalaksana, I. Z., & Suprapto, B. (2023). ***The safety risks of raising the mandatory retirement age for commercial pilots: A safety management perspective.*** Safety Science, 163, 106180. https://doi.org/10.1016/j.ssci.2023.106180	Health and lifestyle	• Pilot retirement age • Skills and training gaps	The document presents evidence that potential safety implications of raising the mandatory retirement age for commercial pilots by analysing accident data, human performance degradation, and industry practices. It highlights increased risks related to cognitive decline, delayed responses, and the limitations of current fitness assessments. The authors argue that without new mitigation strategies, such as adapted training, tailored monitoring programmes, and robust safety management systems, raising the retirement age could compromise safety.	Raising the retirement age without safeguards may reduce safety margins.	Considered – Provides insight into the operational risks of ageing pilots
Hardy, D. J., & Parasuraman, R. (1997). **Cognition and flight performance in older pilots.** *Journal of Experimental Psychology: Applied, 3*(4), 313–348. https://doi.org/10.1037/1076-898X.3.4.313	Health and lifestyle	• Pilot retirement age • Skills and training gaps	The document presents evidence that while older pilots show cognitive decline in secondary tasks (e.g., ATC communication, memory, reaction time), their main flight performance remains stable, likely due to compensating experience. The study highlights the importance of assessing not only core flying skills but also auxiliary cognitive demands, which may degrade with age. It also questions the adequacy of current fitness evaluations and supports continuous performance-based monitoring.	Cognitive ageing affects secondary performance more than core flying tasks.	Considered – Adds evidence on ageing pilots and performance consistency.

Obaidi, A. M., & Al Ali, W. S. (2021). *Factors Affecting the Rate of Fuel Consumption in Aircraft. Sustainability*, 13(14), 8066. https://doi.org/10.3390/su13148066	Work intensity, flexibility and uncertainty	• Fuel management • Commercial pressure	The document presents evidence that operational and commercial pressures, such as strict cost control, limited scheduling flexibility, and complex organisational structures, can lead to unsafe fuel practices. These include reduced investment in fleet efficiency, poor route optimisation, and insufficient margin in fuel planning, all of which may compromise safety during high-demand or disrupted operations. The study calls for closer alignment between operational decision-making and safety performance in the context of fuel usage.	Cost-driven strategies can reduce safety buffers in fuel operations.	Considered – Demonstrates the operational safety impact of economic and scheduling pressures
International Air Transport Association (IATA). (2016). Unstable Approaches – Risk Mitigation Policies, Procedures and Best Practices (2nd ed.). IATA	Work intensity, flexibility and uncertainty	• Go around decisions • Commercial pressure	The document presents evidence that pilots often refrain from initiating go-arounds due to operational pressure, fatigue, peer dynamics, and perceived management attitudes. It highlights that over 97% of unstabilized approaches are continued to land, despite SOPs requiring go-arounds. Organisational factors such as lack of training, unclear or punitive policies, and underfueling can discourage pilots from discontinuing an approach. IATA recommends the implementation of non-punitive go-around policies, better decision-making training, realistic simulator scenarios, and crew empowerment to act without fear of repercussion. Key mitigation strategies include addressing fatigue, ensuring fuel sufficiency, and cultivating a supportive safety culture.	Organisational pressure can inhibit go-around decisions despite unstable conditions.	Considered – Demonstrates how operational pressure can undermine go-around compliance.

Flight Safety Foundation & Presage Group. (2017). ***Go-Around Decision-Making and Execution Project*****.** Flight Safety Foundation.	Work intensity, flexibility and uncertainty	• Go around decisions • Commercial pressure	The document presents evidence that pilots frequently delay or avoid go-arounds due to a combination of psychological and organisational pressures, including perceived expectations from company policy, commercial demands, and fear of criticism. A survey of 2,340 pilots revealed that those who had continued unstable approaches reported lower perceived safety culture, limited empowerment to act, and higher peer pressure. These behaviours are often normalised through weak managerial support and lack of procedural clarity. The study calls for a shift in organisational culture, clearer policies, and greater trust in flight crew judgment to ensure go-arounds are conducted when needed without fear of repercussion.	Organisational and social pressures lead to normalisation of unstable approaches.	Considered – Empirically shows how weak support and commercial pressure reduce go-around compliance. ●
National Transportation Safety Board (NTSB). (2017). ***Administrator v. Bohnet – NTSB Order No. EA-5814*****.** Washington, DC: U.S. Department of Transportation.	Employment and working conditions	• Fraud risk • Atypical contracts	The document presents evidence that a flight instructor falsified logbook entries by certifying simulator training and type rating sign-offs for a pilot, including flight hours logged when the aircraft was out of service. The case exposes vulnerabilities in subcontracted training arrangements, where oversight was weak, and accountability unclear. These structural gaps enabled fraudulent certification practices to go undetected until enforcement action was taken. The order highlights how decentralised employment and training frameworks can facilitate document falsification and erode the reliability of pilot qualifications.	Weak oversight in outsourced training allows certification fraud to go undetected.	Considered – Reveals how fragmented employment structures can enable training record falsification. ●

Spit, W., Sapulete, S., & Verkennis, N. (2019). Methodological Impact Assessment Support on Social Impacts and Circular Economy Indicators: Draft final report Task 1. European Aviation Safety Agency (EASA) / Ecorys, Rotterdam	Employment and working conditions	• Homebase changes • Pilot retirement age • Atypical contracts	The document develops a methodological framework for assessing social impacts (SIA) to result in a single value score for integration into EASA's MCA methodology. The framework specifies 16 social impact criteria (derived from the Better Regulation Toolbox and stakeholder input). It proposes specific quantitative and qualitative indicators and uses a uniform 5-point scoring scale (+5 to -5) for comparing policy options ex-ante. Stakeholders raised concerns regarding the appropriateness of summarizing complex social impacts into a single score.	Development of a structured, indicator-based framework to quantify social impacts into a single comparative score.	Considered – Develops a methodological framework for assessing social impacts in aviation, specifying criteria and indicators. ●

C.2 Literature review on SCP

This annex summarises the findings of the literature review conducted to support the conceptual and regulatory definition of aviation SCP) within the scope of the present study.

To support this exercise, a structured literature review was carried out, drawing upon a broad and diverse set of sources. These include regulatory texts, guidance materials from aviation bodies, academic publications, and documentation from previous EU-funded projects. The sources were identified by ALG during the preparation of the technical offer, supplemented by references provided by EASA during the KoM, and insights from our pool of subject-matter experts. Each source was systematically assessed for its relevance to the three role categories under analysis and its contribution to the development of a harmonised definition of SCP. To consolidate these findings, a dedicated table has been developed, offering a structured overview that underpins the rationale for the proposed SCP definition.

The summary table consolidates the core information extracted from each source using the following fields:

- Source: The official name of the publication or institution consulted.
- Associated SCP: The role categories explicitly or implicitly addressed in the source (i.e. flight crew, cabin crew, operational control staff).
- Main outcomes: A concise summary of the source's main conclusions regarding the definition and scope of SCP.
- Key outcomes: A brief keyword-style summary capturing the source's most relevant contribution to the SCP concept.
- Level of consideration within the project: An assessment of the usability of the source for defining SCP within the scope of this study. The three levels of classification used are:
    - Considered: The source directly contributes to the SCP definition and covers at least two of the three targeted roles.
    - Partially considered: The source offers partial insights or is focused on only one role category.
    - No considered: The source is of limited applicability for SCP definition, thus has not been considered.

The following table summarizes the literature reviewed to formulate the definition of SCP tailored specifically to the retained role categories.

Table 69: Literature review for the definition of SCP.

Source	Associated SCP	Main outcomes	Key outcomes	Level of consideration within the project
European Parliament & Council of the European Union. (2018). ***Regulation (EU) 2018/1139 on common rules in civil aviation and establishing EASA.*** Official Journal of the European Union, L 212, 1–122.	• Flight crew • Cabin crew • Operational control staff	Regulation (EU) 2018/1139 explicitly categorizes certain aviation roles as subject to safety requirements and certification obligations, substantiating their classification as SCP. Under Article 20, pilots and cabin crew involved in the operation of aircraft, and those involved in their training, testing, checking or medical assessment, must comply with essential requirements set out in Annex IV. Article 21 mandates that pilots hold an appropriate licence and medical certificate, while Article 22 requires cabin crew involved in commercial air transport to hold an attestation, with medical fitness assessments required prior to and during service. Article 23 outlines uniform implementation provisions for pilot and cabin crew certification. Article 24–27 regulate training organisations, flight simulation training devices, instructors, examiners, and aero-medical centres, confirming the regulatory control over personnel influencing aircrew safety standards. Operational control staff are also recognized under provisions concerning flight dispatch and ground operations. Article 30(1) and Annex V detail that operators must establish and maintain operational control, including compliance with flight dispatch, load control, and operations manual protocols. Furthermore, Annex V requires operators to ensure that personnel involved in safety-critical activities, such as dispatch and flight watch, are qualified and appropriately trained. Article 29 confirms that such operations	Legal certification mandates confirm the safety-critical status of regulated roles.	Considered – Establishes regulatory foundation for defining safety-critical personnel and their required qualifications. ●

		must comply with essential safety requirements. Additionally, the Regulation mandates organisational approval for entities responsible for training of such personnel (Articles 24, 27) and specifies privileges and enforcement rules under certification frameworks (Articles 15, 16, 23, 30).		
European Commission. (2012). Commission Regulation (EU) No 965/2012 on air operations technical requirements and administrative procedures. Official Journal of the European Union, L 296, 1–148.	• Flight crew • Cabin crew • Operational control staff	Commission Regulation (EU) No 965/2012 explicitly identifies and regulates the roles of Flight Crew, Cabin Crew, and Operational Control Staff through mandatory operational, certification, and training requirements, affirming their status as SCP. For Flight Crew, Annex III (Part-ORO) mandates in ORO.FC that operators must ensure flight crew members are properly trained, qualified, and hold valid licences and medical certificates. Flight crew members are subject to initial and recurrent training, including normal and emergency procedures (ORO.FC.220, ORO.FC.230), and must undergo operator proficiency checks (ORO.FC.230). Fatigue management (ORO.FTL) also applies, underscoring the impact of fitness and alertness on safety. Cabin Crew are explicitly addressed under ORO.CC. They must be suitably qualified, undergo initial and recurrent training, and hold attestation of safety training (ORO.CC.125, ORO.CC.140). Duties explicitly linked to passenger and crew safety include emergency procedure knowledge and response capabilities, with clear requirements for medical fitness, training syllabi, and recurrent checks. Operational Control Staff are addressed primarily through the operator's responsibilities in Annex III (ORO.GEN and ORO.AOC) and Annex IV (Part-CAT). ORO.GEN.110 and ORO.AOC.135 require the nomination and competence of key post holders, including those responsible for operational control, with training and qualifications proportionate to safety responsibilities. Annex IV further outlines those operational procedures (e.g.,	Regulation mandates training and operational standards for all three roles.	Considered – Clearly defines mandatory qualifications and responsibilities for all three safety-critical roles.

