The measurement of system-wide safety performance in aviation: Three case studies in the development of the aerospace performance factor (APF)

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Aviation growth has been accompanied by a plethora of measurements for the performance of its components. Whilst in some areas this is relatively straightforward, e.g. delays or fuel costs, safety is one area of major concern to the major actors in aviation in which it is difficult to measure performance adequately. Currently, safety performance is measured by the use of reported accidents and incidents that compromise certain specified safety criteria in a number of operational areas. A drawback with such measurements is that they can distort the subsequent mitigation efforts by focusing on the performance of a particular local safety measure, rather than considering an integrated system-wide measure.

This paper presents the development of the Aerospace Performance Factor (APF) an approach to the measurement of safety performance using multiple localized safety measures, e.g. reported incidents, weighted by subject matter expert judgment, and normalized against system operations. The weighting is achieved by the use of Analytical Hierarchy Processing (AHP), a methodology used in multi-criteria decision-making analysis. AHP enables a decision maker to portray the relationships between many facets of a complex problem, and incorporates both quantitative and qualitative information including experience and intuition. Hence, the APF methodology can be applied to any organization that needs to assess risk or performance, based on a complex set of metrics.

The paper discusses the philosophy as well as the experience of the implementation of the APF in a number of aviation safety performance measurement applications. Section 1 outlines the state of current measures of aviation system safety, especially those based upon incident data and highlights how perfectly well the APF complements them. In particular, the APF fills a major gap in the current system formed of multiple, discreet measures, by providing a system-wide safety performance measure.

Section 2 defines the methodology used for the APF design and in particular outlines the following:

i) data considerations;
ii) use of subject matter experts;
iii) the use of AHP;
iv) presentation of the APF and uses for diagnostic testing;
v) validation of the results;
vi) effort required in development.

Section 3 then outlines three case studies of APF implementation within the USA and Europe as well as between airlines and Air Navigation Service Providers (ANSPs). The paper concludes in Section 4 with a recap of the lessons learned and outlines further directions for development.

1 State of the art in Aviation safety performance Measurement

1.1. Introduction

Aviation has increasingly sought to measure the performance of its various elements by means of metrics and indicators, a trend that will be further accelerated by future systems such as NextGen in the USA and SESAR in Europe. For certain elements such metrics are relatively straightforward, e.g. capacity and delays, but appropriate safety metrics are less so. An obvious metric is the number of accidents, as ultimate indicator for achieved safety. However, accidents are rare and this metric alone fails to convey the true current state of safety for a system as complex and dynamic as the aviation system. Further, an individual's perception of what constitutes "safe" involves significant personal beliefs based on experience thus making a single metric elusive.

Focus is thus placed upon incidents, i.e. events that can be considered as breaches of specified safety thresholds, which, apart from being more numerous than accidents, are considered to be early warning signals of a potential deterioration in safety. However, problems also lie with the use of incidents as indicators, ranging from their definition to their reporting and the associated reporting culture. Furthermore, having many incident categories may render the assessment of safety at systemic level rather complex. This would require a coherent assessment of the relative importance of multiple incidents and such an assessment will only have credibility if undertaken by subject matter experts with considerable field experience.

Given that incidents are increasingly collected in a reliable manner, it may be possible to develop a safety indicator that incorporates both such multiple sources of data and a coherent judgement about their relative importance. Subsequently, the safety performance of a given system can be measured over a given time horizon, enabling an enhanced risk assessment of the aviation system to be made.

1.2. Current data Collection

I.2.1. The Federal Aviation Administration

The US FAA has historically collected the following data to measure the safety of the system:

- Operational Errors (OE), where less than the prescribed separation exists between two aircraft, subsequently categorised into Category A, B, C, and D, PE (Proximity Event), MVA (Minimum Vectoring Altitude) and Flight Formations, depending on certain criteria;
- Operational Deviations (OD), where an aircraft infringed on an area of airspace;
- Pilot Deviations (PD) – where a pilot deviated from a rule or ATC instruction;
- Runway Incursions (RI), where there is an unauthorised aircraft, vehicle or person on a runway. RIs are subsequently subdivided as Category A, B, C, and D, depending upon certain criteria,
- Near Midair Collisions (NMACs), where a pilot has reported an encounter with another aircraft that the pilot considered potentially unsafe,
- Vehicle and Pedestrian Deviations (VPD), a type of runway incursion involving the unauthorised presence of a vehicle or a person on a runway.

Historically, the US air traffic control system's safety performance has been measured by the use of operational errors. Indeed, until the late 1980s the simple count of such OEs was the measure. Later the OE rate, based upon the number of aircraft safely handled by the system was introduced and refinement to incorporate error severity occurred much later.

It is important to note that that these metrics alone are very crude indicators of safety and ultimately they will need to be refined in order to enhance the predictive nature of any aviation safety measurement tool. However, while limited in detail and not encompassing all system-wide mishaps, these metrics did reflect all available data. Additionally, close to 10 years worth of data was available to support the experimentation on trending.

1.2.2. EUROCONTROL

In 1999 a EUROCONTROL regulation (ESARR 2) was adopted. It covers: the reporting and assessment of safety occurrences in ATM; confidentiality and publication policy, and a severity and risk classification scheme for Europe. The underlying objective was to ensure that at national and European levels formal means exist to:

- assess safety performance and related trends over time;
- identify key risk areas where the ATM system could contribute to safety improvement, and take appropriate actions;
- investigate and assess the extent of the ATM system contribution to the cause of all types of safety occurrences and take corrective measures;
- draw conclusions on how the ATM system could improve safety even in areas where it is not involved in accidents or incidents;
- assess and monitor over time whether technical and operational changes introduced to the ATM system meet their predetermined safety requirements, and take appropriate actions.

ESARR 2 requires States to have in place national means for the reporting and assessment of ATM safety occurrences, and to report annually summary data to EUROCONTROL. This allows the collection of categories of safety occurrences in terms of:

- Total accidents and Total accidents with ATM contribution;
- ATM related incidents;
- ATM specific occurrences (i.e. technical equipment failures),and their sub-classification for (*inter alia)* type of operations, phase of flight, flight rules and class of airspace as well as causes (with or without ATM contribution).

While the reporting culture in Europe is still improving, the quality of the data has certainly improved dramatically over the years and EUROCONTROL has been able to populate some of the safety indicators, such as runway incursions, separation minima infringements, level busts. An overview of Europe's safety performance is provided in the annual Performance Review Report produced by EUROCONTROL's Performance Review Commission and in the Annual Safety Report produced by EUROCONTROL's Safety Regulation Commission.

1.2.3. easyJet

At easyJet, occurrence data is primarily collected by the air safety reporting (ASR) process from the report of an event filed by a crew-member of the airline. In recent years there has been a major improvement in the reporting culture and there is a high degree of confidence in the ASR reporting channels in the airline. The ASR reports are submitted to the Aviation Quality Database (AQD)[1] upon completion of an investigation into an occurrence, and the AQD includes over 150 event categories, causes as well as event narratives. Currently, easyJet categorise the safety incident data according to the following four groups:

- Cabin Operations
- Flight Operations
- Ground Operations (easyJet sometimes call this Airport Operations)
- Engineering

[1] AQD is an integrated safety, quality and risk management system, covering all functions from hazard identification, accident/incident reporting, analysis and investigation through to auditing and corrective action tracking. It has been developed by aviation software specialists and has been used for over 20 years by regulatory authorities, airlines and other aviation related organizations

In addition, another source of safety data for easyJet is the flight data monitoring (FDM)[2], which is the routine collection and analysis of digital flight data generated during flight operations to provide more information about, and greater insight into, the total flight operations environment, This FDM data is increasingly utilised for safety information, identification of threats and the reduction or elimination safety risk.

