Measuring Safety Performance: Strategic Risk Data

(Airline Safety and Human Factors Issues)

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Abstract

Airlines measure safety performance to understand the state of the operations. Much data is collected but it is far from obvious how to handle all the data, act on the result or even to know what can be measured in a meaningful way. The overall purpose of this study is to propose a method for airlines regarding how to evaluate and improve their current practices related to safety performance monitoring and measurement.

Mandatory and voluntary reporting systems capture aspects of the operations but are largely retrospective and do not by themselves provide a predictive safety performance monitoring capability. Flight data monitoring programs and other data sources can add a predictive capability. It is of great importance to understand what data to look for and to understand the relationships between various pieces of data to be able to improve in the name of safety. There is also a great need for practical guidance on how to develop a more predictive safety management.

Human factors is the field believed to have most potential to substantially improve safety. In recent research an approach to airline safety management describes the organizational processes in layers of real-time operational cycles, real-time operations support, tactical and strategic organizational processes. When a systemic view on human factors, including individual, technical and

organizational aspects, is applied to this organizational structure it forms a matrix for strategic risk data that may be used in development of a comprehensive safety parameter scope.

It is believed that the currently dominant safety model approach with the discussion of causality and of latent conditions as root cause or causes still has potential to improve safety due to the existing gap between theory and practice. It is, however, a great challenge to bridge this gap. In this research a five-step methodology is proposed to systematically review: 1) currently known safety performance indicators directly related to safety, 2) contributory factors identified in reports, 3) other contributory factors with validated relationship to safety and 4) links between on the one hand the selected safety performance indicators and identified contributory factors and on the other hand contributory factors linked to other validated sources such as human factors theory. With this revision at hand and 5) using all available data sources it will be more feasible to justify current safety activities and the relevance of data collected. This method is also believed to identify feasible areas of improvements and contribute to balancing resource requirements in relation to the safety benefits coming out of the safety program.

Introduction

Like many other industries aviation faces huge challenges and demands in the future for increased productivity and capacity without compromising safety, or even at the same time increasing safety. Human factors (HF) is often mentioned as cause for over 70 percent of the accidents [1]. Many erroneous actions are brought about by poor design of technology, work and organizational factors. With human factors knowledge better integrated into the development of systems, technology and work processes as well as management systems, safety risks may be reduced.

“For the last 30 years human factors has been expressed as the most critical discipline to improve aviation safety. Despite this fact, the verifiable evidence that human factors research has made a significant difference to aviation safety during this time is not strong" [2]. Considerable achievements have however had an impact and human factors remains the central area where verifiable progress has to be made if substantial gains in safety are to be achieved [2].

Reason [3] discusses both the direct active errors leading to unsafe events as well as contributory factors for accidents in terms of latent conditions, always existing within the organization. It is the outcome of active errors that historically has been described in accident and incident investigation reports. Although latent conditions are not always salient in such reports, today the industry is required to shift from a reactive towards a more proactive and even predictive safety management, in which latent conditions or their contributory impact on safety will be analyzed with a greater interest and priority.

There is a discussion within the safety research community stating that the current model has reached a plateau [4] and that there is a need for a shift of paradigm to radically increase safety [5]. It is however argued here that despite the known limitations to the current model there is potential for improvements within airlines by bridging the gap still existing between practice and current safety model and human factors theory. The approach taken in this research takes the Safety Management System (SMS) as proposed by ICAO [6] as a starting point.

In the EU-funded project Human Integration into the Lifecycle of Aviation Systems (HILAS) [7], one of the objectives is to develop a system that integrates human factors knowledge into management of performance, risk and change.

As part of HILAS this particular study is initiated to come up with suggestions how to improve a proactive and predictive safety management capability by increasing the understanding of safety measures such as safety performance indicators and how to make best use of available safety related data.

Purpose and Method

The overall purpose of this study is to propose a method for airlines how to evaluate and improve their current practices related to safety performance monitoring and measurement. By doing that, the integration of HF data not traditionally used should be made possible. This aims at a comprehensive strategic risk data model allowing predictive safety monitoring in an airline.

The part of the study reported on here is the development of a simple systematic methodology, working in practice for bringing human factors and safety risk theory closer to airline practice. This research takes a starting point in what is readily available today in an airline such as existing sources of data, existing regulatory support and guidelines and company practice, as well as human factors research to date.