		flight dispatch, fuel planning, load control) must be documented and followed (CAT.OP.MPA), with dispatch responsibilities implied in operational manuals and defined command structures (CAT.GEN.MPA.100, CAT.OP.MPA.150). Specific references to dispatch and ground operations personnel requirements appear under AMC and GM documents associated with this Regulation.		
European Union Aviation Safety Agency (EASA). (2024). *Easy Access Rules for Continuing Airworthiness (Regulation (EU) No 1321/2014)* (Revision July 2024). European Union Aviation Safety Agency.	Not applicable (outside scope)	The Regulation (EU) No 1321/2014, as consolidated in the Easy Access Rules for Continuing Airworthiness, provides several explicit references that justify the categorization of certifying staff and maintenance personnel as safety-critical personnel. The regulation defines “certifying staff” as “personnel responsible for the release of an aircraft or a component after maintenance” (Article 2(b)). These individuals must be qualified in accordance with Annex III (Part-66), as detailed in Article 5, which outlines the mandatory licensing and qualification standards for these roles. Furthermore, organisations involved in continuing airworthiness, including maintenance organisations and continuing airworthiness management organisations (CAMOs), must be approved according to Annex II (Part-145), Annex Vc (Part-CAMO), or Annex Vd (Part-CAO) (Article 4(1)). Annex I (Part-M), specifically in M.A.201, assigns responsibility for ensuring that aircraft are maintained in airworthy condition, requiring that maintenance be performed per the Aircraft Maintenance Programme (AMP) and certified through the appropriate release to service. The regulation also mandates that organisations and personnel involved in continuing airworthiness tasks must ensure compliance with airworthiness directives, repairs, inspections, and defect rectifications, and maintain detailed technical records (M.A.301–M.A.305). These detailed regulatory requirements—including qualifications, certification standards, responsibilities for flight safety, and oversight by	Certifying staff and maintenance staff are legally defined and regulated as safety-critical.	Not considered – Focuses on maintenance roles outside the defined scope.

		competent authorities—explicitly establish the safety-critical nature of these roles in the aviation system.		
European Commission. (2020). Commission Delegated Regulation (EU) 2020/2034 of 6 October 2020 supplementing Regulation (EU) No 376/2014 as regards the common European risk classification scheme. Official Journal of the European Union, L 416, 1–10.	None	Commission Delegated Regulation (EU) 2020/2034 supplements Regulation (EU) No 376/2014 and establishes the Common European Risk Classification Scheme (ERCS) for assessing the safety risk posed by civil aviation occurrences. The regulation defines key terms such as certifying staff, safety risk score and outlines the methodology for harmonised assessment across the EU. However, it does not explicitly mention or identify the roles of Flight Crew, Cabin Crew, or Operational Control Staff, nor does it define or justify any of these roles as SCP. The regulation focuses on systemic risk assessment rather than on categorising or defining personnel roles. No relevant information explicitly identifying or justifying aviation SCP roles is found in the source.	Risk scheme defines systemic metrics, not personnel categories.	Not considered – Does not address or define SCP roles relevant to the project scope.
European Union Aviation Safety Agency (EASA). (2024). ***Easy Access Rules for Aircrew (Regulation (EU) No 1178/2011)*** **(Revision December 2024).** European Union Aviation Safety Agency.	• Flight crew • Cabin crew	The Easy Access Rules for Aircrew (Regulation (EU) No 1178/2011), regulates Flight Crew through mandatory licensing, training, medical fitness, and proficiency requirements. Annex I (Part-FCL) and Annex IV (Part-MED) establish strict qualification frameworks, requiring that pilots and other flight crew members hold valid licenses and ratings and undergo regular checks and medical evaluations. Subpart FCL.005 defines flight crew licensing as applicable to those "engaged in the operation of aircraft," and mandates adherence to competence standards to ensure the safe conduct of flight operations. Additionally, Annex III (Part-CC) regulates Cabin Crew certification, requiring operators to ensure that Cabin Crew are "trained and competent to perform duties related to safety" (CC.GEN.025). Furthermore,	Mandatory licensing and training define criticality of aircrew roles	Considered – Establishes comprehensive qualification requirements for aircrew as SCP.

		AMC1 ORO.CC.100 emphasizes that Cabin Crew are responsible for duties directly contributing to the safety of the aircraft and its occupants.		
European Union Aviation Safety Agency (EASA). (2023). Notice of Proposed Amendment 2023-01: Training requirements for flight operations officers and flight dispatchers; amendments related to fuel planning, management and all-weather operations. European Union Aviation Safety Agency.	• Flight crew • Cabin crew • Operational control staff	EASA NPA 2023-01 clarifies that the concept of "aviation safety-critical personnel" (SCP) encompasses roles involved in "operating an aircraft, supporting its operation, and maintaining its airworthiness," including flight crew, cabin crew, and operational control personnel such as flight dispatchers. The NPA further states that these individuals are responsible for tasks that, if performed incorrectly or omitted, could lead to serious safety consequences. It details that SCP must demonstrate medical and psychological fitness, professional competencies, and personal attributes ensuring safe operations under both normal and stressful conditions. The document justifies the SCP categorization by citing their direct involvement in safety-relevant activities and outlines the need for harmonised EU-level regulatory provisions to manage risks associated with SCP performance. Operational control roles are explicitly included in the proposed scope of SCP regulation due to their function in planning, monitoring, and supporting flight operations.	Defines SCP as roles whose actions can critically impact safety.	Considered – Provides regulatory justification for including all three SCP roles.
International Civil Aviation Organization (ICAO). (2019). ***Manual on Ground Handling (Doc 10121)*** **(1st ed.)**. ICAO.	Operational control staff	The ICAO Doc 10121, Manual on Ground Handling (2020), emphasizes the safety-critical nature of ground handling functions by identifying specific responsibilities and associated risks. It explicitly recognizes the role of personnel involved in load control, including those responsible for the preparation and checking of loadsheets and the conduct of weight and balance calculations, as being essential to flight safety. In particular, it states that "any error in the mass and balance of the aircraft can have serious consequences for the safety of the flight" and that "load control is one of the most safety-critical activities in ground handling" (Chapter 3.3). Furthermore,	Load control is a top safety-critical ground task.	Partially considered – Highlights safety relevance of ground tasks interfacing with OCC but outside direct SCP scope.

		the manual details that load controllers must have adequate qualifications, training, and competence, and that errors in this area have been causal factors in multiple accidents. It also highlights the responsibilities of personnel in managing aircraft turnaround, ensuring coordination and accurate information flow between flight crew, OCC, and ground services.		
International Civil Aviation Organization (ICAO). (2018). *Annex 1 to the Convention on International Civil Aviation – Personnel Licensing* (12th ed., July 2018, including Amendment 175). ICAO.	Flight crew	ICAO Annex 1 — Personnel Licensing (2019) provides an explicit regulatory framework that establishes Flight Crew as SCP. The Annex requires that individuals performing functions such as piloting aircraft be appropriately licensed, trained, and medically certified. Chapter 2.1.1 clearly stipulates that "no person shall engage in any activity for which a licence or rating is required unless that person holds a valid licence or rating issued or rendered valid by the Contracting State." Annex 1 further mandates recurrent testing, verification of competency, and medical assessments to uphold operational integrity. The defined licensing standards in Chapter 2 and the exhaustive specifications for knowledge, skill, and experience reinforce the categorization of these roles as safety-critical.	Licensing and medical standards define flight crew criticality.	Considered – Establishes international licensing and competency standards confirming flight crew's safety-critical status.
International Civil Aviation Organization (ICAO). (2022). *Annex 6 — Operation of Aircraft, Part I: International Commercial Air Transport — Aeroplanes* (12th ed., July 2022, ISBN 978-92-9258-473-3). ICAO.	• Flight crew • Cabin crew • Operational control staff	ICAO Annex 6, Part I (2022) explicitly recognizes the safety-critical responsibilities of Flight Crew, Cabin Crew, and personnel involved in operational control. Chapter 4 mandates that the operator shall ensure flight crew members are appropriately licensed, trained, qualified, and medically fit, in accordance with Annex 1. Chapter 6, Section 6.1.1, stipulates that a flight shall not commence unless the crew members are qualified, current, and fit, underscoring their essential role in ensuring operational safety. Chapter 4.8 explicitly states that Cabin Crew members must be trained and competent to perform duties essential to the safety of the aircraft and its occupants in normal and emergency situations. Furthermore, Chapter 4.2.5	All three roles require qualifications to ensure flight safety.	Considered – Supports inclusion of the three roles.

		requires operators to assign responsibility for operational control, and notes that if the operator delegates this to a dispatcher, the dispatcher must be properly trained and qualified. These provisions confirm the inclusion of operational control personnel, such as flight dispatchers, as bearing safety-critical responsibilities. The Annex also mandates competency-based training and checking programmes (Chapter 9) and detailed crew responsibilities during flight (Chapter 13). Taken together, these requirements explicitly establish Flight Crew, Cabin Crew, and Operational Control Staff as SCPbased on their mandatory qualifications, duties, and responsibilities essential to aviation safety.		
International Civil Aviation Organization (ICAO). (2020). ***Cabin Crew Safety Training Manual (Doc 10002)*** **(2nd ed.).** ICAO.	Cabin crew	ICAO Doc 10002, Cabin Crew Safety Training Manual (2nd Edition, 2022), defines a cabin crew member as one who performs duties assigned by the operator or pilot-in-command "in the interest of safety of passengers" and highlights their role in both emergency response and proactive safety management. It underscores that the role of cabin crew in normal, abnormal, and emergency operations necessitates “specialized and thorough training” to ensure proficiency in tasks critical to the safety of the aircraft and its occupants. It details training tasks, competencies, and procedures for various phases of flight reinforcing the critical safety functions carried out by cabin crew, including communication with flight crew, securing the cabin, managing passengers, and responding to onboard hazards or emergencies.	Safety training defines cabin crew’s critical safety function.	Considered – Validates cabin crew’s safety function through operational and training focus.
International Air Transport Association (IATA). (2017). ***Cabin Operations Safety***	Cabin crew	The IATA Cabin Operations Safety Best Practices Guide (2023) states that Cabin Crew are “safety professionals, trained to manage emergencies and ensure passenger and operational safety,” and are responsible for performing safety and emergency procedures in coordination with flight crew. It also outlines that Cabin Crew responsibilities include pre-flight safety	Cabin crew are trained safety professionals with	Considered – Guidance reinforcing cabin

***Best Practices Guide* (3rd ed.).** IATA.		checks, securing the cabin, managing safety-related equipment, and responding to in-flight incidents or emergencies, highlighting their direct influence on passenger and flight safety. Furthermore, mandates that Cabin Crew undergo recurrent safety training, and states that they must remain proficient in safety and emergency procedures (SEPs), further underscoring their operational safety role. The guide also addresses safety reporting culture and hazard identification, requiring Cabin Crew participation in safety management systems (SMS).	emergency duties.	crew's safety critical role. ●

C.3 Literature review on framework linkages

This annex presents the literature supporting the conceptual linkages between Socio-Economic Factors, Risk Areas and Safety Precursors within the framework.