1.3. Limitations to assessing system safety performance

1.3.1. Limitations in the current data collection system

Recent years have seen major improvements in the collection and analysis of safety data by major aviation organisations, whether they be ANSPs or airlines. Whilst there is much to commend the current safety data collection system, there are still a number of limitations and the example of easyJet serves well to highlight these.

Though the airline is currently compliant with regulations regarding its representation and trending of hazards and operational risk, the monthly trending of events as system risk indicators has limitations. Prime amongst them is the fact that the representation is prone to bias by low frequency, high risk events. Furthermore, this representation is not uniform through areas of flight, ground, and engineering and cabin operations.

Whilst the trend analysis of events at easyJet has been adequate to date, due to the expertise and knowledge of the investigators, as the airline expands its operations, increasing variability may occur in the standards of investigation and the perception of risk due to the potential for higher variability in the experience levels of the investigators.

Another aspect to consider is that of the presentation of safety data to the high-level management of the airline. Currently, management is informed of company system risk once a month through the use of a single graph. This representation has no discrimination (or “drill down”) capability for assessing the contribution of the individual departments and their sub departments. Whilst this representation is based upon AQD and FDM data, the representation can be biased by an individual department’s high-risk events, which consequently distorts the perception of the whole system performance. This requirement to represent operational risk from current operations to the senior management, in a clear and understandable format, is similar in all the organisations studied as it provides for a focus as to where resources need to be directed to reduce future risk.

These issues exist in ANSPs as well, due to the use of limited safety metrics. Charts are often comprised of individual measures grouped together with limited trending to “this time last year” comparison and showing a high-level perspective of the organization’s performance.

1.3.2 The requirement for aggregation

The previous section has outlined that the aviation system has traditionally relied on safety metrics based upon individual elements associated with incidents and accidents to gauge performance. In itself, that has served a useful purpose in focussing safety resources on the chosen elements. However, the choice may also lead to distortion as anchoring safety performance on one or two individual measures may lead to an inaccurate picture of a very complex system.

The case of EUROCONTROL highlights the desire to develop an accurate picture of system safety based upon the use of current safety indicators. In 2003 EUROCONTROL considered that these indicators adequately met the safety needs for reactive monitoring and improvement of ATM safety (EUROCONTROL, 2003). However, the desire was to

[2] Also known as Flight Operations Quality Assurance (FOQA)

aggregate these indicators in order to form an overall picture of ATM safety performance. To this end, the Safety Regulation Commission and its Unit (SRC/SRU), Performance Review Commission and its Unit (PRC/PRU) and the EUROCONTROL Safety Programme for ATM (ESP) were asked to pave a way forward for the EUROCONTROL Organisation in establishing a set of safety key performance indicators for ATM. Populating a composite index or a limited set of safety indicators with reliable, consistent and high-quality data was held to be the key to monitoring the European ATM system's safety performance, compliance with EUROCONTROL's strategic safety objectives and its contribution to overall aviation safety.

Developing such an indicator through the incorporation of a number of existing indicators is a major and unprecedented undertaking. Indeed, a literature review conducted by the MITRE organisation (Michael et al., 2006) to discover precedents for an overall aviation safety index, from aviation safety, economic indicators, credit ratings and indices in the bond market as well as the aviation insurance industry, found no close precedents.

2. APF

For an aviation organisation to operate efficiently while fully managing its level of risk, accurate data reporting using multiple sources of information is necessary. This data must reflect quantified information, allowing for repeatable and consistent risk weighting assessment from the experience and judgement of subject matter experts (SME). This judgement needs to offer a balanced perspective of performance to develop an indicator from which long term trends can be identified for better risk management.

The design goal of the APF is to do this in a coherent, robust manner and it aims to provide a graphical representation of a system's overall performance over a long time horizon compared to a specific baseline. It should be noted that the APF should not be used as a sole indicator of a system's performance, rather that it should be one part of a larger set of system safety management system (SMS) measures.

Put simply, the APF is the aggregation of essential system safety elements, as determined by the individual organization, multiplied by the SME weighing value obtained by the AHP process, and then normalised by a denominator that expresses the organization's output.

One can formulate the APF, for a given time period of interest, as follows:
APF = (Sum of weighted occurrences)/ Appropriate denominator

The sum of the weighted occurrences, WEO is:
WEO = w[1] * n[1] + w[2] * n[2] + ... + w[230] * n[230]
where

- w[k] is the weight for events of type k
- n[k] is the count of events of type k

The denominator is the appropriate one chosen by the organisation developing the APF, given its risk priorities. For the FAA and EUROCONTROL for example, this is the number of flight hours flown in the time interval of interest, whilst for easyJet it is the number of flight sectors flown.

2.1 The Analytical Hierarchy Process – AHP

The APF utilizes the Analytical Hierarchy Process (AHP) in part, to establish weighing. A panel of subject matter experts (SMEs) rank the relative level of importance, or influence, of each data element *within the overall system state*. The SMEs compare each element, using a pair-wise comparison system, against the background of a specific assessment question. In the case of an ANSP's safety APF, that question is generally, "Comparing these two elements, which one represents the greater risk to the overall system?", or, "Consider overall system risk. Comparing these two elements, which has more influence on risk?"

The AHP is based on the experience gained by its developer, Dr. T.L. Saaty, while directing research projects in the US Arms Control and Disarmament Agency. It was developed as a response to the finding that there is a lack of common, easily understood, and easy-to-implement methodology to enable the making of complex decisions (Bhushan and Ria, 2004). Since its development, the simplicity and power of the AHP has led to its rapid and widespread use across multiple domains beyond the process of making complex decisions.

The Analytic Hierarchy Process is a theory for the measurement of intangible factors alongside tangibles. Thus it becomes ideal for allowing SMEs to assess "risk" or "safety" elements since they are intangible values to most people.

It finds its best application in decision-making, although it functions equally well making comparisons of variables without necessarily having to take a decision between alternatives. Given its simplicity and ease of use, and relying on the three primary functions of AHP (structuring complexity, measurement, and synthesis), SMEs thoughts and experience can be organized in a manner that is simple to follow and analyze. These characteristics make AHP an effective methodology to a wide range of applications and enable any complex situation that requires structuring, measurement, and synthesis to be better understood.

Important decisions involve three kinds of complexity: Factors can be intangible, involve unknown cost and risk, and have many tradeoffs that are not black and white but involve all sorts of compromise. In addition, complex decisions involve interdependencies and also demand that all the knowledge gained about the unknowns with both sure and risky interactions be synthesized in a logical way that captures the priorities and preferences of the decision makers and/or SMEs.

In addition to the three primary functions, there are three related basic principles of AHP (decomposition, comparative judgments, and hierarchical composition or synthesis of priorities) which are utilized in the AHP methodology. The decomposition principle is applied to structure a complex problem into a hierarchy of clusters and sub-clusters. The principle of comparative judgments is applied to construct pairwise comparisons of all combinations of elements in a cluster with respect to the parent of the cluster. These pairwise comparisons are used to derive 'local' priorities of the elements in a cluster with respect to their parent. The principle of hierarchical composition or synthesis is applied to multiply the local priorities of the elements in a cluster by the 'global' priority of the parent element, producing global priorities throughout the hierarchy and then adding the global priorities for the lowest level elements.

Pairwise comparisons are a fundamental activity of the mind (Lesbesgue and Blumenthal). One must not compare more than about 7 items because of the consistency factor within the set of judgments. This is partly due to a theorem of Wilkinson and also to empirical findings about consistency. Judgments are used to express importance, influence, preference and likelihood. The last of these makes probabilities a special case of pairwise comparisons.

Criteria, or clusters and sub-clusters, do not always need to be assessed in terms of alternatives to determine their importance. A doctor determines which illness is more probable from the symptoms that affect the health of a patient and not from the drug alternatives that are used to cure them. When policies are established their importance derives from the greater good they produce and not from the actions to be taken to implement them.