Innovation lies in making an effort to review the current use of data to theory, building a methodology for both justifying what is currently being done and revising where improvements are feasible or weaknesses revealed. This will also help identify where resources are well spent or more importantly misspent. This paper presents the provisional concepts in how to achieve a meaningful management of existing risk data using finite resources.

Research leading up to this development has mainly been performed within the HILAS project. One source of information is the sharing of knowledge that takes place within the framework of the HILAS project. This research was conducted by a multidisciplinary group of human factors expertise: researchers, pilots, investigators and safety officers in an airline. In addition to an extensive literature review of current research in this area, a number of risk data workshops were carried out. These workshops consisted of initial brainstorming sessions, followed by semi-structured discussion forums. These forums were led by a member of the group and were aided by a range of both internal and external data sources and reference to a generic reporting process. A number of semi-structured interviews were carried out with subject matter experts (SMEs).

An initial safety process workshop examined the intended breadth and depth of this research. An important achievement here was to ascertain industry hopes and anticipated results from this research. This workshop started with a brainstorming session followed by semi-structured discussion of the initial safety parameter scope and detection of safety indicators.

A second data picture workshop was held that further examined the safety parameter scope for this research and focused more heavily on the development of the data picture. Particular attention was paid to the inputs and outputs to and from the data picture and the examination of reporting trend analysis and the identification of safety performance indicators and associated contributory factors. SMEs were interviewed as to the sources that they use as part of the generic reporting process. While attending to the data picture, the clear delineation of internal and external data was made. This workshop also initiated the examination of a number of internal airline safety reports. SMEs presented a number of reports to human factors researchers in order to review the generic reporting process and demonstrate how safety performance indicators and contributory factors could possibly be identified from the data.

A methodology for developing strategic risk data management was elicited from the processes used in this research so far. This methodology was gradually developed as part of the natural process that the group followed and resulted in a proposed methodology that consists of five discrete steps.

Human Factors

The JAA-FAST prioritization of research needs has identified human factors and system change as strategic research priorities for aviation. If this priority is to be fulfilled with a commensurate impact on the aviation sector, then it will have to be based on an approach to human factors, which [2]:

- Is systemic, being fully integrated within each system component of the aviation sector (including technology, organizational systems and social processes),

- Addresses both organizational and operational performance in a valid way,
- Creates the basis for using human factors knowledge captured in both organization and operations for improving both technologies systems and processes, and
- Shows the truly applied side of human factors, developing support for an organization to actually implement human factors knowledge in a continuous human factors innovations system.

All these requirements point to the need to address the way in which human factors knowledge is generated, distributed, implemented and evaluated. The urgency of this task is emphasized by the projected growth of the aviation system over the next 20 years, with unprecedented demands for improving quality and safety while increasing capacity. Reconciling these goals will only be possible if the human and social contribution is addressed in a coherent and systemic manner [2].

The overall goals of the field of HF are to ensure satisfactory working conditions, efficient organizations and competitive enterprises. Clearly, in safety-critical complex systems, safety is a main goal in itself and is believed to be closely linked to the other goals. It is assumed, within the field of HF, that these goals together are accomplished by striving for enhancing human abilities and reducing human limitations throughout the systems in which they act. A systemic view on human factors encompasses several levels such as:

- Interface level (physical or cognitive interface, contextual environment)
- Task level (work content, automation, procedures, methods)
- System level (organizational processes, management systems)

For example a human factors scope could be categorized as the well-known SHEL(L) model where dependencies and interaction between liveware and either software, hardware, environment or other liveware are described. Another way to categorize a systemic view on the

HF scope is by describing contributing factors relating to individual and social processes (social dimension, relations, trust, psycho-social environment, physical, psychological and physiological characteristics), technology (hardware, software, tools, equipment, guidelines and communication) and organizational aspects (management, processes, leadership, psycho-social environment, group dynamics and culture).

Further examples of a common list of causal and contributing factors for accidents [8] that affect performance directly or indirectly are:

- Individual characteristics
- Physical work environment
- Equipment and tools
- Psycho-social work environment (social, psychological)
- Characteristics of work and tasks

Generally these factors affect hazard recognition, decisions to act appropriately and ability to act appropriately, which affect safety in aviation. The inclusion of human factors in organizational processes links strongly to accident and safety models and aspects of latent conditions contributing to poor performance in real-time operations. In fact most of the human factor theory given so far is included below in a causal description of latent conditions in an organization.