C.3.1 Literature supporting the link between Socio-Economic Factors and Risk Areas

This subsection summarises the literature supporting the link between the SEFs defined in the framework and the selected RAs. Its purpose is to document the evidence these relationships. The full list of documentary sources is provided in Annex C.3.3.

Socio-Economic Factor	Risk Area	Rationale	Sources (Document Number)
Employment and working conditions	ACMI	The ACMI operating model degrades the stability of employment conditions by imposing a transitory lifestyle characterized by the use of "makeshift homes" in hotels, which hinders the psychological detachment necessary for recovery and exacerbates cumulative fatigue due to social isolation. This commercial structure facilitates practices of social engineering	17, 26, 27

		and rule shopping, exploiting jurisdictional complexity to minimize labor costs and create legal uncertainty regarding the rights applicable to workers. From a safety perspective, organizational fragmentation between lessor and lessee prevents the effective integration of Safety Management Systems (SMS) and the sharing of critical data such as Flight Data Monitoring (FDM), creating latent vulnerabilities in which contractual insecurity discourages the voluntary reporting of fatigue and operational hazards.	
	Atypical contracts	The proliferation of atypical contracts, such as bogus self-employment, agency-mediated employment, and pay-to-fly schemes, undermines the principles of safety and fair compensation enshrined in the European legal framework, facilitating social dumping practices in which airlines exploit jurisdictional complexity and “rule shopping” to minimize labor costs and evade social security obligations. This structural precarization creates contractual ambiguity that makes it difficult to identify the actual employer and fosters job insecurity that actively inhibits the reporting of fatigue and operational risks, forcing vulnerable workers to prioritize financial stability over the safety and well-being standards protected by EU regulation.	17, 18, 37
	Commercial pressure	Commercial pressure for operational efficiency degrades employment conditions, creating an environment in which financial instability and contractual precariousness force crews to prioritize job security over flight safety. Fear of income loss or the non-renewal of atypical contracts discourages the reporting of unfitness for duty, promoting “presenteeism” and operations under dangerously high levels of fatigue in order to comply with rosters that push legal limits to their extremes. This dynamic, characterized by the perception that management values profitability over well-being (“profit over	8, 9

		safety”), induces chronic stress and circadian rhythm disruption, driving personnel to rely on substances, such as excessive caffeine use for alertness and alcohol or medication to induce sleep, as coping mechanisms necessary to sustain the required work pace.	
	Crew interoperability	Crew interoperability, enabled through the use of multiple Air Operator Certificates (AOCs) and wet-lease contracts, fragments employment conditions and dilutes corporate responsibility, allowing airlines to engage in “social engineering” or rule shopping to exploit jurisdictions with lower labor standards and costs. This structure creates ambiguity regarding the identity of the actual employer and leads to pay disparities among professionals performing the same duties, while the dislocation inherent in operating away from home base and residing in temporary accommodation increases fatigue and psychosocial stress. Operationally, this fragmentation hinders the standardization of Standard Operating Procedures (SOPs) and the effective integration of Safety Management Systems (SMS), creating critical gaps in oversight and discouraging voluntary hazard reporting due to the contractual insecurity faced by workers.	17, 26, 27, 36, 37
	Homebase changes	Inadequate management of changes to the operational home base erodes the stability of employment conditions by turning the worker’s geographic location into a commercial adjustment variable that creates legal uncertainty regarding the applicable labor and social security legislation. This dynamic fosters “forced mobility” and the use of temporary bases that require crews to reside in transient accommodation away from their support networks, preventing effective recovery through rest and severely disrupting work–life balance. Operationally, such frequent changes introduce critical safety risks by increasing cumulative fatigue resulting from long commuting periods, often not counted	17

		as duty time, which raises the likelihood of cognitive errors and compromises flight performance due to the psychosocial stress associated with dislocation.	
	Workforce shortages	Workforce shortages severely degrade employment conditions by forcing organizations to operate with minimum staffing levels and without the necessary personnel "buffers," thereby intensifying workload and reducing opportunities for recovery and rest for existing crews. This lack of human resources pushes the system toward the limits of its capacity, fostering practices such as "presenteeism"—where personnel continue working despite not being in optimal condition due to fear of reprisals or the absence of replacements—and eroding operational resilience in the face of unforeseen events. At the same time, high turnover and the departure of experienced staff, driven by these adverse conditions, result in a critical loss of institutional knowledge and mentoring capacity, weakening supervision and leaving a younger, less supported workforce to manage complex operations under pressure.	10, 20, 28, 39
Health and lifestyle	Commercial pressure	The link between commercial pressure and the deterioration of health and lifestyle in aviation manifests as a critical systemic risk, whereby the prioritization of profitability and operational efficiency over human physiological limits severely compromises the physical, mental, and social well-being of flight crews. This economic pressure drives the implementation of fatiguing schedules and precarious employment models that not only generate chronic exhaustion and psychosocial stress, but also foster "presenteeism," forcing pilots and cabin crew to operate even when unfit for duty due to fear of financial repercussions or job loss. Moreover, roster instability erodes work–life balance, exacerbating social isolation. Taken together, this comprehensive deterioration of health	10, 17, 28, 37

		reduces the cognitive capacities essential for decision-making and normalizes the acceptance of operational risks, thereby directly undermining flight safety margins.	
	Crew interoperability	The interoperability of flight crews, frequently managed through atypical employment models and wet-lease operations, creates an environment of instability that negatively affects professionals' health and lifestyle, thereby increasing operational safety risks. The lack of fixed bases and the variability of rosters hinder effective fatigue management and the recovery of circadian rhythms, while the contractual precariousness inherent in these schemes fosters significant psychosocial stress and the phenomenon of "presenteeism," whereby fear of income loss or job insecurity discourages crew members from reporting illness or fatigue. This dynamic erodes work–life balance and weakens safety culture, as employment uncertainty and the fragmentation of responsibilities among operators obstruct effective risk communication and the consistent implementation of safety management systems.	17, 26, 27, 37
	Generational risk behaviour	The interaction between health and lifestyle factors and generational risk-taking behaviors reveals a complex dynamic in which demographic differences directly influence operational safety and decision-making. While the aging process entails a natural decline in psychomotor and cognitive abilities, often compensated for by experienced pilots through accumulated expertise and anticipatory strategies, there is a latent risk associated with overconfidence bias among older flight crews. At the same time, generational and hierarchical gaps create significant communication barriers, frequently inhibiting younger crew members from voicing safety concerns to senior captains, thereby weakening the effectiveness of Crew Resource Management (CRM). In addition, the	5, 6, 11, 21, 28, 41

		demands of the aviation lifestyle, characterized by chronic fatigue and circadian rhythm disruption, foster maladaptive coping mechanisms across generations, such as the use of substances to regulate the sleep–wake cycle. This, in turn, exacerbates mental health issues and work–life conflicts, ultimately compromising overall fitness for flight.	
	Go-arounds	Reluctance to execute a go-around following an unstable approach is not usually a purely technical failure, but rather the manifestation of a deterioration in the pilot's overall well-being, in which accumulated fatigue impairs the executive functions critical for situation assessment and fuels "press-on-itis," driven by the desire to complete the flight and obtain rest. Simultaneously, mental health factors such as emotional dysregulation and stress distort risk perception and self-confidence, predisposing the crew to riskier behaviors or to disregarding safety warnings, while an organizational environment characterized by commercial pressure or the absence of a just culture imposes psychological barriers and fear of reprisals, thereby inhibiting the corrective action necessary to ensure operational safety.	7, 13, 23, 24, 41
	Homebase change	Frequent or poorly managed changes to the operating base act as a systemic disruptor of crews' overall well-being, as forced mobility and life in temporary accommodation prevent the necessary psychological detachment from work and degrade sleep quality compared with rest at home. This geographical instability, exacerbated under atypical employment models, compels long commuting periods that increase cumulative fatigue and pre-duty wakefulness, while administrative uncertainty regarding applicable legislation and the detachment from family support networks generate psychosocial	11, 17, 27, 28

European Union Aviation Safety Agency

		stress and isolation, eroding the mental resilience essential to maintaining operational safety.	
	Pilot discretion use	The recurrent use of pilot discretion to extend duty periods, far from being an exceptional measure for unforeseen circumstances, has become a systemic adjustment mechanism that severely degrades crew health and lifestyle by pushing them beyond their physiological limits of alertness and recovery. This practice increases exposure to both acute and cumulative fatigue by prolonging wakefulness during critical phases, while implicit organizational pressure and fear of repercussions for refusing such extensions generate a significant psychosocial stress burden known as “pilot pushing.” Furthermore, the inherent unpredictability associated with the routine use of discretion destabilizes personal planning and rest, eroding social well-being and masking structural deficiencies in rostering that ultimately compromise operational safety margins.	28, 29, 30, 33
	Pilot retirement age	Extending the retirement age of pilots beyond 65 years raises a critical dichotomy between the inevitable natural physiological and cognitive decline, characterized by reduced processing speed and working memory, and the protective value of accumulated experience, or “crystallized intelligence,” which often allows these deficits to be compensated for through advanced operational strategies in routine situations. However, such an extension introduces latent safety risks associated with a higher prevalence of mild cognitive impairment and medical incapacitation events, making the implementation of rigorous and tailored health protocols indispensable, as standard medical examinations may be insufficient to detect subtle functional declines that could compromise responses to complex emergencies or adaptation to new technologies.	19, 21, 25

	Workforce shortages	Labour shortages act as a structural determinant that severely degrades the health and lifestyle of aviation professionals, as insufficient staffing forces the remaining workforce to absorb excessive workloads, extending operational duty periods and drastically reducing the time required for physiological recovery. This systemic pressure generates critical levels of chronic fatigue and emotional exhaustion (burnout), exacerbated by constant time pressure to complete safety- and service-related tasks, which increases susceptibility to human error and weakens operational resilience. Moreover, imbalances in team composition, marked by the loss of experience and high turnover, erode social cohesion and supervisory capacity, fostering a vicious cycle of increased sickness-related absenteeism and forced "presenteeism," in which the deterioration of worker well-being directly compromises flight safety margins.	9, 19, 27
Education in the context of Just Culture	Crew interoperability	Education within the framework of Just Culture, designed to foster trust and learning from errors, structurally conflicts with the risks arising from crew interoperability, where contractual precariousness and organizational fragmentation undermine the effectiveness of such training. While safety pedagogy promotes reporting without fear of reprisal, the reality of atypical employment and wet-lease models generates job insecurity that actively discourages the reporting of incidents and fatigue due to fear of contract termination or income loss. At the same time, ambiguity regarding the identity of the responsible employer and the lack of standardization in operational procedures (SOPs) across different operators hinder the practical application of learned concepts and obstruct the transparency required for reporting systems to function effectively. Consequently, employment instability and unequal access to recurrent training prevent the principles of Just Culture from taking root, creating a vulnerable workforce that	17, 18, 26, 28, 34, 36, 37