The APF structures the organization's elements into clusters and sub-clusters via the development of a mindmap which establishes the relationships between the elements. Using pair-wise comparisons of the various elements within the mindmap then leads to the creation of the priorities, of weights, of each element as determined by the organizations SMEs. The use of the weighing system within the APF is as much art as science. It is designed to incorporate various elements into the APF equation, assess relative importance of those elements by Subject Matter Experts (SMEs), and display the data in a format that is usable both by high level organizational management as well as by detailed analysts.

The pair-wise comparison is accomplished using dedicated software that allows weightings executed concurrently but, crucially, independently by multiple subject matter experts. For more details about the software and the process, see Annex 1.

At the end of the weighting exercise the group is presented with the collective data and given an opportunity to discuss the results and make any subsequent modifications if necessary. Figure 1 below shows the results from a EUROCONTROL ESARR2 exercise

Two parameters of the weighting exercise are very important: consistency of weights for each SME (e.g. if A>B and B>C, then C<A would be inconsistent). The second one is the consistent weights between SMEs, perfectly illustrated by the graph below, showing one particular weighting from EUROCONTROL. It is clear that with one exception, all other SMEs had almost identical views.

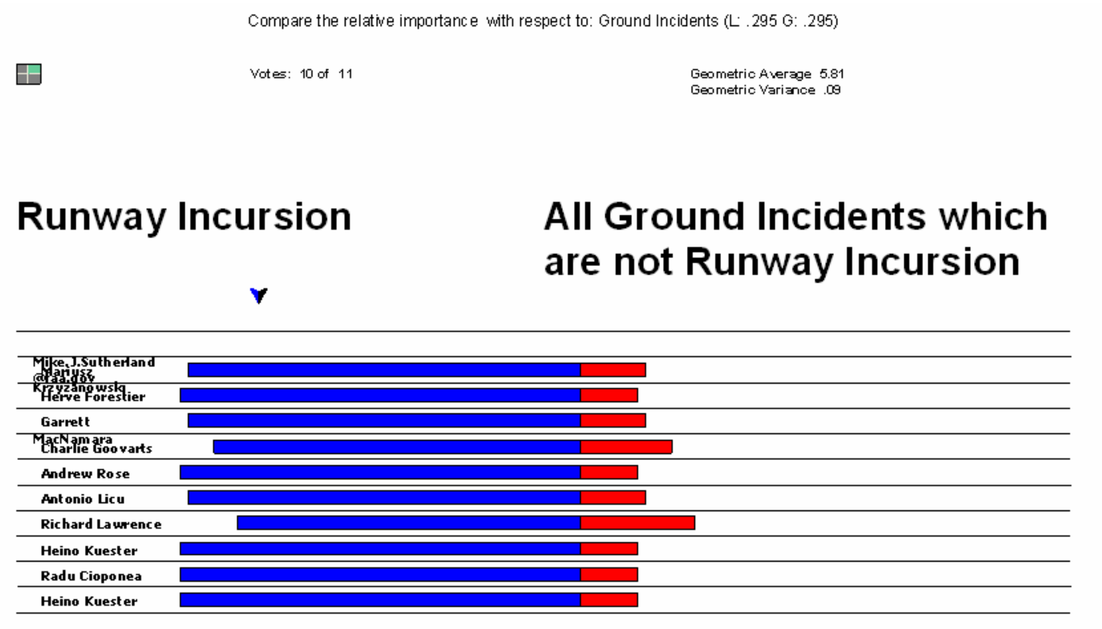

Figure 1: Sample of Group weighting result

3. Case Studies

This section outlines the generic methodology of developing an APF for any organization, department, or operation.

The generic process to set up an APF Mindmap is outlined in Figure 2.

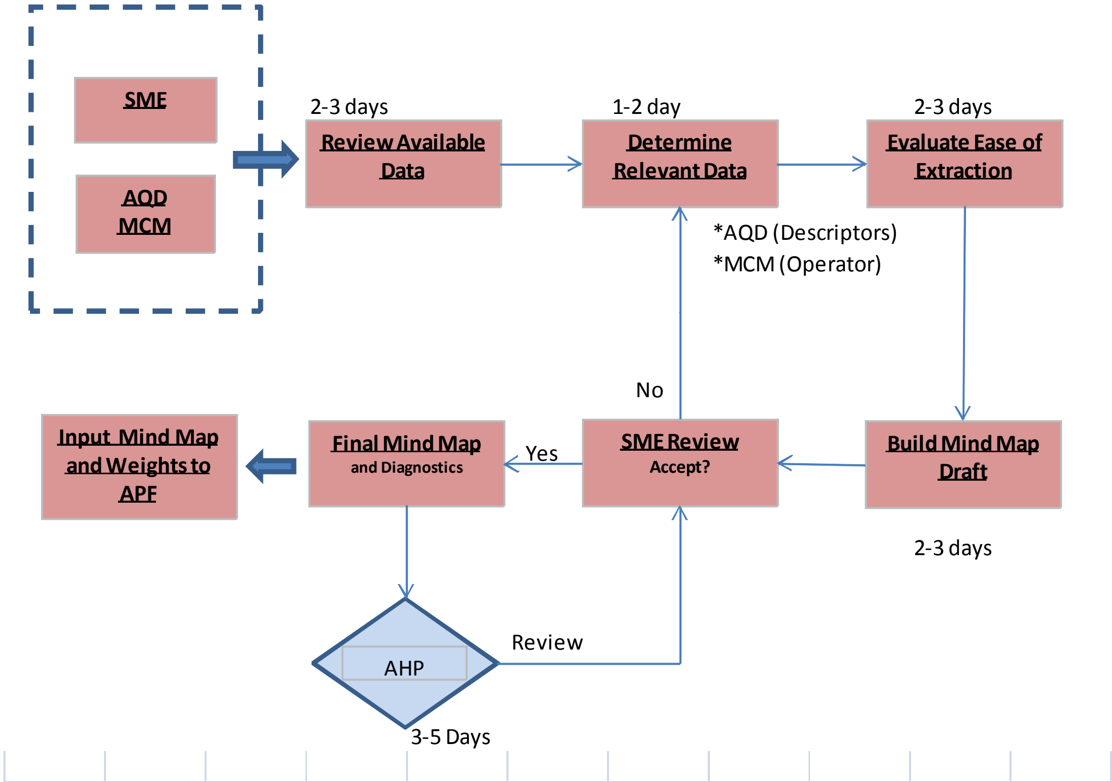

Figure 2: Mindmap Development Process

3.1 Data requirements

An important aspect in the development of the APF was the use of the existing data sources outlined in Section 2 by the various organisations.

While the FAA reports outlined in Section 2 are often limited in detail and may not encompass all system-wide mishaps, this does reflect all the available data. Additionally, the FAA has the advantage of having such data for nearly 10 years, thereby enabling ease of trending.

Within easyJet, the Flight Ops group was chosen for the prototype APF calculation. easyJet classifies 145 Flight Operations event types.

For EUROCONTROL, the data submitted annually within the framework of ESARR2 (some 15000 events per annum) was the target for APF

It is worth noting that some events can fall under multiple categories. For example, a particular incident can be in both the flight operations and ground operations categories. Likewise, an incident can be both classified as e.g. a level bust and as separation minima infringement depending upon the narrative submitted by the pilot and its interpretation based upon the AQD categories.

3.2 Building of Hierarchies – development of a mind-map

The case of the FAA APF development is instructive. In order to do this, the OEs, PDs, NMACs, PDs, RIs and VPD are placed in a hierarchy, using a mindmap that represents a logical relationship of the elements with each other, see Figure 3.