Latent conditions are pre-existing conditions or resident pathogens [3, 9] that always are present in an organization. Latent conditions may be poor equipment, interface or task design, inappropriate sleep schedules and fatigue, system design, conflicting goals, defective organization (internal communication), bad management decisions, unsuitable procedures, clumsy automation or training deficiencies.

Most latent conditions start with the decision makers. These people are subject to normal human biases and limitations, as well as to very real constraints of time, budget and politics. The causal story is described to start with the strategic organizational factors and processes: strategic decisions, generic organizational processes, forecasting, budgeting, allocating resources, planning, scheduling, communicating, managing, auditing and the like. The consequences of these are then said to be communicated throughout the organization to individual workplaces, control rooms, flight decks, air traffic control centers and maintenance facilities and so on where they reveal themselves as risks or factors likely to promote unsafe acts.

Risks and factors likely to promote unsafe acts due to their impact on human performance are, for example, undue time pressure, inadequate tools and equipment, poor human-machine interfaces, insufficient training, under-manning, poor supervisor-worker ratios, low pay, low status, macho culture, unworkable or ambiguous procedures, poor communications and the like.

Safety Management System Guidance and Regulations

Central documentation relating to Safety Management Systems in general as well as what to do with safety-related data is the ICAO Safety Management Manual [6, 10]. In this documentation, safety performance monitoring is addressed. The term “statistical safety performance indicators” is explicitly used as a historic safety achievement record. These can be both at a higher level such as accident rates or broken down into areas such as losses of separation, engine shutdowns and TCAS advisories.

The term safety health is used with other indicators relating to organizational activities, e.g. if specific processes are in place. Indicators of poor safety health could also be an inadequate organization and resources for the operations, inadequate training programs or poor safety culture.

In the second edition of the ICAO SMM document [6], safety performance monitoring and measurement form a part of safety assurance. At the same time safety assurance ensures the identification of areas in need of new safety risk controls. Many internal information sources are listed that may help in conducting this work. Both versions of the ICAO SMM have a clear relationship to the reasoning within resilience theory [11].

Like ICAO, Transport Canada emphasizes the importance of assessing individual areas of concern rather than measuring accident rates [12].

In the current EU-OPS (and former JAR-OPS) the requirements are general and do not go into any depth of detail regarding safety assurance and safety performance indicators, although there is a requirement to evaluate relevant information relating to accidents and incidents, which indirectly implies looking at specific data/indicators [13]. Safety risk management including performance monitoring is part of the proposed requirements addressed in EASA NPA-22c [14]. Since the coming EASA implementing rules will be binding they will be less specific compared to the JAA system to allow for some flexibility. The future system will however rely more heavily on performance monitoring [15].

Reactive, proactive and predictive safety management perspectives are discussed in the second edition of the guidelines and framework from ICAO. The traditional approach has been to react to undesirable events by investigations finding cause and then through regulations and rules avoid it happening again.

Today, ICAO makes a distinction where reactive method responds to the events that already happened, such as incidents and accidents. Reactive safety management may be sufficient. "The contribution of reactive approaches to safety management depends on the extent to which the investigation goes beyond the triggering cause(s), and includes contributory factors and findings as to risks" [6].

The predictive method captures system performance as it happens in real-time normal operations to identify potential future problems. This includes a culture to "aggressively seek information from a variety of sources which may be indicative of emerging safety risks" [6].

In general it is apparent that making use of available data is an essential part of an airline's safety management system. Looking for information not as easily or readily available is equally important. However, information about what to do with and how to handle the majority of data available in an airline is not readily available. Setting an acceptable safety performance target for a large part of the available data may be very difficult if the relationships (to the extent that they can be discovered) between contributory factors and actual outcomes (accident/incidents) cannot be established.

Airline Safety Data

Today most airlines acknowledge a systemic human factors framework, although it in most cases is not explicitly expressed or stated. Implications of that acknowledgement are visible in many areas, e.g. incident/accident investigation methods, content of Crew Resource Management (CRM) training, meeting agendas/minutes, as well as in other organizational processes and activities. Conducting surveys addressing safety culture or other specific areas of interest is also a manifestation of the recognition of deeper underlying factors that are important for the management of airline safety risk.

The issue is not the amount of data. The question is rather how to handle all this data. Without a clear strategy on how to do this airlines may lose focus and revert to simply measuring what is readily available, but potentially less meaningful.