		perceives safety as an individual responsibility rather than a shared organizational commitment.	
	Generational risk behaviour	Education within the framework of Just Culture acts as a key mitigating mechanism against generational risk-taking behaviors by dismantling hierarchical and age-related barriers that often inhibit critical safety communication and error reporting. By clearly distinguishing health-related issues—such as stress management, mental health, and the use of substances to cope with lifestyle demands—from intentional violations, it fosters an environment of psychological safety that enables crews to report “unfit-for-duty” conditions without fear of reprisal or stigmatization. This continuous training recalibrates risk perception, addressing both the overconfidence bias associated with experience among senior personnel and the insecurity and job precariousness affecting younger crew members, thereby aligning individual behaviors with organizational safety standards.	5, 6, 8, 11, 16, 17, 41
Resource constraints and dynamics within the human resources market	ACMI	Resource constraints and demand volatility drive airlines to rely on the ACMI (wet-lease) model to ensure operational flexibility, introducing structural complexity that challenges cohesive safety management and organizational resilience. This dynamic fosters regulatory fragmentation and “rule shopping,” whereby discrepancies in oversight standards between the lessor State and the lessee State can dilute safety surveillance and facilitate labor cost reductions through precarious conditions. Operationally, the lack of effective integration of Safety Management Systems (SMS)—specifically the sharing of Flight Data Monitoring (FDM) data and incident reports—prevents a unified view of risks, while the transient lifestyle of crews operating from temporary bases exacerbates cumulative fatigue and hinders its mitigation due to the absence of stable routines and	17, 27, 35, 37

		social support. Consequently, prioritizing commercial terms and fleet availability within leasing contracts may inadvertently marginalize safety protocols, creating latent vulnerabilities in a system where operational responsibility is dispersed.	
	Commercial pressure	Commercial pressure to reduce costs and maximize operational output exacerbates human resource constraints, encouraging the adoption of precarious employment models, such as zero-hour contracts and bogus self-employment, that directly link income to flight activity, thereby discouraging the reporting of fatigue and promoting “presenteeism” (flying while unfit) due to financial insecurity. This dynamic, compounded by staff shortages, induces the phenomenon of pilot pushing, whereby management exerts implicit pressure to operate at the limits of physiological and legal capacity in order to meet schedules. As a result, crews are forced to rely on harmful coping mechanisms, such as the use of stimulants and sedatives, to manage disruptive sleep cycles, while organizational fragmentation through outsourcing and wet-leasing dilutes standardized safety oversight.	11, 14, 17, 26, 28, 37
	Crew interoperability	Crew interoperability, driven by the need for operational flexibility in the face of resource constraints and cost pressure, introduces systemic risks arising from the lack of harmonization of standard operating procedures (SOPs) and the difficulty of effectively integrating Safety Management Systems (SMS) across different operators, thereby fragmenting the oversight of critical risks. This dynamic encourages practices of “social engineering” or rule shopping, through which cross-border legislative differences are exploited to reduce costs and circumvent social security obligations, generating labor	17, 26

		inequalities and contractual ambiguity that erode reporting culture and complicate the clear allocation of responsibilities for safety oversight.	
	Generational risk behaviour	Resource constraints and cost pressure in the labor market have normalized precarious employment models, such as atypical contracts and pay-to-fly schemes, which disproportionately affect younger generations of pilots due to their high training-related debt. This financial vulnerability and contractual insecurity incentivize “presenteeism”, the practice of flying while fatigued or ill out of fear of losing income or employment, and encourage the use of substances as coping mechanisms to manage chronic fatigue and stress arising from unstable rostering that undermines work–life balance and mental health. At the same time, high staff turnover and the departure of experienced professionals erode the necessary transfer of knowledge (mentorship), making it more difficult for younger pilots to develop a mature and resilient risk perception in the face of operational demands.	14, 17, 19, 21, 28, 37
	Workforce shortages	Workforce shortages, exacerbated by resource constraints and cost pressure, compromise operational safety by normalizing minimum staffing models that intensify workload and fatigue, thereby reducing recovery margins in the face of errors and unforeseen events. This dynamic leads to a critical erosion of institutional “tacit knowledge” due to the departure of experienced personnel and the insufficient capacity to mentor new generations, while the simultaneous reduction of financial and human resources within regulatory authorities weakens effective system oversight, increasing operational fragility and making it more difficult to maintain required safety standards.	9, 10, 20, 37

Work intensity, flexibility and uncertainty	Commercial pressure	Commercial pressure acts as a catalyst that exacerbates work intensity and exploits job insecurity, forcing flight crews to operate under constant “haste” and aggressive productivity targets that prioritize profitability over safety margins. This dynamic foster the phenomenon of “pilot pushing,” whereby management implicitly pressures crews to fly despite adverse conditions, systematically using regulatory flexibility, such as duty extensions through commander’s discretion, to compensate for planning deficiencies and resource shortages. Furthermore, the contractual insecurity inherent in atypical employment models discourages the reporting of fatigue due to fear of economic retaliation, promoting “presenteeism” (working while unfit for duty) and pushing professionals to rely on harmful coping mechanisms, such as the use of stimulants and sedatives, to artificially manage sleep–wake cycles that are incompatible with operational demands.	11, 12, 14, 17, 28, 30
	Go-around decisions	The convergence of high work intensity and contractual uncertainty creates an operational environment in which the decision to execute a go-around is often perceived as a professional risk rather than as a safety tool, thereby discouraging its use. Time pressure to meet tight schedules induces hurrying and reduces the level of vigilance required to detect unstable approach parameters, while job insecurity, typical of atypical contracts, creates an implicit fear of managerial retaliation due to the operational costs associated with aborting a landing. This scenario is further exacerbated by cumulative fatigue resulting from demanding rosters, which fuels the phenomenon of “press-on-itis” (the fixation on continuing) in order to complete the duty period, thereby compromising the cognitive capacity to prioritize safety over mission completion.	12, 17, 23, 24

	Pilot discretion use	The recurrent reliance on the use of commander's discretion reveals a systemic dysfunction in which high work intensity and scheduling uncertainty force a tool designed for exceptional contingencies to be used routinely as a mechanism to compensate for staff shortages and unrealistic planning. This dynamic expose flight crews to severe levels of cumulative fatigue by extending legal duty limits under implicit organizational pressure, commonly referred to as "pilot pushing", where a significant fear of employment-related reprisals for refusing such extensions discourages dissent and masks the real operational risks by effectively nullifying the protective intent of flight time limitations.	28, 30

C.3.2 Literature supporting the link between Risk Areas and Safety Precursors

This subsection summarises the literature supporting the link between the RAs identified in the framework and the SPs. Its objective is to document the evidence underlying these relationships.

Risk Areas	Safety Precursor	Rationale	Sources (Document Number)
ACMI operations	Fatigue	The operational structure of ACMI leasing exposes crews to unique fatigue risks driven by "forced mobility" and long-term placement at outstations, where the ability to recover is structurally degraded compared to home-base operations. Crews living in airport hotels for extended periods face a distinct "rest environment" where they are constantly	26, 27

		surrounded by work reminders and colleagues, preventing the psychological detachment and familiar routines necessary for effective recovery, which leads to "accumulated fatigue" that traditional regulations often fail to capture. Furthermore, the business model relies on high-utilization leases, particularly during summer peak periods, where the demand to fulfil contract hours can saturate crew duty limits, making fatigue risk management a critical yet often strained component of the operation.	
	Lack of awareness	Lack of awareness is a systemic risk in ACMI operations caused by the breakdown in safety data sharing between the lessor (operator) and the lessee (client airline). The literature highlights that lessees often lack access to critical safety information, such as Operational Flight Data Monitoring (OFDM) reports or incident data from the wet-leased aircraft, which degrades the host airline's Safety Management System (SMS) capability to identify trends or latent risks within their own network. This "blind spot" prevents the formation of a complete picture of operational safety performance, leaving the organization unaware of compromising trends until an incident occurs.	26
	Lack of communication	Lack of communication stems from the interface between two different corporate and national cultures, often exacerbated by language barriers and divergent Crew Resource Management (CRM) standards. The literature indicates that language difficulties and differences in CRM protocols between the wet-lease flight crew and the lessee’s cabin crew or ground staff are common contributory causes that compromise safety, particularly during stress or abnormal operations. Additionally, ambiguous lines of responsibility regarding operational control and the transmission of safety-related data	26

		can lead to delayed reactions or failures to exchange crucial safety actions between the two organizations.	
	Lack of knowledge	Lack of knowledge arises from operational mismatches where crews may be technically qualified but unfamiliar with the specific operational environment or aircraft configurations of the lessee. Crews operating under wet-lease agreements often encounter differences in aircraft configuration, cabin layout, and equipment compared to what they or the host airline's support staff are accustomed to, creating gaps in technical familiarity that can disrupt workflow. Furthermore, specific route competencies—such as knowledge of local terrain, weather unpredictability, or saturated airspace procedures specific to the lessee's region—may not be adequately consolidated in the visiting crew's training, increasing the risk of errors due to unfamiliarity with the local operating environment.	26
	Norms	The fragmented nature of wet-leasing fosters the development of hazardous norms where divergent organizational cultures clash, potentially eroding adherence to standardized safety protocols. Discrepancies between the lessor's and lessee's interpretations of crew duty time restrictions or maintenance intervals can generate tension, leading to informal "workarounds" or desynchronization in working procedures to meet commercial demands. Additionally, the fear of repercussions in a contract-based environment can suppress safety reporting; crews may normalize the practice of not reporting accumulated fatigue because they fear it will not be supported by strict regulatory definitions or could jeopardize their standing with the leasing agency.	26, 27

	Stress	Stress in ACMI operations is generated by the psychosocial strain of social isolation and the precarious nature of the employment model. Crews often experience significant "work detachment" issues, as long-term hotel stays remove them from family support systems and domestic stability, creating an environment of loneliness and inability to fully utilize leisure time for psychological restoration. This personal stress is compounded by the professional pressure inherent in atypical contracts often used in wet leasing; pilots in these arrangements report significantly more negative perceptions of organizational support and higher anxiety regarding employment stability compared to direct employees, creating a backdrop of chronic occupational stress.	15, 31, 40
Atypical contracts	Fatigue	The literature indicates that Fatigue is exacerbated by atypical employment models because the inherent lack of financial security, such as in zero-hour or "pay-per-flight" contracts, creates a perverse incentive for aircrew to operate even when exhausted. Pilots and cabin crew on temporary agency contracts often lack access to sick pay, leading to "sickness presenteeism" where individuals fly while unfit or fatigued to avoid losing income or risking contract non-renewal, a behaviour less prevalent among directly employed peers. Furthermore, business models reliant on these contracts (often Low-Cost Carriers) tend to utilize Flight Time Limitations (FTL) as productivity targets rather than safety caps, scheduling crews to the legal maximums with minimum rest, which pilots describe as a primary driver of cumulative exhaustion and microsleeps.	17, 36, 37
	Lack of knowledge	Lack of knowledge is a distinct risk in atypical employment arrangements, as temporary agency workers and those in "pay-to-fly" schemes often receive less investment in training and possess lower experience levels compared to directly employed staff. Survey	17, 36, 37