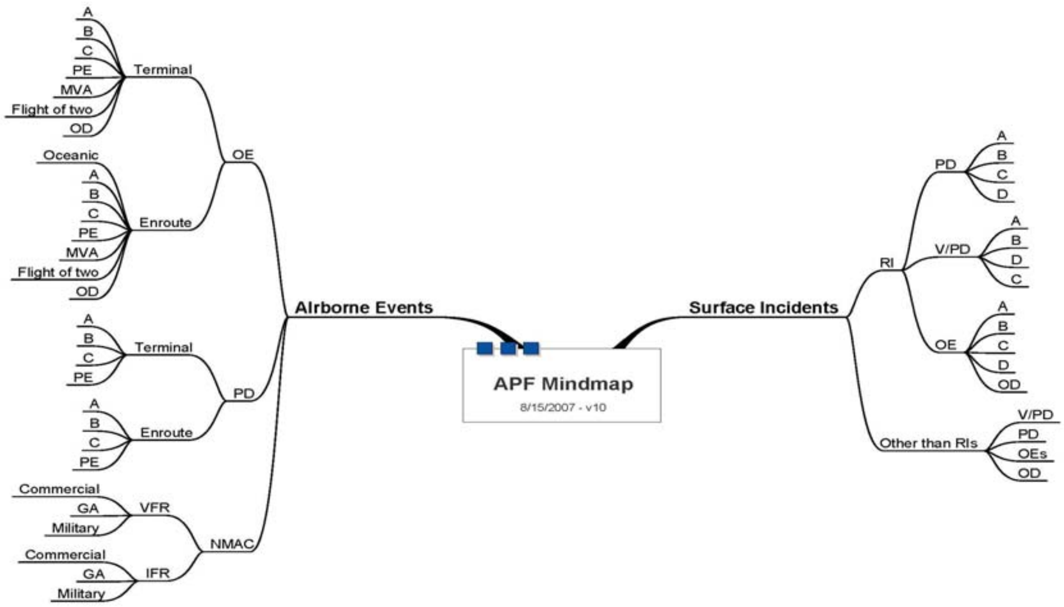

Figure 3: Original FAA safety mindmap

The aim of this is to create a picture of the ATC system as it relates to each of its components, as based upon the collected safety data. The logic of this representation is to separate elements associated with surface operations from those associated with airborne operations. Subsequently, sub-grouping is conducted for terminal and en-route operations. By this manner, events are placed within their logical place within the system, e.g. an oceanic mishap is grouped with "airborne en-route" and an ATM caused runway incursion is grouped with "surface runway incursions". The correct mapping of these relationships is vital to ensure that the SMEs can weigh the datasets in the APF process. Figure 4 shows the mindmap developed for easyJet and Figure 5 shows the EUROCONTROL mindmap

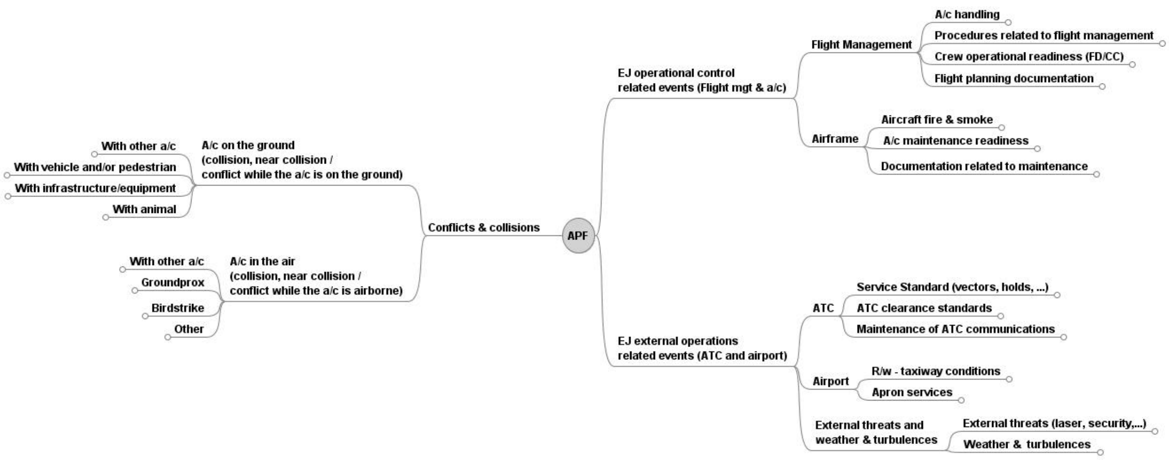

Figure 4: easyJet mindmap.

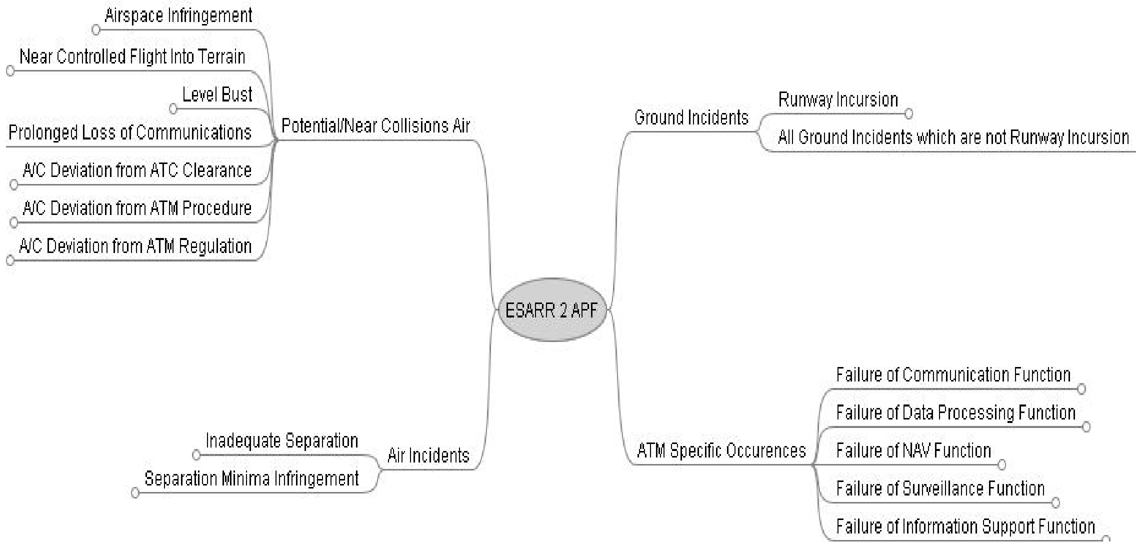

Figure 5: EUROCONTROL ESARR 2 mindmap

3.3. Data classification and mind-map development at easyJet and EUROCONTROL

Based upon discussions with easyJet personnel, a re-grouping of events was undertaken to better reflect flight operations. This reorganization was conducted in a logical manner and ensured that the groupings for each category were coherent and ensured balanced categories. The final weights for easyJet are shown in Figure 6:

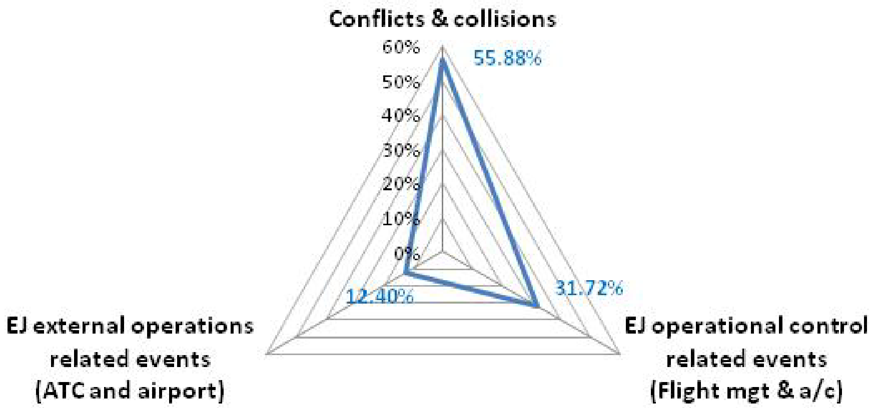

Figure 6: easyJet weights- easyJet Process for Verification of the APF output consistency (optional)

This task maps the previous Safety Review Board (SRB) output (from a three month period) to the APF output based on historical data. The aim of this task is to assess the capability of the AFP to identify the risk issues that the current SRB tools and methods identify, including an identification of the risk assessment methodology and a check with the incident reports from easyJet department.