In related research [16] the following main characteristics of the operational risk environment in aviation have been identified:

- Very low rate of serious incidents (hull loss, fatality). Too low for direct computation of an operator (airline, maintenance company) risk index.
- High frequency of discrete operational units (flights, aircraft checks).
- High acceptance of normal operational performance monitoring enables the generation of large amounts of data on normal operational performance (both human and technical).

- Strong institutional and regulatory requirements for reporting occurrences and other operational deviations generate both a wide range and a large number of reports on relatively minor failures (in terms of consequences).
- Rapidly increasing IT integration across the organization, including operational areas, enables the linking of a wide range of data sources (including planning, technical, human resources, operations, quality and safety).

Many sources of data are available such as safety and voluntary reporting, flight data monitoring, technical and maintenance data, training and checking data, line checks, LOSA, inspections, investigations, audits and surveys. Other information such as weather and airport status data, rostering data, flight delays, employee experience, age and medical records are also available. Data characteristics depend on the possible means available to collect data and what can be measured. The output of these systems substantially differs from each other. They can differ both in terms of actual format (electronic/paper) but also in terms of quality, quantity and frequency as well as level of analytical sophistication or rawness. It is for example widely recognized that crews' performance under supervision, such as line checks, differ from their behavior during normal line operations.

Merging and integrating data, automated or manually, from various sources can be very troublesome, requiring investments not only in human resources but possibly also in new hardware and supporting computer systems. The current global economic downturn makes development and innovative investments more difficult to get accepted. Also, often a legacy structure built over time relating to both the selection and use of various tools as well as working routines makes data integration difficult. Some systems may have been developed in-house for a specific purpose. Later, the same system may have been given new features to allow for example new statistical analysis capabilities. Data and/or conclusions from that system should ideally be possible to combine with data from other systems, possibly off-the-shelf systems 10 years younger.

The traditional "silos" within an airline can also lead to a fragmented data picture within the organization. For example, the maintenance department may have purchased a computer system with analytical tools supporting maintenance operations without any consideration of other internal data categorization standards. Similarly the chosen safety reporting classification standard may not be harmonized with other systems' data (or new international standards not available at the time of development). There may also be reluctance within departments to change the classification and categorization scheme to allow harmonization and easier data integration because of a perceived risk of giving up the historical data record.

Discussion

From the regulatory requirements and guidelines it is clear that the use of data and safety performance monitoring and measurement is an essential part of an effective safety management system. However, how to do it in a smart way is not described very explicitly. Although the regulatory guidance indicates that efforts relating to safety indicators should go beyond merely looking at the absolute obvious, again, practical guidance is needed. The regulatory framework sets a minimum monitoring and measuring standard to build on. This may on the other hand lead to a compliance culture rather than a developing and innovative culture where new ways of probing the organization are explored. Dijkstra [17] describes how "airlines safety departments to some extent do what is expected and do what they always have done with little thought of the real reasons for doing things that way."

Yet, many of the proposed measuring activities from various organizational bodies are already taking place in many airlines. In that sense many airlines already meet the key issue of being predictive rather than reactive in their safety work. The fact that many of the recommended practices relating to safety performance monitoring/measurement and an SMS already are taking place in an airline do not automatically mean that those activities actually are effective. Work within this research proposes an expanded picture of a predictive safety parameter scope integrating data in new ways.

Predictive Safety Parameter Scope

When describing how to be predictive the monitoring of normal operations is often mentioned. Given a human factors scope that covers the full organizational context, this implies that monitoring normal operations not only covers the monitoring of the actual flight operations but also to the extent possible the monitoring of all organizational processes and activities.

Various types of data about the organization and the operations are already available in an airline as described earlier. Most data, however, is without doubt from the actual flight operations context. In general, the closer you are to the real-time operations the closer you are to actual safety-related outcomes. The higher up you move in the organizational layers the further away you move from actual direct safety-related outcomes. These layers are more relevant for understanding latent conditions and measuring contributory factors.

Certain types of data undisputedly relate directly to safety, such as fatal accidents, hull losses and severe incidents. The use of this data is clearly reactive. Other factors relate to safety in less obvious ways. In fact, they may work as blockers/defenses, against risks or as catalysts to catastrophe depending on how they combine with other conditions present. The use of this data may be considered proactive. With careful investigations and aggregating data proactive activities may be conducted with reactive data. In compliance to regulatory guidance flight data monitoring is considered predictive but in case there is no obvious line of reasoning behind the selection of this data it means that the activity may not be considered predictive.