		data reveals that aircrew employed via intermediary agencies are significantly more likely to report that they do not receive sufficient education and training compared to their direct counterparts. This issue is compounded in "pay-to-fly" schemes, where young, inexperienced pilots pay for line training to build hours, potentially entering the cockpit with minimal operational exposure and a focus on debt repayment rather than skill consolidation.	
	Workload	The precursor of Workload is intensified by atypical contracts, particularly within the low-cost carrier (LCC) sector where these employment models are most prevalent, due to the maximization of asset utilization and the removal of operational buffers. Crews working under these arrangements often face "maxed out" rosters characterized by multiple short sectors, short turnaround times, and long duty days that push the limits of human performance to maintain commercial viability. The unpredictability of zero-hour or standby contracts adds to this burden, as crews may face sudden spikes in task saturation without adequate prior planning, while "forced mobility" requiring frequent changes between operational bases adds significant logistical workload and instability to their duty periods.	17, 36, 38
	Pressure	Atypical contracts generate acute Pressure by creating a coercive environment where professional safety judgments are often overridden by the fear of economic reprisal or job loss. The literature highlights that pilots on precarious contracts (e.g., self-employment or agency work) are significantly more likely to feel pressured to fly despite being fatigued or when their professional judgment indicates they should not, compared to directly employed colleagues. This "pilot pushing" is reinforced by the perceived lack of	17, 28, 36, 37

		protection against dismissal; temporary staff often fear that filing safety reports or refusing discretion to extend duty hours will result in their contracts not being renewed or being assigned fewer flight hours in the future.	
	Stress	Stress acts as a chronic background condition for those on atypical contracts, driven by financial volatility, legal uncertainty, and the psychosocial strain of precarious employment. Pilots and cabin crew in these arrangements experience significant anxiety related to the unpredictability of their income—often exacerbated by high training debts in "pay-to-fly" scenarios—and confusion over applicable tax and social security jurisdictions, which degrades their mental well-being and ability to focus. The literature notes that agency workers report lower job satisfaction and higher levels of cynicism, stemming from a perception of being treated as "second-class citizens" with fewer rights and benefits than direct employees, creating a "culture of fear" that permeates their daily operations.	17, 37
	Complacency	The literature indicates that satisfying commercial performance targets, such as on-time departures or overhead cost reductions, can inadvertently foster complacency by creating a false sense of security where personnel believe no further safety improvements are necessary. When airline management actively demonstrates that profit and efficiency are the primary goals, or when organizational processes are deemed adequate simply because no accidents have occurred, a lack of critical self-assessment sets in, allowing hazards to go undetected. Furthermore, in contexts of reduced operations or financial downturns, the resulting operational "underload" can paradoxically generate a	1, 20

		perception of a less risky environment, causing staff to lower their guard and fail to strictly follow safety procedures.	
Commercial pressure	Fatigue	Fatigue is structurally embedded by commercial pressure as airlines strive to achieve unit cost savings through the maximization of aircraft and labour utilization, resulting in heavier schedules that push human physiological limits. To remain competitive, operators often utilize Flight Time Limitations (FTL) not as safety boundaries but as productivity targets, rostering crews to the maximum legal limits with minimum rest, which pilots describe as a primary cause of severe accumulated exhaustion. This dynamic leads to "pilot pushing", the implicit management pressure to fly despite fatigue to maintain schedules, forcing crews to ignore their physical state to support the employer's economic survival.	28, 31
	Stress	The tension between safety objectives and financial imperatives generates significant occupational stress, particularly when employees fear that reporting safety issues or declaring themselves "unfit to fly" could jeopardize their employment or financial standing. Economic stressors, such as the fear of job loss during downturns or the pressure to perform in roles with limited advancement, contribute to anxiety and depression among crews who must constantly balance intense job demands with the need for economic survival. Additionally, the perception that management prioritizes commercial interests over workforce well-being leaves employees feeling unsupported and psychologically strained, further degrading their mental health.	13, 28, 34, 37
	Norms	Financial and operational pressures drive a "practical drift" where the baseline performance of a system gradually departs from its intended design as personnel adopt	1, 3, 4, 24

		local workarounds to cope with daily resource limitations and demands. Over time, these commercially driven deviations evolve into the "normalization of deviance," where shortcuts taken to meet efficiency targets—such as skipping checks to ensure on-time departures—become the accepted standard of behaviour, passively tolerated by management and pilots alike. Consequently, non-compliance with safety policies can become a collective industry norm, as adhering strictly to procedures is perceived as an impediment to getting the job done within the constraints of time and budget.	
	Pressure	The drive to meet commercial deadlines and reduce costs exerts acute external pressure on operational personnel, creating an "Efficiency-Thoroughness Trade-Off" where individuals are implicitly judged on their speed rather than their safety compliance. This pressure manifests as "press-on-itis," or the compulsion to complete a mission despite adverse conditions, such as continuing unstable approaches to avoid the costs and delays associated with a go-around. Pilots on precarious contracts are particularly vulnerable to this coercion, often feeling forced to make decisions that favour the air carrier's commercial schedule over the safest course of action to avoid disciplinary or financial repercussions.	17, 23, 24, 34
	Workload	Cost-cutting strategies associated with commercial pressure often result in lean staffing models, which significantly increase the individual workload for cabin and flight crews by removing necessary operational buffers. High task intensity, driven by the need for rapid aircraft turnarounds and high asset utilization, can exceed the capacity of personnel, leading to task saturation and a higher probability of errors. Furthermore, commercial objectives often compel crews to perform additional non-safety duties or work extended	4, 10, 31, 32, 33, 37

		shifts without adequate support, pushing their mental and physical workload beyond sustainable safety limits.	
Crew interoperability	Lack of assertiveness	The literature indicates that crew interoperability, often facilitated by atypical employment models and multi-AOC structures, creates a precarious operational environment that significantly inhibits assertiveness by fostering a "culture of fear" where personnel hesitate to challenge unsafe situations due to job insecurity. Pilots and cabin crew working under temporary agency contracts or within fragmented operator groups report a heightened fear of reprisals, such as contract non-renewal or disciplinary action, if they refuse discretion to extend duty periods, report fatigue, or raise safety concerns. This reluctance is exacerbated in mixed-crew environments where steep trans-cockpit authority gradients and social status differences—such as those between senior captains and junior contracted flight attendants—discourage lower-ranking crew members from speaking up or challenging decisions, even when safety is compromised. Furthermore, the financial pressure inherent in "pay-to-fly" or zero-hour arrangements, often found in these interoperable models, creates a coercive dynamic where the fear of loss of income overrides the professional obligation to assertively declare oneself unfit to fly.	5, 6, 17, 28, 36, 37
	Lack of communication	Lack of communication Lack of communication in interoperable operations stems from the systemic fragmentation of procedures, language barriers, and the absence of shared mental models between crews deployed across different Air Operator Certificates (AOCs) or in wet-lease arrangements. The literature highlights that crews often face confusion regarding the "chain of command" and which Standard Operating Procedures (SOPs) or flight instructions take precedence when the operator of the aircraft differs from the	5, 6, 17, 18, 26, 36

		employer, leading to errors in coordination and task execution. Operational mismatches, such as differences in aircraft configuration, cabin layout, and technical terminology between the lessor and lessee, hinder the clear exchange of essential safety information. Additionally, the lack of joint training and face-to-face pre-flight briefings in these fluid operational structures prevents the formation of "Team Mental Models" (TMMs), resulting in crews operating as separate subgroups rather than a cohesive unit, which increases the likelihood of misunderstood warnings and uncoordinated responses during emergencies.	
Fuel management	Lack of resources	The literature highlights that accurate fuel management is critically dependent on the availability of precise data resources, such as Zero Fuel Weight (ZFW) and Dry Operating Weight (DOW); a lack of accurate documentation or calculation tools in this area can lead to erroneous flight path selection and improper fuel loads, resulting in either operational limit exceedances or financial losses due to displaced cargo,. Furthermore, a shortage of time and insufficient support from ground crew staff during the pre-flight planning phase restricts the flight crew's access to refined meteorological and routing information, which are essential resources for making optimal fuel decisions before departure. In terms of physical equipment, deficiencies in airport infrastructure or the unavailability of serviceable Ground Service Equipment (GSE) create resource constraints that force inefficient ground manoeuvres, thereby increasing fuel consumption through extended taxi times and congestion. Additionally, during periods of reduced operations, a lack of maintenance resources and regular system usage can compromise the fuel supply itself,	20, 22

		leading to undetected hazards such as microbiological growth or sediment contamination in hydrant systems.	
	Workload	High operational workload and the associated fatigue are identified as direct causal factors for cognitive performance failures, including specific errors such as fuel miscalculations, where the mental processing capacity required to manage complex logistics is degraded. Effective fuel management requires continuous attention to trajectory-based operations and aircraft energy states; however, excessive workload can overwhelm flight crews, impairing their ability to actively monitor thrust and drag variables, which is a contributing factor to unstabilized approaches and inefficient energy dissipation. Conversely, conditions of operational underload, such as long duration flights dominated by autopilot usage, can reduce engagement and unmask physiological sleepiness, creating a hazard where crews may fall asleep and fail to monitor fuel progression, potentially leading to fuel exhaustion. Furthermore, high workload manifested as time pressure can force personnel to rush duties, leading to the intentional skipping of essential safety steps, such as truncating pre-flight inspections intended to verify fuel quantity and aircraft readiness.	3, 7, 22, 23, 31
Generational risk behaviour	Distraction	Evolving lifestyle trends and cultural shifts regarding work-life boundaries significantly contribute to distraction, as the intrusion of personal demands into the professional sphere pulls attention away from safety-critical tasks. The literature highlights that the struggle to maintain a "normal life" and manage domestic responsibilities while dealing with irregular rosters prevents crew members from mentally "detaching" from work, creating a persistent internal distraction where family and social commitments compete	6, 8, 41

		for cognitive resources during duty periods. Furthermore, specific lifestyle habits observed in cabin crew cultures, such as the desire to explore destinations during layovers rather than resting ("work hard, play hard"), can lead to a physiological state where the individual is physically present but mentally disengaged or easily distracted due to lack of restorative downtime. Additionally, emotional dysregulation, which varies by individual disposition and coping style, has been identified as a key variable that influences concentration by altering attentional state, making individuals more susceptible to distractions caused by internal emotional states.	
	Lack of awareness	Generational differences significantly influence lack of awareness through mechanisms of overconfidence and inexperience, which distort the accurate perception of operational reality. Research indicates a dichotomy where older, more experienced pilots may suffer from an "overconfidence bias," leading them to underestimate risks and overestimate their capabilities, potentially resulting in a lack of awareness regarding dangerous situations or their own performance limitations. Conversely, younger or less experienced pilots are more prone to accidents related to "inadequate situation evaluation" and judgment errors, stemming from a lack of consolidated experience to draw upon for situational recognition. Furthermore, age is associated with the perception of safety culture, where both younger and older employees have less favourable perceptions of "just culture" than mid-career employees, potentially leading to a lack of awareness regarding the importance of reporting hazards or understanding systemic safety nets.	8, 21, 34, 41
	Stress	Stress is exacerbated by generational and cultural shifts regarding financial stability, career progression, and the management of emotions. The literature notes that younger	8, 28, 41

		pilots and crew members often face precarious employment conditions (e.g., low-cost carrier models, lack of permanent contracts) and high training debts, creating intense "psychosocial stress" and "realistic fears" about job security that degrade mental well-being. This generation also exhibits higher vulnerability to depression and anxiety compared to the general population, partly driven by these work-related stressors. Additionally, the inability to effectively regulate emotions—a trait explored in relation to coping styles—serves as a critical internal stressor; pilots with higher emotional dysregulation and avoidant coping styles struggle to manage the inherent pressures of the aviation environment, leading to reduced self-confidence and increased psychological strain.	
	Workload	The management of workload is distinctly affected by age-related physiological changes and lifestyle-induced capacity reductions. For older pilots, the literature describes a decline in "fluid intelligence" and processing speed, which can result in cognitive overload during novel or high-demand emergency situations where they cannot rely solely on "crystallized" experience, making standard tasks feel more workload-intensive. Conversely, younger crew members often report higher levels of fatigue and sleepiness, partly attributed to lifestyle factors and social demands that reduce physical energy reserves, thereby diminishing their capacity to handle operational workload effectively. Furthermore, cultural expectations within airlines can lead to "pilot pushing," where commercial pressure compels crews to accept excessive workloads (e.g., maximum duty hours) despite not being physically fit to do so, pushing the human performance envelope to its breaking point.	6, 8, 14, 21, 28

