FLIGHT SAFETY FOUNDATION

GLOBAL SAFETY INFORMATION PROJECT

Data Analysis Toolkit

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Welcome

Thanks for your interest in enhancing aviation safety data collection and processing systems (SDCPS). This toolkit conveys knowledge gained by Flight Safety Foundation about data analysis practices (an element of *data processing*) among aviation service providers — such as airlines, aircraft maintenance and repair organizations, and air navigation service providers — and civil aviation authorities in two world regions. We see opportunities to further standardize the work of data analysts as they address the most critical accident categories in commercial air transport, business aviation and other industry sectors.

Aviation service providers, the largest group of stakeholders, ideally will progress from basic to advanced stages of data analysis, much as their organizations evolve through the intensity levels discussed in the companion *Data Collection Toolkit* prepared by the Foundation's Global Safety Information Project (GSIP).

Aviation industry data analysts, at a minimum, monitor safety performance indicators (SPIs), which focus on the highest risks that need to be addressed across your organization, and formally declare their risk levels according to a standardized risk matrix (i.e., probability versus severity). Typically, you will later identify the main drivers and obstacles to improving SPIs, trace events that have driven trends and identify primary causes from sources such as accident reports and report summaries.

At subsequent advanced levels, you will look outside your organization to address the influences of operating conditions seen elsewhere and/or to thoroughly study investigative findings and contributing factors. We encourage you and every stakeholder — including regulators — to derive the most actionable mitigation plans possible in order to avoid becoming so mired in high-level theory that you never take concrete action.

Some aviation industry data analysts focus on data metrics chosen because of a known close relationship of the metric to an undesired state (in the terminology of bow-tie analysis), such as an undesired aircraft state. An undesired aircraft state is a condition that, in the absence of an adequate response, may lead to an unwanted outcome such as triggering a special warning to the flight crew, exceeding an operational limit or contributing to fatalities, injuries and/or damage in an accident. You will supplement these data metrics with others that "fill in the picture" of your most likely range of issues/situations leading to undesired aircraft states, all eventually leading to risk mitigations.

The Right Analysis

Participants in our focus groups and workshops raised concerns about challenges they face in performing the "right" analysis, one that accomplishes the stated goals. For example, flawed analytical practices sometimes degrade results — or worse, intentionally non-objective techniques produce predetermined (favorable) results.

They noted that aviation service providers also discover valid but unexpected results from a particular choice of analysis. For example, a single report can identify a new hazard (whereas many reports usually are required), and, at other times, a new trend emerges as the most significant hazard. Both situations should be anticipated and addressed in your safety management system (SMS) or the SMS of your state safety program (SSP). Ultimately, a data analyst must produce credible evidence of whether the risk of the particular outcome is acceptable (that is, whether to stop operations, require monitoring or allow flights or other aviation operations to continue).

In several states, representatives of airlines told us that sometimes they cannot be confident about the accuracy of data trends that regulatory authorities generate from airline data. This may introduce uncertainty as to which risk-analysis techniques work best when introducing new aircraft types, new technologies and systems.

Other challenges in achieving the right analysis are conflicts in terminology and taxonomies that interfere with data analysts properly classifying data or analytical results for comparability; effects from varying quality and quantity of data that are not considered adequately; and de-identification of data (which some call *filtering*) that protects source confidentiality to the extent of constraining or blocking analytical insights.

Other issues mentioned included insufficient data-mining capabilities (possibly limited by restrictions in public safety information); lack of scalable data analysis methods to enable industry-wide results to be applied by individual operators; and missed opportunities to collaboratively identify systemic hot spots. Flight data monitoring programs, despite strong endorsement by chief executive officers, have some of the most complex data parameters and the most difficult challenges for effective analysis, airlines said. While these programs have the potential to identify exceedances across a number of event sets, it takes extensive time and effort to customize these programs to an organization's operational norms, they said.

Other stakeholders described stark imbalances in which the *data collection* activities take precedence over *data analysis* capabilities. The GSIP researchers concluded in part, "The organization and analysis of a large volume of data can heavily consume both time and resources. This can make reaching accurate conclusions difficult. Financial and human resource limitations also impact data analysis. There are a limited number of SDCPS specialists [in some states] with adequate educational qualifications and applicable work experience."

We have highlighted concepts and best practices in this toolkit to help you make tactically sound choices about how to analyze data collected within your SMS, including risk management within your state safety program, based on information shared with GSIP researchers and on the FSF proposals.

Traditionally, inspectors and auditors looked for a system's absolute compliance with a regulatory requirement as the principal countermeasure to aviation threats and errors. Today, a major role of data analysis is to predict the effectiveness of barriers through analysis of data metrics. (The effectiveness of relying on regulatory compliance versus barrier effectiveness metrics has not been established.)

Toolkit Introduction

This *Data Analysis Toolkit*, partly based on input to the Foundation from participants in focus groups and workshops, responds to SDCPS stakeholders' requests for a harmonized taxonomy and terminology for SDCPS across the globe so that every stakeholder can easily exchange replicable, real-world examples of SPIs, safety performance targets, bow-tie diagram–based analyses, and other best practices.