For example, an airline is using a flight data monitoring program, monitoring its normal flight operations regularly and compiling reports showing statistics and trends relating to selected indicators. These indicators may have been selected either based on the airline's own experience of its being relevant for actual safety-related outcomes or because of industrywide and available knowledge about these indicators and their relationship to actual safety-related outcomes. Perhaps they are selected simply because they were easy to measure and meet the regulatory requirements.

How does an airline know that the monitoring and measuring activities currently conducted are effective and justified? As already discussed they can be proactive and justified based on following up and investigating incidents and accidents. The currently selected set of indicators or set of contributory factors monitored consequently have developed over time based on how well the airline has managed to learn from its past safety record. But the chosen indicators and contributory factors that are being monitored and trended may have been selected from the airline's own experience. They may also be based on well-known industry and research information and facts about the importance of various factors on safety. Ideally the chosen indicators and contributory factors should be selected based on knowledge both internally and externally.

Possibly an airline is not aware if the current safety performance monitoring and measurement activities cover the full human factors scope. The airline may also not be fully aware of how the safety performance indicators and other safety-related performance monitoring have come about. To expand the current safety performance monitoring and measurement, "self awareness" about the current status with respect to this topic is required.

Human Factors Scope

The human factors scope presented so far in this paper covers the full organizational context of an airline, including the individual, technology and organizational aspects.

Within HILAS a model is under development consisting of four different organizational layers starting with the real-time operational cycle layer followed by the real-time operational support layer and finally the tactical management process (occurrence layer) and the strategic management process (system layer). Ongoing and continuous interaction takes place within and between layers. Processes at all of these layers contribute to the overall safety performance in the real-time operations. Supporting these activities and communication is a data management structure. Data in itself can take various forms as addressed above.

Drawing a table with a human factors view covering individual aspects as well as technology and organizational aspects on one axis and the four different organizational layers on the other axis covers the safety parameter scope or in other words an airline human factors scope. Throughout this matrix it is then possible to identify relevant human factors parameters. It is also then possible to map relevant latent conditions and possible unsafe outcomes. Exemplifying dependencies between these should contribute to bringing practice closer to theory and to support safety activities.

There is an important distinction to be made between actual known safety-related outcomes such as serious incidents and accidents on one hand and possible contributory factors on the other hand. On the one hand there are the known outcomes and on the other hand there is the known theory behind what is affecting human performance. In a space between the two there are possible relationships which could be further explored to find new ways of combining safety-related data in an efficient and relevant way. From this a strategic risk data scope could be derived contributing to a highly efficient and predictive safety management.

Direct Safety Performance Indicators

Safety Performance Indicators (SPIs) are retrospective in nature — they are outcomes of events that have already occurred. When beginning to address the task of structuring data and drawing a data picture, SPIs are the chosen starting point because we definitively know the outcome and have data available. A more difficult task lies in how to select which "day-to-day" indicators to look at, complementing the SPIs.

Naming indicators “safety indicators” is a bold step in itself because it assumes you know what is good and what is bad. Against the backdrop of the widely accepted ideas of latent conditions combining in unexpected ways, it may be difficult to come up with guaranteed indicators, safe targets, etc.

To distinguish contributory factors and indicators in general from key safety performance-related outcomes the term Direct SPI (DSPI) is chosen for the latter. A proposed list of DSPIs is included in table 1. The incidents that these indicators relate to are without doubt safety-related. This does not automatically mean that an incident in itself will lead for example to injuries. In fact, a great majority of incidents are unnoticed by the passengers. However, these same indicators could also include severe incidents, accidents and hull losses.

Each individual airline must determine what constitutes a significant outcome with potentially very serious consequences.