Go-around decisions	Complacency	Complacency undermines the go-around decision-making process by fostering an overconfidence bias where pilots believe they can salvage an unstabilized approach or correct deviations that exceed safety parameters without aborting the landing. The literature indicates that pilots who exhibit complacency often view unstable approach criteria as unrealistic or too conservative, leading them to rely on their past success in recovering non-compliant approaches rather than adhering to established safety gates. This false sense of security is exacerbated in environments where automation is heavily relied upon; pilots may become disengaged from the active monitoring of the aircraft's energy state, assuming the systems will manage the profile, which delays the recognition of the need for a go-around until safety margins are critically eroded. Furthermore, a lack of recent negative consequences from continuing unstable approaches reinforces a psychological state where the risks are underestimated, leading flight crews to prioritize the "mission" of landing over the procedural requirement to go around.	6, 9, 12
	Fatigue	Fatigue significantly impairs the cognitive resources required to execute a go-around decision, as the manoeuvre demands a sudden shift from a monitoring state to a high-workload, active control state that a tired pilot may physiologically resist. Research highlights that fatigue degrades executive functions, such as complex decision-making and reaction time, making pilots more susceptible to "plan continuation bias" or "get-home-itis," where the desire to land and rest overrides the safety imperative to abort the approach. Fatigue is identified as a primary cause for the failure to recognize an undesired aircraft state, with studies showing that high Time Since Awake (TSA) correlates with significantly more tactical decision errors and errors of omission, such as failing to call out deviations. Additionally, the reluctance to initiate a go-around is often linked to	9, 10, 20, 32

		the lethargy and cognitive slowness associated with sleep debt, which hampers the crew's ability to process dynamic cues during the critical final approach phase.	
	Lack of assertiveness	Lack of assertiveness is a critical barrier to go-around execution, primarily manifesting when a Pilot Monitoring (PM) or First Officer hesitates to challenge a Captain who is continuing an unstabilized approach. The literature identifies steep trans-cockpit authority gradients and a "culture of fear" regarding reprisals or management criticism as significant inhibitors that silence necessary safety callouts. Pilots often report feeling discomfort in challenging others or fear that initiating a go-around will be viewed as a professional failure or an overreaction, leading to a failure to intervene even when safety limits are clearly violated. This lack of assertiveness is compounded in organizations without a robust non-punitive go-around policy, where the social pressure to conform to the Pilot Flying's actions or the perceived commercial pressure suppresses the vocalization of the "Go-Around" command.	6, 9, 23, 24
	Lack of awareness	Lack of awareness prevents the timely initiation of a go-around because flight crews fail to perceive or comprehend the cues indicating that the aircraft has entered an unsafe energy state or position. High-fidelity analysis of go-around decision-making reveals that pilots who continue unstable approaches often score significantly lower on "anticipatory awareness" (seeing threats moving in time and space) and "functional awareness" (knowing instrument readings), leading them to miss critical deviations in speed, sink rate, or flight path vector. This loss of situational awareness can be induced by fixation on the landing point or distraction, preventing the crew from projecting the aircraft's future state and realizing that stabilization criteria cannot be met by the decision altitude.	6, 9, 23, 24

		Furthermore, a lack of awareness regarding the specific risks associated with the go-around manoeuvre itself, such as spatial disorientation or somatogravic illusions—can lead to poor execution once the decision is finally made.	
	Lack of teamwork	Lack of teamwork compromises the go-around decision by fragmenting the shared mental model required to manage the approach, leading to uncoordinated actions and ambiguous communication between crew members. Effective Crew Resource Management (CRM) relies on the Pilot Monitoring (PM) actively cross-checking the Pilot Flying (PF) and providing standard callouts; however, the literature notes that in many unstable approaches, there is a breakdown in this coordination where roles become unclear and essential monitoring tasks are abandoned. Poor teamwork is evidenced by the absence of "active communication" regarding aircraft state, where silence is misinterpreted as agreement to continue, rather than a lack of acknowledgment of the risk. Additionally, inadequate briefing of go-around procedures and responsibilities prior to descent leaves the crew unprepared to act cohesively when an unexpected threat arises, resulting in confusion rather than a unified response.	9, 23, 24
	Norms	Norms that deviate from written procedures create a pervasive "normalization of deviance," where continuing an unstabilized approach becomes the accepted standard of behaviour rather than the exception. Industry data reveals a staggering non-compliance rate, with approximately 97% of unstable approaches being continued to be landing, suggesting that the collective industry norm is to ignore go-around policies. This behaviour is driven by informal practices where pilots adopt personal, subjective thresholds for stability (e.g., believing they can stabilize below 500 feet) instead of	9, 23, 24

		adhering to the operator's prescriptive rigid gates. Over time, these informal habits drift away from the official Standard Operating Procedures (SOPs), reinforced by peer behaviour and the lack of negative outcomes in previous violations, effectively nullifying the safety barriers intended to mandate a go-around.	
Homebase chnages	Distraction	The frequent modification of home bases and the phenomenon of "forced mobility" introduce significant external and internal distractions by disrupting the stability of a crew member's personal life and logistical routine. The logistical complexity of commuting between a residence and a shifting or remote "assigned base"—which often differs from the actual home—creates a cognitive burden related to travel arrangements and time management that competes for attention with operational duties. Furthermore, the lack of control over base allocation and the potential for sudden relocation generates profound feelings of "loneliness" and social isolation, forcing crew members to manage the internal distraction of homesickness and the inability to attend to personal and family events while on duty,. This transience also creates administrative distractions regarding taxation and legal compliance across different jurisdictions, pulling focus away from flight preparation and safety tasks.	17, 38
	Fatigue	Fatigue is exacerbated by homebase changes because the misalignment between a crew member's residence and their assigned base necessitates extensive commuting, which significantly increases the "time since awake" prior to operating a flight without being counted as duty time. The crash of Colgan Air flight 3407 serves as a critical example where long-distance commuting resulted in the pilot being awake for over 30 hours, severely impairing performance. Additionally, frequent relocations or long-term	7, 7, 27, 28, 33, 37

		outstation assignments force crews to reside in "make-shift homes" within hotels, where the lack of a familiar rest environment and the inability to physically detach from the work environment hinders effective sleep recovery and contributes to accumulated exhaustion. The necessity to wake up earlier to accommodate long commutes from temporary accommodation further restricts the window for restorative sleep, leading to sleep debt and a reliance on napping to function.	
	Stress	Stress is structurally generated by the insecurity and unpredictability of "forced mobility," where atypical employment contracts compel pilots to move bases at the operator's request, rendering it difficult to maintain a stable family life or social support network. This lack of agency over one's living situation and the inability to plan for the long term creates chronic psychosocial stress and anxiety regarding future stability. The pressure to accept relocation to bases that are not the individual's choice, driven by business staffing needs rather than personal preference, places crew members in a state of continuous adaptation and emotional strain. Moreover, the financial and logistical burden of operating from a base different than one's home, often without adequate per diem remuneration or support for the time spent out of base, acts as a persistent stressor that degrades mental well-being and increases irritability.	17, 28, 37
Pilot discretion use	Complacency	Recurrent reliance on pilot discretion fosters complacency by normalizing the deviation from standard fatigue regulations, leading to a "normalization of deviance" where extending duty periods becomes a routine operational fix rather than an exceptional safety protocol. The literature indicates that when Commander's Discretion (CD) is utilized frequently—such as the 18.7% of pilots reporting its use two or more times	29, 30

		within a four-week period—it masks systemic rostering inadequacies and insufficient staffing buffers, causing the extension of duties to be viewed as a standard expectation rather than an unforeseen event. This habitual use creates a false sense of security where operators may view "prudent planning" as an unnecessary cost, assuming that pilot discretion will always be available to absorb delays, thereby failing to proactively improve future planning or acknowledge the erosion of safety margins inherent in pushing crews beyond prescribed limits,.	
	Fatigue	The use of pilot discretion acts as a direct multiplier of fatigue by legally permitting flight crews to operate beyond the maximum daily Flight Duty Period (FDP) limits that were scientifically established to safeguard alertness. Pilots report that rosters are often designed to the maximum legal limits, meaning that even minor delays necessitate the use of discretion to complete the mission, forcing crews to extend their wakefulness into zones of "severe fatigue" and often encroach upon the Window of Circadian Low (WOCL). The decision to extend is described as a "bet on the future" with high uncertainty regarding the crew's physiological capability to maintain performance, and despite regulations stating crews should not operate when fatigued, the systemic reliance on these extensions exacerbates cumulative exhaustion and increases the risk of sleep-related performance decrements during critical flight phases.	28, 29
	Pressure	External pressure is a primary driver of pilot discretion use, creating a coercive environment where flight crews feel compelled to prioritize commercial schedules over safety limits due to fear of organizational reprisals. Survey data reveals that a significant majority of pilots (65.8%) are concerned about negative consequences from their airline	17, 28, 30

		if they refuse to extend a flight duty under discretion, with this figure rising to over 80% in certain jurisdictions, directly contradicting the regulatory requirement for a non-punitive environment. This phenomenon, described as "pilot pushing," involves implicit management pressure to fly as many sectors as possible, leading pilots to agree to extensions to avoid "making waves" or jeopardizing their employment, particularly those on precarious contracts who fear non-renewal.	
	Stress	The necessity to exercise discretion generates significant stress by placing the heavy cognitive and emotional burden of operational continuity and safety assessment solely on the commander during high-stakes situations. The decision-making process is fraught with interpersonal conflict and anxiety, as pilots must weigh the immediate commercial needs—such as avoiding flight cancellations and stranding passengers—against their own fitness for duty and that of their crew, often without adequate support or "buffers" from the operator. This situation creates a "culture of fear" and psychosocial stress where pilots experience anxiety about potential disciplinary investigations or being labelled as uncooperative, thereby depleting the mental resources required for complex decision-making and effective communication during the extended duty period,.	28, 29
Pilot retirement age	Lack of awareness	The literature indicates that extending the pilot retirement age carries risks related to Lack of awareness because aging is associated with a decline in "fluid intelligence," working memory, and perceptual-motor skills, which are critical for processing novel environmental cues and maintaining an accurate mental model of the flight path during dynamic situations. While older pilots often rely on "crystallized intelligence" and extensive experience to anticipate routine events, research demonstrates that they	21, 25

		exhibit slower information processing speeds and reduced visual-spatial reasoning capabilities, which can lead to delayed recognition of hazards or "loss of situational awareness" errors, particularly when monitoring automated systems. Furthermore, age-related declines in cognitive inhibition may prevent older pilots from effectively filtering irrelevant information or discarding outdated procedures, thereby distorting their perception of the current operational reality and reducing their ability to anticipate future system states during unexpected changes.	
	Workload	Workload management is identified as a critical vulnerability for older pilots due to a physiological reduction in "processing resources" or cognitive capacity, meaning that older individuals typically have less spare mental capacity available to handle surges in task demand compared to their younger counterparts. Although experience can mitigate this by making routine tasks automatic, the literature highlights that older pilots are more prone to cognitive overload during high-intensity scenarios—such as engaging in secondary tasks like Air Traffic Control communications while flying—where the combined demands exceed their diminished processing limits, leading to performance breakdowns or the shedding of tasks. Additionally, age-related issues such as "progressive dysexecutive syndrome" or general declines in executive function can specifically impair multi-tasking and planning abilities, causing pilots to struggle with complex sequences or time pressures, which increases the likelihood of rushing, missed steps, or errors of omission when operational tempo is high.	21, 25, 32
	Fatigue	Fatigue is exacerbated by workforce shortages as airlines, particularly Low-Cost Carriers (LCCs) and those recovering from crises like COVID-19, are compelled to utilize flight and	9, 10, 20, 33