Following Mindmap development, a daily operational process is required to provide easyJet decision makers with updated APF output. Such a process can be performed using internal easyJet personnel and resources, or by outsourcing the APF infrastructure support. A projected APF support process model is depicted in the following diagram:

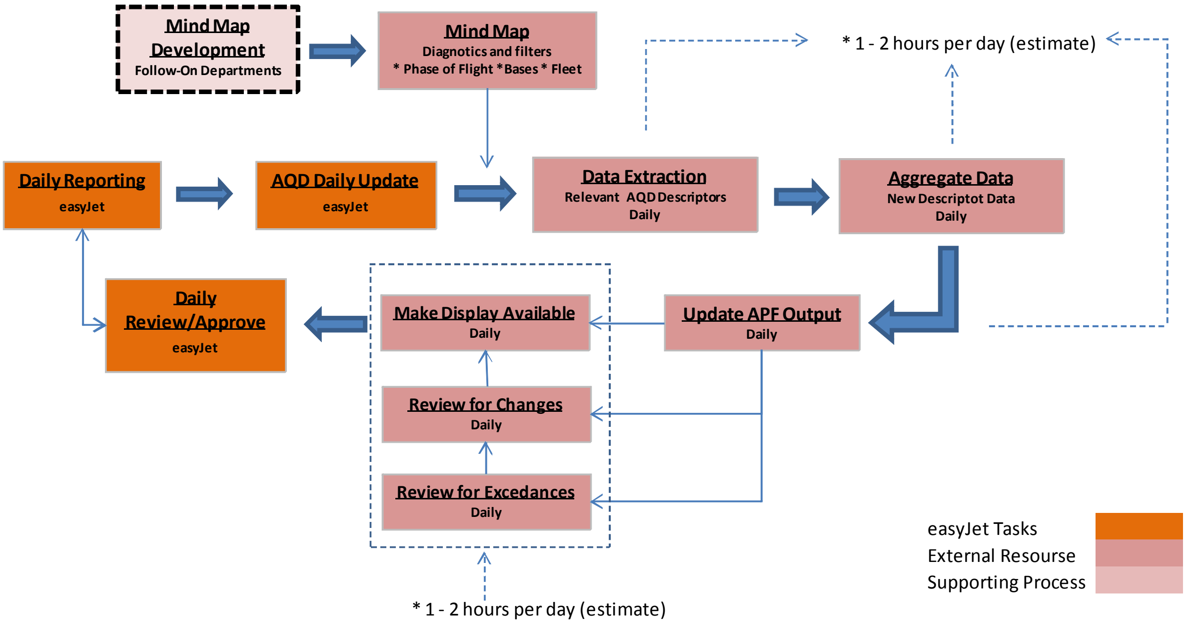

Figure 7: Daily easyJet APF Support Process

3.4 EUROCONTROL APF Development

In a process similar to that of easyJet, EUROCONTROL used the ESSAR2 data from the annual templates. The quality of the data had evolved over the years and EUROCONTROL was in the position to start populating some of the safety indicators (such as runway incursions, separation minima infringements, level busts etc).

After several iterations, a robust and balanced Mind Map has been agreed and the definition of the terms to be weighted and the questions asked to the experts were also improved. The SMEs with various backgrounds (OPS, ENG, SMS, ATC and Pilot experiences), who between them had a combined ATM/aviation experience/knowledge of approximately 350 years, were then presented with the paired comparison and a rating scale and asked "*Which of these 2 choices represents a greater risk to the safety of the ATM system?*" By making the comparison of the various elements the experts used their judgments about the elements' relative significance and a ratio scale was created. The 'pairwise' evaluations created by the SMEs were converted then in weights for each element of the APF hierarchy structure depicted in the Figure 5.

The weighting exercise of the ESARR2 APF led to similar results concerning the risks and the priorities at European level. Remarkably, experts with fairly different backgrounds, from different organisations and of different nationalities weighted consistently when accurate definition and explanation of what was to be weighted was provided. The final ESARR2 weights are shown in Figure 8. The overall final inconsistency rating was less then 0.15 which compares favourably with similar results from FAA weightings and is an important element in the validation process of the APF.

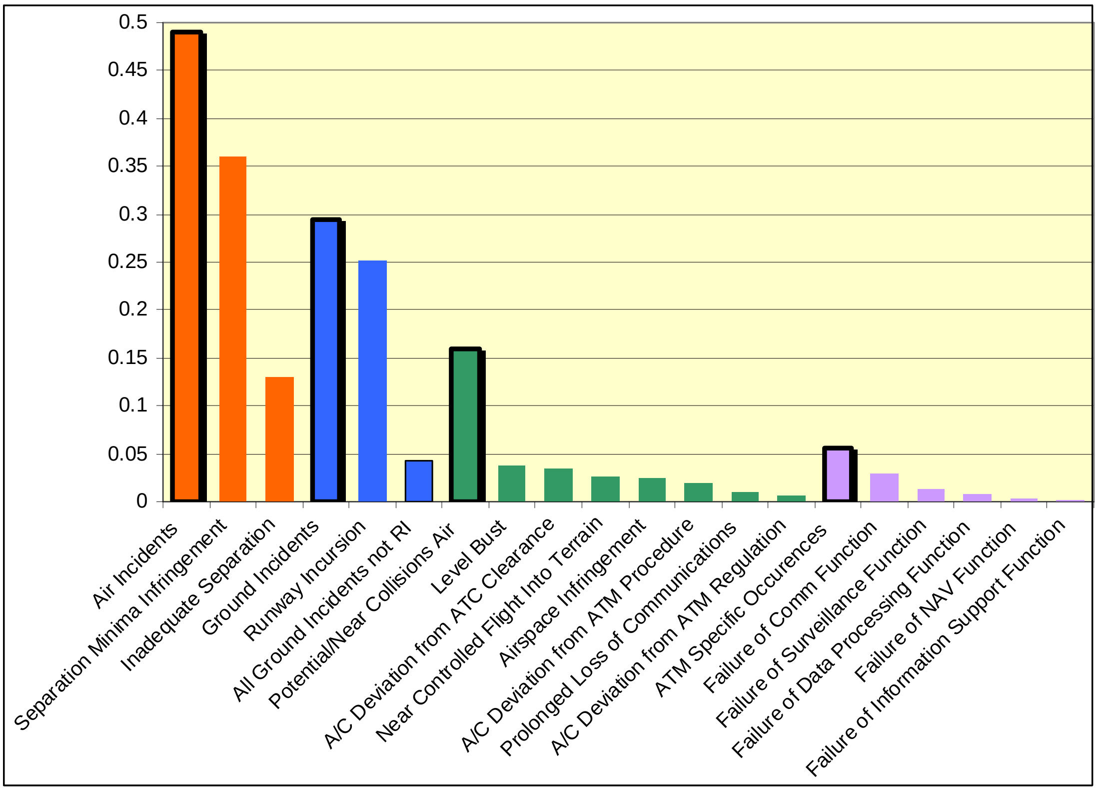

Figure 8: ESARR 2 APF – weights

The relative contribution of the elements (and branches) of the model to the performance of the European ATM/airspace can also be applied to time-series data collected over other time periods. EUROCONTROL decided that the most robust data from ESARR 2 Annual Summary Templates starts in 2006. By examining the performance of the system over time, a view of the historical performance might also lead to an expectation of the future direction (Figure 9).