Table 1– *Examples of Direct Safety Performance Indicators*

Examples of Direct Safety Performance Indicators (DSPIs)
Stability/attitude control problem
Runway incursion/excursion
Altitude penetration
Takeoff with incorrect configuration or weight calculation
EGPWS activation
ATC clearance not followed
Hard landings
Stick shaker activation
Tail strike
Emergency declared
Smoke and/or fire aboard the aircraft
Severe wind shear/(wake) turbulence
Failure of aerodrome facilities affecting takeoff and landing performance
Air proximity (including TCAS RA)
Bird strikes
Engine shut-down/failure/overheat/fire/stall
Landing gear (including brakes) problems requiring use of non-normal procedures
Flight control problems requiring use of non-normal procedures
Loss of electrical source
Fuel distribution problems requiring use of non-normal procedures
Fuel spillage
Significant loading error or loading errors of dangerous goods
Incorrect de-icing or the need for de-icing not discovered
Unruly passenger onboard
Threats (bomb, hijack)
Stability/attitude control problem
Runway incursion/excursion

The Direct SPIs should together give a rather full picture of the (past) safety status of the airline. The fact that these indicators are retrospective is not the same as them being of no value. They may indicate where to look deeper, contribute to the safety awareness, etc. The fact that an organization is looking deeper at them may also help to identify (unrelated) new safety hazards. Ideally, the DSPIs can also be linked to further underlying contributory factors.

The ultimate task involved in this research is to establish a way in which to reliably predict future outcomes and risks from examining the past. It is the relationship between the selected DSPI and the factors that contributed to the outcome in a unique way that informs us of a potential hazard. The investigation of further underlying contributory factors must consequently be pursued in order to distinguish the unique relationships between the factors and the DSPIs.

Contributory Factors (CF)

To enable looking forward by examining the past and the present, the underlying events of an occurrence rather than the actual occurrence itself must be investigated. Integrating and discovering subtle trends from various systems where the information separately may be insignificant but together forms a significant negative trend is not easy.

This is where the data picture starts to get very complicated and consequently it is of vital importance that (event) data is clearly and systematically categorized across the airline *as a whole*. Without a clear picture of this information, it will be almost impossible to trace relationships between DSPIs and contributory factors accurately or reliably.

In addition to the question of how to use available hard data, the question of how to combine this data with "soft" human factors data such as culture, management commitment, personal communication, etc. arises. This again demonstrates how important it is to have a clear and structured format for listing all data. If data is categorized in the correct manner and their source information is also clearly linked, it will be much easier to integrate data from different sources and in different formats. Without such a structure, the data will be blind from both input and output.

Integrating Data

To actually link all information/data together in an inclusive way, creating a full understanding of the "safety state of the airline," is however not easily achieved. In order to make practical use of the data some selection or combination of indicators must be made. Without a clear idea about how to do that it may be difficult to move beyond looking at what is easily measured.

All the factors related to safety risk in aviation may be combined to create the possibility of an integrated assessment of risk, which has the following characteristics [16]:

- It links data representing the state of the system to data representing a variety of outcomes of operational activity. This is the basic requirement for the analysis of risk.
- No single metric of system failure is possible. Rather it is necessary to construct a composite metric compiled from different types of outcome. These will include technical, operational and human performance indices, which relate to different degrees of severity of outcome (from normal operational success to mandatory reportable occurrence).
- A wide variety of different data sources (again representing human, technical and operational factors) is relevant to defining relevant states of the system, which potentially are probabilistically related to the composite of outcome metrics outlined above.
- The risk metric is therefore based on a complex process of statistical data analyses, driven by reasoned judgment, which constructs a balanced analysis that integrates all relevant information in a composite overview.

Within the HILAS-project an effort has been made to discuss how to capture technical data and link it to human factors data, thereby bringing new ideas to the HF scope [18]. In this work a model of HF influence and traceability for maintenance organizations is explored. Aggregating and using this data will allow for monitoring correlations and regressions between human factors and key performance indicator data.

A system process model description helps to better be able to understand how a specific piece of data fits the overall picture. In other parts of HILAS, research is carried out to develop an operational process model of the operational system in order to manage and make sense of this complexity in range and types of data [19]. Even without an operational process model this complexity may be dealt with by systematically reviewing available sources of risk data, available types of data by a theoretical line of reasoning. Perhaps then new relevant combinations of various data may be linked to a comprehensive scope of human factors with regard to safety in aviation.

It is assumed that there is still potential to improve safety using already available airline data by utilizing data in new and integrated ways. As already discussed, a vast amount of data is available within the systems of an airline. Additional data and information gathering may further add to the picture but may not be first priority. A five step method is proposed that on paper may look simple but in reality may require some deep rethinking about current airline data handling practices. The method addresses how to make best use of the data already available within an airline. By going through these five steps an airline should be able to discover where efforts are worthwhile or when a different approach may be more appropriate. Also, the simple fact that the organization is addressing these issues may in itself contribute to the safety culture and safety awareness of the organization.