Workforce shortages		cabin crews to the maximum legal limits of Flight Time Limitations (FTL) to maintain schedules with minimum staffing. The literature indicates that operating with "minimum crew" or flying short-crewed due to sickness removes necessary operational buffers, forcing the remaining personnel to absorb additional duties and work extended hours, which directly contributes to severe accumulated exhaustion and physical deterioration. This systemic understaffing leads to routine assignments of maximum duty days with minimum rest periods, creating a scenario where crews are unable to recover adequately between shifts, thereby increasing the risk of falling asleep on duty or experiencing performance impairments during critical phases of flight.	
	Lack of resources	Lack of resources manifests during shortages as a critical deficit in available time, support staff, and training capacity, forcing personnel to improvise or operate without standard safety nets. The literature highlights that a scarcity of ground handling and maintenance staff leads to inadequate pre-planning and pressure to release aircraft quickly, potentially causing staff to cut corners or skip essential checks due to the unavailability of peer support or supervision. Furthermore, a shortage of competent instructors and access to simulators creates a bottleneck in training, meaning that returning or new staff may be deployed with "low recency" and insufficient mentorship, lacking the consolidated knowledge resources required to handle complex operational disruptions effectively.	4, 19, 20
	Stress	Stress arises from the psychosocial pressure and job insecurity inherent in understaffed environments, where the fear of employment loss or letting down colleagues suppresses safety reporting. Research indicates that workforce shortages create a "culture of fear" where crew members experience high anxiety about reporting sickness or fatigue, fearing	8, 12, 19, 37

		disciplinary action or non-renewal of temporary contracts, which compels them to work while unfit. Additionally, the inability to secure leave or predictable rosters due to insufficient crew numbers generates chronic work-life conflict and emotional exhaustion, as individuals struggle to balance intense operational demands with personal well-being, leading to feelings of being unsupported and psychologically strained.	
	Workload	Workload is directly intensified by workforce shortages as the reduction in personnel necessitates the consolidation of multiple roles and safety tasks onto fewer individuals, frequently pushing them toward task saturation. The literature notes that operating with minimum crew complements increases the "load per person," requiring cabin crew to manage multiple emergency exits or handle passenger disruptions without assistance, which significantly elevates physical and cognitive demands. This task densification is further aggravated when airlines expand routes without proportionally increasing staff, forcing existing crews to execute service and safety duties at a rushed pace within tighter turnaround times, thereby increasing the likelihood of errors and reducing the capacity to monitor for threats.	8, 9, 10, 12

C.3.3 Mapping of documentary sources

This subsection provides the documentary sources referenced in Annex C.3.1 and C.3.2. To ensure clarity and avoid duplication, sources are identified using document number identifiers.

Numeration	Source
1	International Civil Aviation Organization. (2018). Safety Management Manual (SMM) (4th ed., Doc 9859). ICAO.

2	Federal Aviation Administration. (2016). Human factors design standard (HF-STD-001B). U.S. Department of Transportation.
3	Civil Aviation Safety Authority. (2023). Safety behaviours: Human factors for pilots (3rd ed.). CASA.
4	UK Civil Aviation Authority. (2003). Aviation maintenance human factors: Guidance material on the UK CAA interpretation of Part-145 human factors and error management requirements (CAP 716). CAA Safety Regulation Group.
5	Ford, J., Henderson, R., & O'Hare, D. (2013). Barriers to intra-aircraft communication and safety: The perspective of the flight attendants. The International Journal of Aviation Psychology, 23(4), 368–387. https://doi.org/10.1080/10508414.2013.834167
6	Ford, J., O'Hare, D., & Henderson, R. (2014). Flight attendant and pilot perceptions of in-flight events. International Journal of Human Factors and Ergonomics, 3(1), 1–14. https://doi.org/10.1504/IJHFE.2014.062545
7	Brown, L., Schoutens, A. M. C., Whitehurst, G., Booker, T., Davis, T., Losinski, S., & Diehl, R. (2014). The effect of blue light therapy on flight crew members' behavioral alertness. SSRN Electronic Journal. https://doi.org/10.2139/ssrn.2402409
8	Mumtaz, S. H. (2017). Analysis of mental health issues and its implications on cabin crew at Emirates Airlines (Master's thesis). Middle Tennessee State University.
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13	Lindsey, W. N. (2022). Strategies for reducing occupational stress on cabin crewmembers in the airline industry (Doctoral dissertation). Walden University.
14	Wen, C. C. Y., Cherian, D., Schenker, M. T., & Jordan, A. S. (2023). Fatigue and sleep in airline cabin crew: A scoping review. International Journal of Environmental Research and Public Health, 20(3), 2652. https://doi.org/10.3390/ijerph20032652
15	Mei, H. R., Hsu, C. Y., & Hu, C. J. (2023). Exploring relationships between health-related lifestyle habits and fatigue among flight attendants and trainees. Work, 74(4), 1361–1369. https://doi.org/10.3233/WOR-211355
16	European aviation organisations. (2015). European corporate just culture declaration (Signed in Brussels on 1 October 2015). Endorsed by EASA, ECA, CANSO, ACI Europe, and other European aviation stakeholders.
17	Brannigan, C., Amaral, S., Thorpe, C., Levin, S., Figg, H., Neiva, R., Morgan-Price, S., Troncoso Ferrer, M., García Fernández, C., Moya Izquierdo, S., Castillo, L., Tallos, J., & Molina, C. (2019). Study on employment and working conditions of aircrews in the EU internal aviation market: Final report. European Commission, Directorate-General for Mobility and Transport. https://doi.org/10.2832/37654
18	Reader, T. W., Parand, A., & Kirwan, B. (2016). European pilots' perceptions of safety culture in European aviation (Future Sky Safety Deliverable D5.4, Project P5). EUROCONTROL / Future Sky Safety.
19	European Union Aviation Safety Agency (EASA). (2021). Safety issue report – Skills and knowledge degradation due to lack of recent practice (Version 2.0). EASA Together4Safety

20	European Union Aviation Safety Agency (EASA). (2021). Review of aviation safety issues arising from the COVID-19 pandemic (Version 2, April 2021). EASA.
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24	Flight Safety Foundation. (2017). Go-around decision-making and execution project: Final report. Flight Safety Foundation.
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27	Gíslason, S. H. (2015). The effects of ACMI flight crew's long-term outstation hotel stay on accumulated fatigue. Transport and Aerospace Engineering, 2015(2), 36–41. https://doi.org/10.1515/tae-2015-0005
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29	European Cockpit Association (ECA). (2025). Commander's discretion: Guidelines on ORO.FTL.205(f) of Commission Regulation (EU) No 83/2014 (CD 2.0). ECA.
30	Baines Simmons Ltd. (2023). A fatigue survey of European pilots. European Cockpit Association (ECA).
31	Efthymiou, M., Whiston, S., O'Connell, J. F., & Brown, G. D. (2021). Flight crew evaluation of the flight time limitations regulation. Case Studies on Transport Policy, 9(1), 280–290. https://doi.org/10.1016/j.cstp.2021.01.002
32	International Civil Aviation Organization. (2016). Manual for the oversight of fatigue management approaches (2nd ed., Doc 9966). ICAO.
33	International Air Transport Association (IATA), International Civil Aviation Organization (ICAO), & International Federation of Air Line Pilots' Associations (IFALPA). (2015). Fatigue management guide for airline operators (2nd ed.). IATA
34	EUROCONTROL. (2023). Just culture... revisited (HindSight Magazine, Issue 35). EUROCONTROL.
35	De Coninck, J., & De Vos, M. (2019). Atypical employment in aviation: Final report. Ghent University, European Social Dialogue Committee for Civil Aviation, with financial support from the European Commission.
36	Brannigan, C., Amaral, S., Thorpe, C., Levin, S., Figg, H., Neiva, R., Morgan-Price, S., Troncoso Ferrer, M., García Fernández, C., Moya Izquierdo, S., Castillo, L., Tallos, J., & Molina, C. (2019). Study on employment and working conditions of aircrews in the EU internal aviation market: Final report. European Commission, Directorate-General for Mobility and Transport. https://doi.org/10.2832/37654
37	Ydersbond, I. M. (2022). The organisation of the Norwegian aviation sector in a European context (TØI Report 1869A/2022). Institute of Transport Economics (TØI).

38	Turnbull, P. (2020). Tackling undeclared work in the air transport sector, with a special focus on bogus self-employment of aircrews: A learning resource. European Platform Tackling Undeclared Work, European Commission.
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C.4 KSIs: Definition, measurement, and data sources

The following table provides an overview of the KSIs considered in the study. For each RA, the table summarises the associated KSIs, the socio-economic dimension they are intended to capture, the way each indicator is operationalised and measured, and the data sources used for its assessment. This overview ensures traceability between the identified RAs the empirical evidence collected, and the resulting indicators used in the analysis.