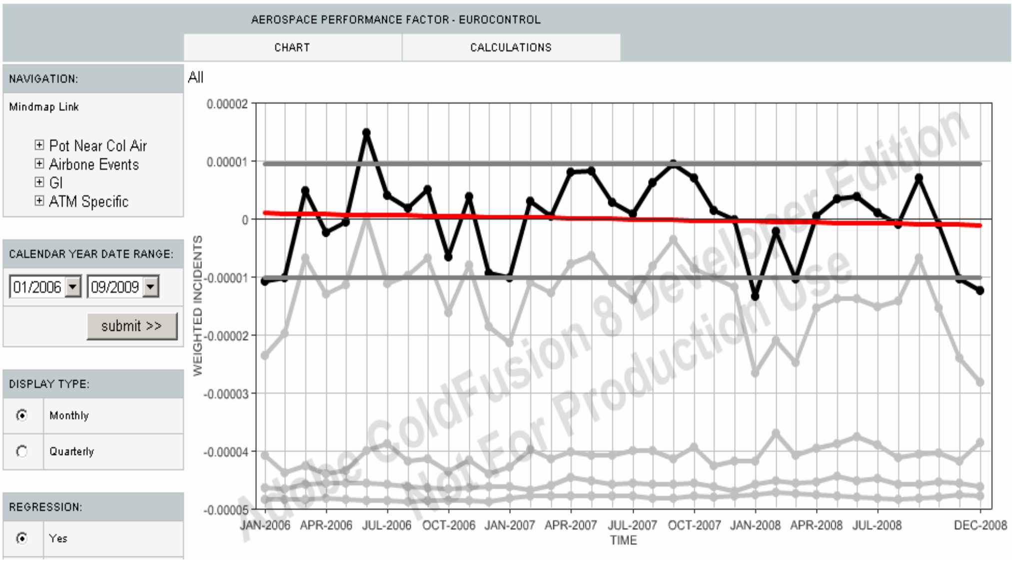

Figure 9: The EUROCONTROL ESARR 2 APF – overview

The EUROCONTROL APF chart shown here contains a number of essential elements that are described below. The APF itself is shown on the upper chart, while the lower chart shows the total flight hours from the reporting States considered for the period 2006-2008. The elements represented on the APF chart are:

- the dark black line, which is the actual overall APF (main value);
- a baseline, which represents the impact of all incidents normalized by time for a predetermined time frame and indicated by the zero line;
- an acceptable level of performance, as determined by the organization, plotted against the Y-axis as the two parallel lines above and below the baseline;
- a linear regression red line indicating the general trend of the data over the selected time period.
- the light grey lines below the baseline are the subordinate elements which, when aggregated together, create the collective organizational APF (black line);
- the mindmap, represented in a collapsible tree form, to the left of the graphs;
- a number of options below the mindmap tree, where certain values of the APF representation can be varied.

To ensure that safety levels are maintained or improved, systematic safety monitoring processes should evaluate, as a matter of routine, achieved safety performance in all safety-related operational activities. EUROCONTROL believes that the APF (as shown in Figure 9) can be used by ATM decision makers to analyse trends, detect unwanted deterioration in safety levels and support the development of effective improvement plans. The APF can also be used to assess the extent to which political, strategic, regulatory and industry safety targets are being met.

While the APF shows macro changes in the collective elements, it can also show variations in the subordinate elements to allow an organization to identify what factors are influencing the overall performance. Figure 10 shows the first level of “drill down” capability into the data.

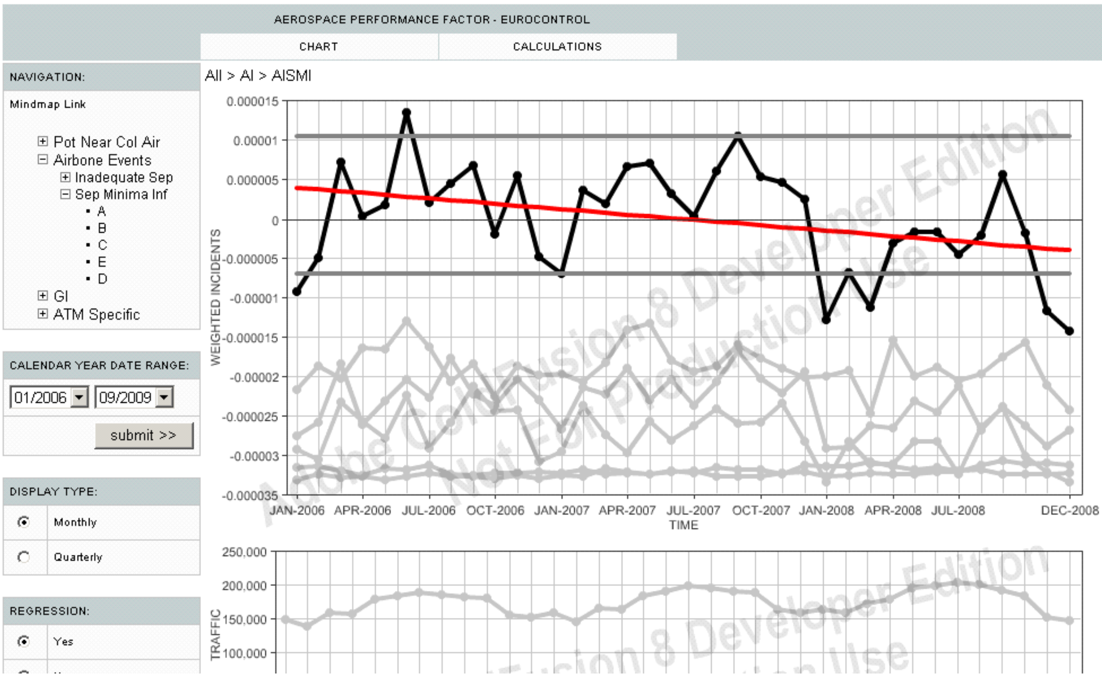

Figure 10: Drilling down on Separation Minima Infringements using the EUROCONTROL ESARR 2 APF

As the “drill down” process moves into more specific data, the APF enters the diagnostic section. Within the diagnostic section, the raw data is presented based on the categorisations and classifications of the organisation. Figure 11 shows sub-grouping of factors, or elements, associated with Separation Minima Infringements.

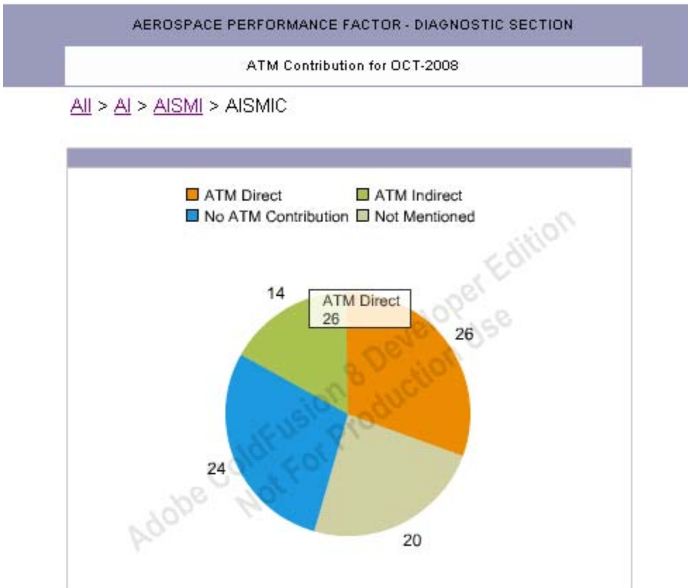

Figure 11: Diagnostic level within EUROCONTROL ESARR 2 APF

3.5 FAA – ATO

The FAA safety APF enhances the original design currently being used by easyJet and EUROCONTROL and provides an improved graphic representation of the data as well as refined Y-axis performance parameters.