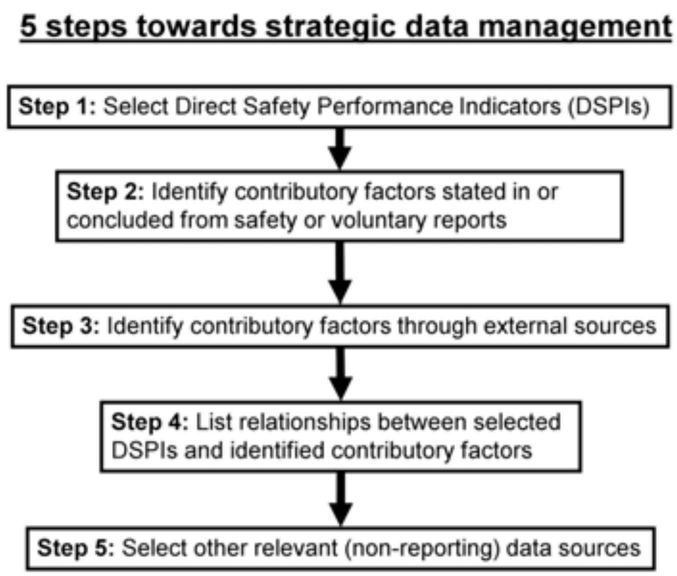
Developing Strategic Risk Data Management

By developing strategic risk data management this research attempts to show that it is possible to improve the prediction of future safety risk scenarios and prevent them, by examining the past whether it is based on incident data, normal operations data or other organizational data.

The following proposed five steps evolved as a methodology to address the issue of systematically reviewing what is known and what is measured and if current safety activities are justified and smart with regard to this. This methodology hopefully helps shed some new light on how available data may be used to its full potential. Potentially some activities may be identified as meaningless. It may also become apparent that some data is lacking to cover a truly predictive safety parameter scope.

The systematic way in which we approached this research question is contained in the following five steps (figure 1):

Figure 1. 5 Steps towards strategic data management



Below, these steps are described and explained in greater depth. Examples of challenges that are associated with each step are also described.

Step 1: Select Direct Safety Performance Indicators (DSPIs)

This step involves the selection of DSPIs (as described above) to particular issues, concerns and operational outcomes that the airline wants to address, define further and analyze.

The DSPIs should initially primarily be chosen irrespective of possible means of collecting data relating to them. The DSPIs can however arise from issues highlighted in incident/accident reporting, from current issues noted by senior management, from fleet captains, perhaps highlighted by the training department, by other airlines, airport operators or indeed industry regulators.

It is important that the Direct SPIs selected reflect the individual nature of the organization's practices, culture and nomenclature. For the purpose of the development of the strategic risk data management it is also important that each individual organization define its DSPIs.

Example of challenge	Possible resolution
Limiting the selection of the DSPIs to key safety related performance outcomes rather than including everything from the beginning	Start with a top-10 list.

Step 2: Identify Contributory Factors stated in reports

This step involves reviewing the contributory factors and possible root causes as concluded in internal investigations and occurrence reports relating to the selected DSPIs (in step 1). Reports should be examined and investigated in order to determine the contributory factors associated with each DSPI. Each identified corresponding contributory factor should then be listed, with its relationship to the DSPIs, building up a data framework. Step two requires the examination of existing data available (i.e., internal occurrence and safety reports to date).

Example of challenge	Possible resolution
Data are not categorized in the same way as the identified and selected Direct SPIs or subsequent investigations are incomplete or non-exhaustive.	This is difficult, especially if the report is short or scant in detail (as many of them can be), but it is important to get as much information as possible from the original source before going elsewhere. It could be appropriate to examine other internal reports on the same DSPI to look for terms that can be associated with the specific DSPI that are perhaps not mentioned explicitly.

Step 3: Identify Contributory Factors through external sources

Select other contributory factors through other external data available such as external databases, regulatory reports or research articles. This process is the same as that of step 2. Expand the list of contributory factors and relate the new ones to the selected DSPIs, if possible. The only difference is that the reports and information are external as opposed to internal. The list of DSPIs and contributory factors within the data framework becomes expanded.