Table 70: Overview of the Key Socio-Economic Indicators (KSIs)

Risk area	KSI ID	KSI	What measures	How it is measured	Potential Source	Final source	Answered

ACMI operations	ACMI01	ACMI exposure ratio	Measures the organisational dependency to ACMI business model.	Percentage of flights operated under ACMI agreements.	ADS-B, OAG	None	No
	ACMI02	Fleet age exposure	Measures the age profile of the ACMI fleet.	Average age of aircraft in ACMI operations relative to total fleet.	ADS-B, OAG, Cirium	None	No
	ACMI03	Fleet Mobility Rate	Measures the geographic and operational mobility of the fleet.	Percentage of aircraft in ACMI operations deployed across multiple regions or operators.	ADS-B, OAG, Cirium	None	No
	ACMI04	ACMI Wellbeing Pressure Index	Measures the share of personnel in ACMI operations reporting wellbeing issues linked to operational or commercial pressure.	Nº of ACMI respondents who agree that almost always their workload has exceeded the capacity to manage it effectively.	Survey	Survey (Question 49)	Yes
	ACMI05	ACMI Reporting Willingness Ratio	Reflects the proportion of ACMI staff who feel comfortable reporting.	Percentage of ACMI respondents who strongly agree that are not confident to report their own mistakes	Survey	Survey (Question 49)	Yes
	ACMI06	ACMI Employment Precarity Index	Measures the prevalence of perceived unstable or atypical employment conditions	Percentage of ACMI respondents who has a short-	Survey	Survey (Question 9)	Yes

				term, self-employed or pay-to-fly contract.			
Atypical contracts	AC01	Direct Employment Ratio	The proportion of personnel directly employed by the airline versus those engaged through other means.	Percentage of people not "Permanent Direct employement contract with the airline".	Survey, Eurofound EWCS	Survey (Question 9)	Yes
	AC02	Contract Precarity Index	Reliance on limited-duration, zero-hour, or 'pay-to-fly' contract models, which are forms of atypical employment.	Percentage of crew (self-employed + zero-hour + fixed-term + PtF).	Survey, Eurofound EWCS	Survey (Question 9)	Yes
	AC03	Cross-Border Registration Index	Mismatch between an airline's primary AOC country and the legal jurisdiction of its crew contracts.	Percentage of crew contracts r egistered outside the airline's AOC country.	Survey, Eurofound EWCS	Survey (Question 77)	Yes
	AC04	Departure intention rate	Percentage of crew considering leaving the airline.	Percentage of respondents considering very likely to leave their airline in the next 12 months.	Survey	Survey (Question 26)	Yes
	AC05	Base-Payroll Jurisdiction Mismatch Rate	Crew are employed under a legal/tax jurisdiction different from their operational base.	Percentage of crew whose pay roll jurisdiction differs from the ir operational base.	Survey, Eurofound EWCS	Survey (Question 78 and 80)	Yes

Commercial pressure	CP01	Turnaround median time	Typical time an aircraft spends on the ground between arriving at the gate and departing for its next flight.	Average time of departure pushback - average time of arrival at gate.	OAG, Cirium	None	No
	CP02	Fleet utilization rate	Average number of hours per day that each aircraft in the fleet is used for flight operations.	Total block hours flown by the fleet in a period / (Number of aircraft in fleet x Number of days in period).	OAG, CAPA Aviation	None	No
	CP03	Roster capacity utilization	Flight crew operating at or near their maximum flight limits.	Percentage of respondents who almost always operate at or near their regulatory flight and duty time limits.	Survey	Survey (Question 59)	Yes
	CP04	Short-notice roster change frequency	Frequency of late-notice changes.	Percentage of crew respondents reporting having had more than six roster changes within 24 hours of planned duty.	Survey	Survey (Question 69)	Yes
	CP05	OTP pressure perception	Link between high-levels of perceived commercial pressure and self-reported use of substances.	Percentage of crew reporting that pressure to maintain on-time performance almost always compromises priority over safety considerations.	Survey	Survey (Question 68)	Yes

	CP06	Share of off-duty substance use among high-pressure Personnel	Link between high-levels of perceived commercial pressure and self-reported use of substances.	Percentage of staff reporting both high-pressure and off-duty substance use / Total number of staff reporting high-pressure.	Survey	None	No
	CP07	Share of wellbeing issues among high-pressure personnel	Link between high levels of perceived commercial pressure and self-reported wellbeing issues.	Percentage of staff reporting both high-pressure and wellbeing issues / Total number of staff reporting high-pressure.	Survey, ECA Social Rating	None	No
	CP08	Commander's Discretion Usage Rate	Number of instances where the commander extends the duty period beyond FTL.	Percentage of respondents who do not agree that commander's discretion is used appropriately.	Survey	Survey (Question 40 and 41)	Yes
Crew interoperability	CI01	Cross-AOC flight ratio	The extent to which crew interoperability is used.	Percentage of respondents reporting that they frequently operate under an AOC different from their primary one.	Survey, NAA Audits	Survey (Question 50)	Yes

	CI02	Perception of SOP Clarity	The percentage of crew who feel they have total clarity on their roles and Standard Operating Procedures (SOPs) when working under a different Air Operator Certificate (AOC).	Percentage of respondents reporting that roles and procedures are very unclear when operating under a different AOC.	Survey	Survey (Question 52)	Yes
Fraud risk	FR01	Fraud detection confidence index	Stakeholder confidence in the system's ability to detect fraud.	Percentage of respondents who are very unconfident in the current system ability to detect and prevent fraud.	Survey	Survey (Question 91)	Yes
	FR02	Perceived Forum Shopping Prevalence	Average confidence score among respondents regarding the effectiveness of existing fraud detection mechanisms.	Percentage of respondents who are very unconfident in the current system ability to detect and prevent fraud.	Survey	Survey (Question 87)	Yes
Fuel managemen t	FM01	Commander fuel discretion	Measures pilots' tendency to use discretion to uplift fuel beyond operational requirements.	Percentage of respondents very likely to use discretion to uplift fuel beyond standard operational requirements.	Survey, Case study	Survey (Q15)	Yes
	FM02	Low fuel occurrence	Measures how often aircraft operate in conditions where fuel reserves are critically low	Number of reported low-fuel events per 1,000 flights.	ECR, Survey, Case study	None	no

Go-around decisions	GO01	Point-to-point Pilot Go-Around	Pressure to avoid go-arounds.	Percentage of respondents reporting undue pressure to avoid go-arounds.	Survey	Survey (Question 92)	Yes
	GO02	Network Pilot Go-Around	Pressure to avoid go-arounds.	Percentage of respondents reporting undue pressure to avoid go-arounds.	Survey	Survey (Question 92)	Yes
	GO03	Go-Around Pressure Differential	Go-around pressure differential	Percentage of respondents who strongly agree that they are concerned about potential negative consequences or reprimands after performing a go-around.	Survey	Survey (Question 93)	Yes
Generational risk behaviour	GR01, GR02	Pilot age distribution	The demographic spread of ages across the pilot workforce	Percentage breakdown of crew across age brackets.	Survey	Survey (Q3)	Yes
	GR03	Contract type vs. age distribution	Whether certain employment contracts are more common within specific age groups	Percentage of respondents without permanent direct employment contract.	Survey	Survey (Question 3 and 9)	Yes
	GR04	Generational work-life balance gap	People very dissatisfied with their work life balance	Percentage of respondents very dissatisfied with their work life balance.	Survey	Survey (Question 48)	Yes

	GR05	Generational safety culture perception	Trust in safety reporting systems and perceived commercial pressure.	Percentage of respondents who strongly disagree that they can report their own mistakes wihtout negative consequences.	Survey	Survey (Question 49)	Yes
	GR06	Age-induced substance use	Link between high levels of perceived commercial pressure and self-reported off-duty substance use as a coping mechanism.	Share of staff within each age group reporting off-duty substance use in conjunction with high perceived commercial pressure.	Survey	None	No
Homebase changes	HC01	Homebase change rate	Overall rate of workforce relocation	Percentage of respondents who experienced one or more relocations within the last 12 months.	Survey	Survey (Question 42)	Yes
	HC02	Average frequency of homebase changes per affected crew	Intensity of relocation	Percentage of relocated crew who experience more than one homebase change within the last 12 months.	Survey	Survey (Question 42)	Yes

	HC03	Voluntary report rate for relocated crew	Willingness of relocated crew to submit voluntary safety reports	Percentage of relocated crew reporting who do not feel at all comfortable to submit voluntary safety reports.	Survey	Survey (Question 42 and 67)	Yes
	HC04	Relocation Notice Period Compliance	Crew who report receiving the contractually minimum advance notice before a mandatory home base relocation	Percentage of relocated crew reporting that they received less than 14 days' notice before a mandatory homebase change.	Survey	Survey (Question 44)	Yes
Pilot discretion use	PD01	Prevalence of discretion use	Crew who have been directly affected by the use of commander's discretion	Percentage of respondents reporting that they have been affected by the use of commander's discretion.	Survey	Survey (Question 33)	Yes
	PD02	Perceived Frequency of Discretion Use	Crew who used of commander's discretion as a regular rather than an exceptional event	Percentage of respondents perceiving that commander's discretion is used frequently rather than as an exceptional measure.	Survey	Survey (Question 35)	Yes
	PD03	Perceived average	The typical self-reported length of a duty period extension.	Typical self-reported length of duty period extensions (in	Survey	Survey (Question 36)	Yes

		duration of discretion		minutes) when commander's discretion is applied.			
	PD04	Perception of Appropriate Use	Crew who believe the use of discretion at their airline is excessive and not used as a flexibility tool for safety	Percentage of respondents who do not agree that commander's discretion is used appropriately.	Survey	Survey (Question 40 and 41)	Yes
	PD05	Crew consultation rate	Crew who report not being consulted about their alertness level before an FDP extension.	Percentage of respondents reporting that they are not consulted about their level of alertness every time a FDP extension is decided.	Survey	Survey (Question 38)	Yes
	PD06	Reporting confidence index	Level of trust pilots have in the company's safety culture after using discretion	Pilots confidence in the reporting environment after using discretion.	Survey	None	No
Pilot retirement age	PR01	Pilot age distribution	Demographic breakdown of the pilot workforce	Demographic breakdown of the pilot workforce across predefined age bands, calculated as a weighted average using the midpoint of each age band.	Survey, Airline HR data, License holders	Survey (Question 3)	Yes

	PR02	Median age of pilot workforce	Midpoint of the age distribution of all pilots	Median age of the pilot workforce, defined as the age-band midpoint at which the cumulative frequency exceeds 50% of pilots.	Survey, Airline HR data, License holders	Survey (Question 3)	Yes
	PR03	Retirement wave projection	Current pilot workforce that is expected to retire	Percentage of respondents that is above 60 years of age.	Survey, Airline HR data, License holders	Survey (Question 3)	Yes
Workforce shortages	WS01	National pilot availability index	Indicator of the national supply of certified pilots relative to the country's flight activity.	Ratio of active ATPL licences issued by the national aviation authority to total annual flight hours operated in the country.	License registry + ECTRL, OAG for FH	None	No
	WS02	Perceived High Utilization Rate	Crew operating consistently near their maximum legal duty limits.	Percentage of respondents who strongly agree that they operate consistenly near their legal duty limits.	Survey	Survey (Question 19 and 20)	Yes

	WS03	Perceived Staffing Adequacy	Staff who feel their department has not enough personnel.	Percentage of respondents who strongly agree that staffing levels are insufficient to manage daily workload safely and effectively.	Survey	Survey (Question 21)	Yes
	WS04	Average Crew Tenure	Average years of service across all active crew members by airline.	Average length of time, in years, that crew members have been employed.	Survey	Survey (Question 5)	Yes
	WS05	Peak Season Demand Ratio	Busiest operational month compared to the yearly average.	Ratio between flight hours in the busiest operational month and the average monthly flight hours for the year.	OAG	None	No

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