Analyzing safety data has become the norm among airlines in several parts of the Asia and Pacific and Pan America regions of the world, GSIP researchers found. Some GSIP participants said they strongly favor a high level of global standardization in SDCPS practices in data analysis, including related quality standards. Over time, we intend for the *Data Analysis Toolkit* to further explore existing best practices, especially how to consistently capture significant insights from flight data monitoring processes.

As explained in the *GSIP Toolkits Introduction*, some aviation safety professionals find it helpful to perform data analysis for their organization with awareness of the intensity level continuum (see the matrix on page 6). We likewise recommend self-assessments over time of your risk-management practices while keeping in mind the intensity levels defined for GSIP.

- As with each of our toolkits, GSIP proposes common terms to describe a progression in the intensity level of any SDCPS. If your organization is operating at the first level, you are routinely conducting basic-analysis activities to display your rate of occurrence on key SPIs against a specific target and against past performance levels. For example, if your organization has an SPI for resolution advisories from traffic-alert and collision avoidance systems (TCAS RAs), you regularly calculate performance in this area against your organization's current annual safety performance target for TCAS RAs.

  Your organization also continually conducts risk assessments on any newly discovered hazards. Each risk assessment indicates whether mitigations are required and, if so, which person or department is responsible for managing the risk and taking necessary mitigation actions. Organizations generally use an internally generated, but standardized, risk matrix to determine acceptable levels of risk, levels that require ongoing monitoring as risk mitigations continue, and levels that are unacceptable for operations until an effective mitigation is in place.

- If your organization is operating at the second (higher) intensity level, you calculate rates from other data that contribute to the top-level SPIs. At this level, your organization can track and plot performance based on the dependent conditions that create, for example, the TCAS RA events. TCAS RA events may be driven by hearback and readback types of air traffic controller–pilot clearance miscommunication. The appropriate analysis to be conducted in this situation would outline all the specific causes of TCAS RAs experienced throughout the reviewed period. The analysis can include examining hot spot areas overlaid on a navigational chart or airport diagram. It also can include basic breakouts (subfactors) of key situations that lead to a TCAS RA.

- If your organization is operating at the third intensity level, you generate more mathematical and statistical indicators of the effectiveness of some of your barriers to an undesired state through your safety assurance data. These may combine sources such as flight data monitoring, line operations safety audits/assessments and inspections. These efforts indicate where you will find specific weaknesses to be addressed in each set of barrier processes. Generally, it is a difficult task to make a complete determination of barrier effectiveness and to understand your degree of compliance with standard operating procedures prior to TCAS RA events. Statistical controls also can be applied to a number of barriers by establishing performance requirements to meet acceptable levels of undesired aircraft states.

- The fourth GSIP intensity level means that you understand, to the most complete extent in bowtie-analysis language, all the barriers and the recovery effectiveness — at the entire-industry scale and in cooperation with state, regional and global regulators and with the world community of aviation service providers. This may only be possible when your analysis is conducted in a collaborative method with all responsible stakeholders.

In some countries or regional groups, gathering industry results and publishing collective performance information from many participants gives the best sense of the risks to the commercial aviation industry, for example. Issues like TCAS RA hotspots can be understood to a much greater degree and lead to mitigation efforts that are based on a wide range of experiences.

Your starting point likely will be assuring that data analysis for your SDCPS occurs in accordance with standards and recommended practices published by the International Civil Aviation Organization (ICAO) in Annex 19, *Safety Management,* or more specifically under your state's Annex 19–compliant civil regulations and related guidance.

Key Insights and Considerations

As noted in the *GSIP Toolkits Introduction* — regardless of your organization's level of intensity — you can calculate and predict, from the probability of the specific threat and the probability of a known unsafe outcome, how effective your existing barriers will be.

That document strongly recommends taking advantage of the power of *bow-tie diagram* methodology in your SDCPS. This is an appropriate and readily understandable framework for analyzing data streams, and it is compatible with your data collection, data analysis, information sharing and information protection activities. In data analysis, this method is especially worth considering because of what the diagram reveals across the most prominent accident paths (i.e., links through a bow-tie analysis) that you study.

Studying bow-tie diagram connections (interrelationships) among threats, undesired aircraft states, barriers/barrier failures, recovery actions/recovery failures and outcomes on the diagram enables you to take a quantitative approach. That is, you calculate numerical scores accounting for severity and probability, avoiding problems of a more subjective/qualitative approach. Because mathematics and statistical probability can connect any accident path to any undesired outcome on a bow-tie diagram, you can readily determine the highest priorities for risk mitigation. The bow-tie diagram also provides a top-down look, giving you the best picture of key accident paths — and what further data and studies are necessary.

Adopting this method begins to generate a top-down look at your SMS, showing where you need to plan to have an audit/inspection, where you need to obtain safety performance feedback and data, and how you will manage the resulting risk register. For commercial air transport stakeholders, we noted in our *Data Collection Toolkit* that the U.K. Civil Aviation Authority has published template bow-tie diagrams for its Significant Seven accident categories (airborne conflict, controlled flight into terrain, airborne or post-impact fire, ground handling, loss of control, runway excursion and runway incursion). These bow-tie diagrams can serve as a data-analysis starting point for any aviation service provider or regulator studying these or other accident categories.