Example of challenge	Possible resolution
What happens if the contributory factors found are too generic to be linked to specific SPIs in a meaningful way?	List them anyway to expand the relevant data picture.

Step 4: List the relationship between selected DSPIs and identified contributory factors

Steps 1 to 3 are concerned with ascertaining what data and sources of information you have, where it comes from and in which format. This ensures that data are comprehensive and comprehensible. Limitations and difficulties with the current practice should become apparent. Step 4 begins with the examination of the relationships between individual elements of the data so that the data picture becomes meaningful. It involves listing on one hand the possible relationships between the contributory factors and the DSPIs and on the other hand justifying the contributory factors by line of reasoning from a theoretical perspective or other source.

The act of listing the relationships (between the contributory factors and safety performance indicators) itself takes the form of an exercise in deducing the strength that each contributory factor has on the DSPIs (bearing in mind that this strength can be both positive and negative).

Determine how to describe and measure the strengths and weaknesses of these links/relationships. A suggested approach is to ask SMEs to interpret a number of reports and to establish their thoughts on how factors either mitigated or exacerbated the outcome. Once relationships and their relative strengths have been defined this will facilitate the analysis and investigation of contributory factors that are present in normal operations as well as in incidents and occurrences. No relationships between a contributory factor and a specific DSPI should be assumed. Only determined relationships should be listed.

Example of challenge	Possible resolution
Unable to list any relationships.	Use the data framework as a template for systematically working through each DSPI and assigning the corresponding CF identified in steps 2 and 3. Steps 1, 2 and 3 gradually build up the data picture for an organization. By following these steps in order, users will be guided through this process of establishing internal data pictures firstly, and then examining external sources thereafter. The use of a data framework delineates data relationships derived internally or externally whilst allowing comparison between the two.

Step 5: Select other relevant (non-reporting) data sources

This step requires the consideration of the other tools that may be used (i.e., sources other than reporting systems) for measuring the contributory factors determined to be important. To achieve this it may be useful to interview personnel who are involved in the analysis and handling of reports, as they will have first-hand knowledge of the systems and different data sources available. This would not only include staff from the safety department, accident/incident investigators, human resource staff, the training department, etc., but also operational and technical personnel. This may seem like an enormous task. However, at a first stage it is primarily intended to create awareness and better understanding of current practices and helps prioritizing future activities and improvements.

This step includes relating or combining various types of data from within one data source (such as FDM data) or by combining data from multiple data sources. Such an approach is aided by having a reference tool such as the data framework.

Example of challenge	**Possible resolution**
Integrating data from various sources is very difficult and resource demanding.	Integrating data from numerous formats will always require some effort. However, this task requires less effort if you have already established a data framework to make reference to. If too many resources are deemed required, initially be satisfied by the knowledge about what you know and what you do not know.

Once step 5 has been completed, the data picture has been defined in terms of DSPIs and relevant contributory factors, both contributory factors possible to link to specific DSPIs as well as contributory factors known to be important for airline safety performance in general. After conducting these five steps it should be possible to justify current safety activities and judge the relevance of data collected. The resulting safety parameter scope and the development of a strategic risk data picture should be considered a continuous process as managing, maintaining and monitoring data are ongoing tasks.

Future Research

Further empirical research is currently being carried out to implement, evaluate and validate the methodology to date. This involves the use of existing airline data and other available external information. Future research may also address how to best share analyzed and rich data within the aviation industry.

Concluding Remark

The analysis of data as discussed in this paper implies that by identifying causal relationships between various types of data in new ways it is possible to become more predictive. Of course it will not be possible to eliminate all latent conditions by this work. But the logic assumed here is that many analyzed identified risks do have relatively simple causality and that there is a potential, still, to improve safety using this logic since much data existing in the system is not fully explored today.

Throughout this paper, considerable effort has been made to contextualize this research within the parameters of current practice (in the field of aviation), historical methods, regulatory guidance and models for rationalizing risk. Many historical practices are by some considered redundant and the future is considered (by many) to lie in resilience engineering, whereby an organization and its practices must strive to be resilient in order to be able to survive and to function to full potential. This paper proposes a method to explore if these traditional methods/models have indeed been bled dry or if there is still some life left in them. Perhaps you do not have to choose, but the middle road exploring both sides, combining data in new ways as well as developing the resilience concept as you walk along may be the most fruitful and pragmatic path. In fact, it may be two sides of the same coin.

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