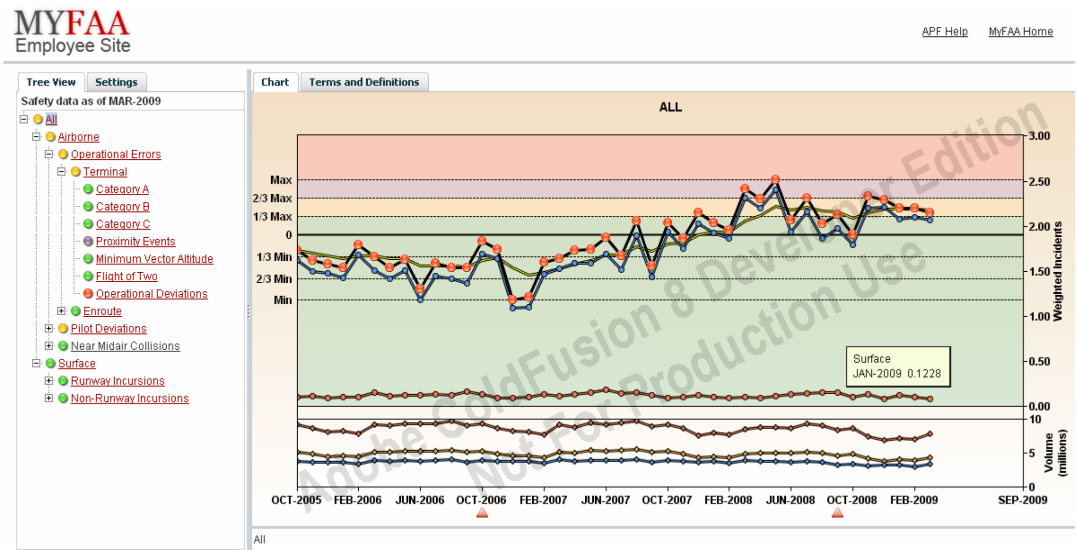

Figure 12: FAA safety APF

Figure 12 shows the enhanced performance graph referred to as the “min-max-mean”. In an effort to develop a methodology for the organization to establish yearly goals, the data was plotted for the baseline period. Then the maximum and minimum values were determined with the resulting mean calculated. The mean was set as the Y-axis baseline and the Max and Min plotted from the actual weighted data. The band was then subdivided into 6-units, represented as 1/3 Max, 2/3 Max, Max, 1/3 Min, 2/3 Min and Min. By so doing the organization can now set specific targets, i.e., for FY10, maintain performance within the Max and Min level; for FY11, maintain performance between 2/3 Max to 2/3 Min, etc.

Colors are used to indicate the performance sectors as follows:

- Green: Between 1/3 Max and below.
- Yellow: Between 1/3 Max and 2/3 Max.
- Purple: Between 2/3 Max and Max
- Red: Max or Above

The tree view shown on the left side of the APF graph provides color coded radio buttons that use the color schemes above to indicate the level of performance of the APF, as well as the various subordinate components, as of the end of the selected time period. Thus the organization can see at a glance those elements that are operating “in the green” or elsewhere on the performance scale.

The diagnostics sections provide more specific operational factors as well as components associated with the data elements. See figure 13.

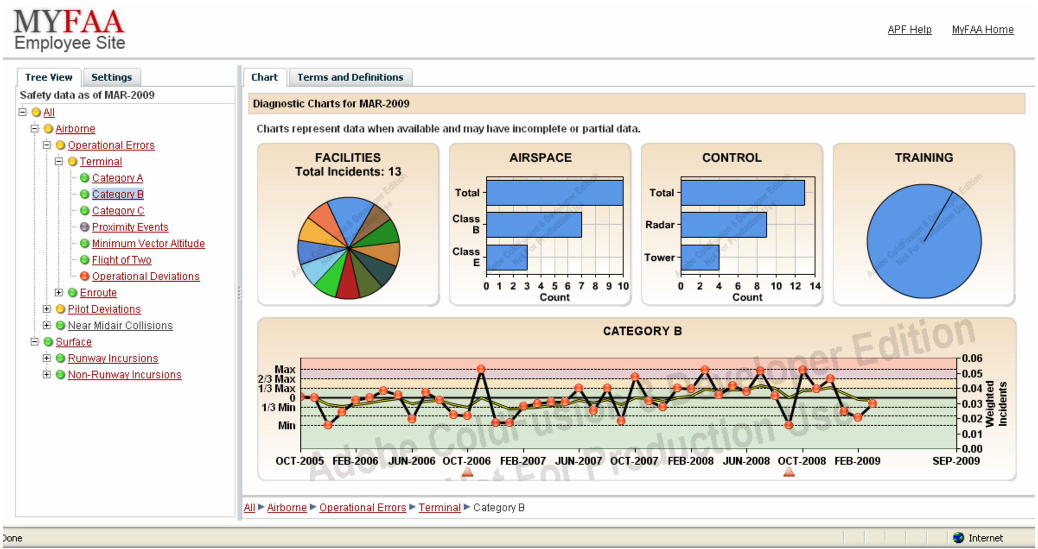

Figure 13: FAA APF diagnostic page

4. Conclusion

The APF has been accepted by EUROCONTROL and easyJet as a method of presenting operational data, determining targets, and maintaining operational performance over time. Data mining, at a very basic level, is feasible to support the quest for contributing factors before operational parameters are penetrated.

In addition to the three organizations highlighted in this paper, the United States Naval Safety Center, Air Navigation Service Providers from Germany, Ireland, Poland, Spain, France, Netherlands, Romania and Southwest Airlines are either developing operational APFs or exploring implementation of the methodology.

The APF methodology is an entirely new way of looking at data and should not be compared to other legacy systems. Unlike engineering solutions, any system whereby humans are involved, either as designers, operators, or users, needs to include the human assessment of intangible aspects of the system. Assessing those intangible elements, specifically areas associated with safety, importance, influence, or risk, requires the use of experienced subject matter experts which is accomplished through the AHP process.

There is nothing wrong with how risk is assessed using the Safety Management System (SMS) risk methodology. Nor is the APF methodology of assessing importance, or risk, wrong. They are just two separate methods that must be accepted as they are with the full understanding of the methodology, benefits, and limitations of each.

Note to readers:

easyJet Airlines is the second biggest low fares carrier in Europe. It is a pan European company flying to 26 countries and has over 180 Airbus A319/320 and Boeing 737NG aircraft. easyJet flies to 103 destinations with over 400 routes across Europe and North Africa and flew in excess of 40 million passengers last year.

EUROCONTROL, the European Organisation for the Safety of Air Navigation, has as its primary objective to develop a seamless, pan-European air traffic management (ATM) system that fully copes with the growth in air traffic, while maintaining a high level of safety, reducing costs and respecting the environment. EUROCONTROL has 38 Member States which collectively control some 10 million IFR flights a year, for a total value of over €8Bn.

The FAA is the world's largest air navigation service provider and aviation regulator. As the initial driving force behind the development of the APF, the FAA quickly moved to gather aviation expertise from various segments of a worldwide industry to enhance safety and operational performance on an international basis.

In addition to the application of safety elements within APF methodology, the same practices are being applied for the development of APF's for efficiency and individual ATC facility effectiveness.