By determining which data streams are crucial to understanding your highest-risk issues, your own bow-tie diagrams will point you to the necessary data and analyses. You can start with the currently known, fatal accident risk numbers, then work back through accident/incident data, data from mandatory occurrence reporting, and eventually voluntary safety reporting data. This yields what you can expect to see in your actual risk and SPIs. In many ways, the data collection requirements may grow through iterative steps as your analysis strengthens.

In short, bow-tie diagrams provide preliminary understanding of the areas of analysis within your SMS (or the SMS of your SSP), including a deep look into key connections between your barrier effectiveness and undesired aircraft states. The diagram serves as an objective basis for refining data collection, enhancing audit and inspection programs, and calculating the overall barrier effectiveness in some accident paths.

From these diagrams, you can determine where additional collaborative work is indicated, encouraging stakeholders to come together to share and exchange data relevant to the specific diagram and accident paths. This is important because no individual stakeholder likely will be able to assume responsibility for all threats, barriers and recovery actions. Watch for examples of fellow stakeholders' other best practices for data analysis in the *Data Analysis Toolkit* as this website is updated.

Community Insights

Over time, plans call for our *Data Analysis Toolkit* to add links (under this subtitle) to include detailed examples of international best practices in risk analysis, as well as references to information sharing and the importance of safety information protection.

Such stories and lessons learned ideally will incorporate data analysis illustrations for subjects such as assessing risks through airline self-assessments and external auditing. Data visualization examples also are being curated to show the latest ways that event data, rates and correlations between one data stream and others enhance comprehension and inspire replication.

Guidance Resources

Regarding international expectations for safety data analysis in civil aviation, as noted earlier, first check ICAO's standards and recommended practices — starting with Annex 19, *Safety Management.*

GSIP researchers find that normalized rates of occurrence have been produced for just about any risk management topic. Therefore, success in making valid comparisons during data analysis is increasingly likely. Often, the normalized rates are available to share with safety professionals as discussed in our *Information Sharing Toolkit*.

Opportunities to Share

From the outset of GSIP, Flight Safety Foundation has requested permission to publish brief de-identified narratives, articles and illustrations about safety data analysis experiences from aviation safety professionals and organizations. We welcome you and fellow Data Analysis Toolkit visitors to take advantage of this website to share with peers worldwide how you have turned generic data analysis techniques into best practices that fit your organization. Hundreds of GSIP participants and many others will appreciate the chance to learn from your experiences, and we will follow confidentiality standards recommended by the U.S. Federal Aviation Administration and Flight Safety Foundation on vetting materials and protecting your privacy.

Global Safety Information Project (GSIP)

Overview Matrix Of Intensity Levels

Risk management is a tool for decision making and improving safety performance. As it is executed, additional learning continues to take place, which expands our knowledge on hazards and our horizons of influence. GSIP recognizes this ever-expanding growth of risk management and therefore incorporates a level of intensity across our toolkits. The following chart includes a simplified version of the different levels of intensity across all risk management safety activities.

	SMS Core Level	Expanded Level	Advanced Level	Industry Level
Data Collection	Data are collected to adequately monitor the normal hazards an organization may encounter and to support a functioning SMS.	Data are collected to understand both the hazards and exposure to operations with those hazards (e.g., *flight data acquisition systems).*	Data are collected to advance understanding of primary causes and contributing factors (e.g., *monitored data through LOSA).*	Data are collected to utilize and contribute to a larger industry understanding through bow tie organization of events (e.g., *data collection with industry partners).*
Data Analysis	Data are analyzed to determine acceptable risks. Safety performance indicators with current status against objectives.	Data are analyzed to understand all direct hazards and their impact on undesired outcomes. Multiple hazards are each examined for their influence on risk.	Data are analyzed to understand all potential direct and indirect hazards and their impact on undesired outcomes.	Data are analyzed to understand all industry impacts on safety. The math behind paths leading to and from an undesired state are well understood.
Information Sharing	Information sharing of performance results is comprehensive within an organization (e.g., within one organization).	Information sharing of performance and key areas of linked performance is performed among divisions or industry peers at detailed levels (e.g., ANSP to ANSP).	Information sharing is across the industry for key risks and mitigations. Generally this is through presenting detailed independent investigative work in the data (e.g., ANSP to airline).	Information is shared and managed across the industry for benchmarking capabilities and emerging conditions. Cooperative analysis is conducted (e.g., pooled data).
Information Protection	Individuals and organizations are protected against disciplinary, civil, administrative and criminal proceedings, except in case of gross negligence, willful misconduct or criminal intent.	The protection extends to certain mandatory safety reporting systems. In Annex 13, the protection extends to final reports and investigation personnel.	Further protection mechanisms may be in place to implement just culture principles and cross-industry support for strong safety reporting cultures.	Protection is formalized at the highest level between countries through memorandums of understanding or similar agreements.

ANSP = air navigation service provider; LOSA = line operations quality assurance; SMS = safety management system