References

[1] Michael B. Callaham, M.B., Millner, D.C., Sood, N.P. and L. A. Wojcik (2006) National Airspace System (NAS) Performance Factor (NPF) Analysis Final Report September 2006, MTR 06060106R1 MITRE TECHNICAL REPORT

[2] EUROCONTROL Performance Review Commission, Performance Review Report covering the calendar years 2007 and 2008 (PRR 2007, PRR 2008), EUROCONTROL, Brussels.

[3] ESARR 2 - Reporting and Assessment of Safety Occurrences in ATM; Released Issue: 03/11/2000 Edition: 2.0

[4] easyJet (2009) Aerospace Performance Factor (APF) Project Initiation Document

EAM2-GUI1 Severity Classification Scheme for Safety Occurrences in ATM ; Released Issue: 12/11/1999 Edition: 1.0

[5] EAM2- GUI2 Publication and Confidentiality Policy; Released Issue: 12/11/1999 Edition: 1.0

[6] EAM2-GUI9 – Annual Summary Template; Released Issue 25/07/2005 Edition: 1.0

[7] EAM2-GUI10 - Guidelines for the Completion of the Annual Summary Template – Ed 2006

[8] SRC DOCs 31, 35, 37, 41, 43 and 44 – SRC Annual Safety Report 2003, 2004, 2005, 2006, 2007 and 2008

[9] Strategic Safety Action Plan - SAFREP TF Report to Provisional Council: ATM Incident Reporting Culture: Impediments and Practices (Nov 2005)

[10] European Safety Programme for ATM (ESP) – 2nd SAFREP TF Report to Provisional Council - Roadmap for the Development of the Safety Key Performance Indicators in ATM (November 2007)

[11] SAFREP Ad-Hoc KPI group – minutes of the meeting from WS 13, 14, 15, 16 and 17 (Nov 2008 – June 2009)

[12] Lintner, T.M. and S. Smith (2008) Future Concepts for Measuring Aviation Safety, Performance, & Effectiveness, Presented at the Society of System Safety Conference, Singapore 2008

[13] Lintner, T.M., Smith, S. and S. Smurthwaite (2009) The Aerospace Performance Factor: Utilization of the Analytical Hierarchy Process to develop a balanced performance and safety indicator of the National Airspace System for the Federal Aviation Administration Effectiveness, Presented at 10th International Symposium on the Analytical Hierarchy Process (July 29- Aug 1/2009 – University of Pittsburgh)

[14] Blumenthal**,** A.L. (1977) The Process of Cognition, Prentice Hall

[15] Saaty, T.L. (2005) The analytic hierarchy and analytic network processes for the measurement of intangible criteria and for decision making, in Figueira, Jose; Greco, Salvatore; Ehrgott, Matthias (Eds.) Multiple Criteria Decision Analysis:State of the Art Surveys, International Series in Operations Research & Management Science , Volume 78, Chapter 9.

[16] Wilkinson, J.H. (1958) The Calculation of the Eigenvectors of Codiagonal Matrices, The Computer Journal 1958 1(2):90-96

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Tom is a Program Manager with the Federal Aviation Administration, Air Traffic Organization, Washington, DC with over 37 years of aviation experience. He graduated from Dowling College, in Oakdale New York, where he studied business management, aviation science and physics. He began his career with FAA as an air traffic controller at New York City's LaGuardia Airport and the New York Terminal Radar Approach Control facility. In his 30 years with FAA, Tom has worked in two regions, four ATC facilities, and held numerous positions during two tours of duty at the Washington Headquarters level. While Chief of Staff of the FAA Air Traffic Safety Oversight Organization, Tom began the research and development effort that would become the future Aerospace Performance Factor, APF.

An active pilot throughout his career, Tom has worked for PanAm World Services, Flight Safety International and several corporate operators. A certified Flight Instructor, he holds licenses as an Airline Transport Pilot, Airline Dispatcher, and Control Tower Operator. Tom is a citizen of Ireland and the US and is a trained safety auditor with EUROCONTROL.

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Steve is a Program Manager with the Runway Safety Program, Federal Aviation Administration, Washington, D.C. He is a graduate of St. Martins College, in Lacey Washington and attended graduate system safety program studies at the University of Southern California, Los Angeles. Steve is a member of the System Safety Society, Capital Chapter and was the General Conference Chair for the 1997 International System Safety Conference held in Washington, D.C. He has served as the Director of Government and Inter-Society Affairs for the System Safety Society and was instrumental for establishing the weighting process for the APF.

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Simon is currently the Head of Safety Development at easyJet and a line Captain on Boeing 737. Prior to that role he was the easyJet Flight Operations Quality and Safety Manager. He has been working on the evolution and implementation of an integrated Safety Management System (SMS) in easyJet inclusive of the Aerospace Performance Factor (APF). He chairs the SMS working group in the EU HILAS commission project and is a member of the ICAO FRMS Sub committee generating guidance material on Fatigue Risk Management (FRMS) for member states. He has published six papers on FRMS in airline operations and is documenting his work as part of his post graduate studies at London City University.

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Tony is an experienced ATM safety expert with an operational air traffic control and engineering background. He worked previously with ROMATSA, the Romanian ANSP, and with the Romanian Civil Aviation Authority. He joined EUROCONTROL within the Safety Regulation Unit in 1999, where he led the development, maintenance, and promotion of various EUROCONTROL safety regulatory requirements, such as ESARR 2 (Reporting and Investigation of Safety Occurrences in ATM), ESARR 5 (ATM Staff Competency) and 6 (Software in ATM systems). He has managed the Strategic Safety Action Plan and European Safety Programme for ATM (ESP) implementation. He has particularly worked on Just Culture with the aim of clarifying and promoting the concept and he leads the Safety KPI development work in Europe. Since January 2009 he is managing in the EUROCONROL Network Development Pillar the safety, security and human factors activities

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Radu has an experience of over fifteen years in ATM, having started with ROMATSA, the Romanian ANSP as an engineer developing ATC systems and in particular an ATC simulator. He then moved to EUROCONTROL over ten years ago where he managed the area of safety performance within the PRU, writing annual reports on the status of European safety performance. Radu has done extensive work in the area of Just Culture and he is a fellow of the Flight Safety Foundation, dealing with precisely the same issues.

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Miss Marie-Dominique Dupuy is a Research Assistant part of the Air Traffic Management team within the Imperial College Engineering Geomatics Group and member of the Transport Risk Management Group since 2006. Her research activities focus on aviation safety, trajectory prediction modelling, and ATM-ATC incidents investigation and analysis. She has previously worked on the development of airspace safety indicators for the Civil Aviation Authority of New Zealand and on the development of a trajectory prediction model for a conflict detection and resolution algorithm taking into account uncertainties for which she receives a Best Paper Award at the 26th “Digital Avionics Systems Conference” (DASC) held in Dallas, Texas, USA, in October 2007.

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Dr Arnab Majumdar is the Lloyds Register Educational Trust Lecturer in Transport Risk Management and the team leader of the Air Traffic Management Group at the Centre for Transport Studies, Imperial College London. He holds the following degrees including a Phd. from Imperial College London on the topic of developing frameworks for airspace capacity estimation based upon simulation modelling of air traffic controller workload. Since December 2008, Dr. Majumdar has been appointed as the Lloyds Register Educational Trust Lecturer in Transport Risk Management at Imperial College and now heads a team of researchers analysing risk in all transportation modes.

Dr. Majumdar has spent well over a decade researching air transport, first as a research associate and then as a research fellow at Imperial College London. In particular he has investigated the problems of air traffic management and control (ATC/ATM) in Europe, especially those involving the modelling of European airspace capacity using air traffic controller workload and complexity issues. The major organisations with which he has conducted research in this area include EUROCONTROL, the UK’s National Air Traffic Services (NATS), US Federal Aviation Administration (FAA), the Airways Corporation of New Zealand, and his research has made important contributions to understanding the nature of air traffic control and management (ATC/ATM) in Europe and globally.