# The Application, Utility and Acceptability of Data Analytics in Safety Risk Management of Airline Operations

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Abstract One area the aviation industry is grappling with is the quantification of the probability of occurrence of safety incidents. Currently, aviation professionals involved in safety risk management mostly rely on collective experience to determine probability of incident occurrences and apply it to the International Civil Aviation Organisation (ICAO) matrix or equivalent to evaluate the risk. A number of limitations linked to the use of risk matrices will be explored in this paper. It is the aim of this paper to explore statistical methods that can be used to determine the probability of safety occurrences and come up with an algorithm that can be used by airlines using available safety data. The novelty of this research is that it combines the exploration of use of statistical techniques to quantitatively assess risk using Flight Data Monitoring (FDM) and other data, with acceptability of Safety Risk Management (SRM) data analytics by operational personnel. The paper also explores the contributory factors leading to the reluctance of operational personnel to use data analytics to inform their risk assessments despite the increasing availability of operational data and advancement in technology.

## 1. Motivation and research problem statement

The research idea stems from the perceived reluctance of the aviation industry to apply data analytical tools to improve safety risk assessment in Safety Management Systems (SMS) despite the availability of data from flight data recorders and safety reports. Safety risk is defined by ICAO (2018) as "The predicted probability and severity of the consequences or outcomes of a hazard". In order to determine the safety risk index, probability and severity scores are combined in an alphanumerical format. Many airlines use the ICAO Safety Management Manual (2018) recommended matrix shown in figure 1, in their risk assessments.



| Safety Risk | | Severity | | | | |
|---|---|---|---|---|---|---|
| Probability | | Catastrophic A | Hazardous B | Major C | Minor D | Negligible E |
| Frequent | 5 | 5A | 5B | 5C | 5D | 5E |
| Occasional | 4 | 4A | 4B | 4C | 4D | 4E |
| Remote | 3 | 3A | 3B | 3C | 3D | 3E |
| Improbable | 2 | 2A | 2B | 2C | 2D | 2E |
| Extremely improbable | 1 | 1A | 1B | 1C | 1D | 1E |

Figure 1. Safety Risk Matrix. Source: ICAO Safety Management Manual, 4th Edition

ICAO (2018), defines probability as "the likelihood that a safety consequence or outcome will occur". The distinction between 'improbable' and 'extremely improbable' as an example, in practical terms, is vague and unhelpful, thus exposing some weaknesses in this matrix. While enhancements have been made in some organisations to adapt this matrix to suit their operations, the current matrix format (Figure 1) is still in use by many airlines and endorsed by numerous competent authorities.

There have been many criticisms to the use of safety risk matrices. Cox (2008) asserts that risk matrices have poor resolution and can incorrectly assign higher qualitative ratings to a risk of relatively smaller value leading to suboptimal resource allocation. Cox further argues that matrices consist of ambiguous inputs and outputs. Barry (2021) also argues that there has not been a lot of research looking into their validity, effectiveness and also evaluation of their performance in improving risk management decisions. Probabilities of occurrence require subjective interpretation and different users may obtain differing ratings of the same quantitative risk depending on their operational experience and national culture. Hubbard (2009) points out that the approaches that aviation organisations are using to manage risk lack quantitative analysis. Consequently, organisations are most likely to come up with ineffective strategies which might worsen the risk situation.

Lishuai, Harisman, Palacious and Welsch (2016: p.1) affirm that "modern aircraft systems have become increasingly complex to a degree that traditional analytical systems have reached their limits". Current methods are tailored to detect hazardous behaviours on parameters that have been pre-defined and they miss vital operational risks that are unlisted or unknown.

Risk assessment in big organizations with multi-operational domains is becoming increasingly challenging. Employing an effective method along with realistic pair comparisons taking opinions of organisational experts and removing the inherent bias in their inferences is problematic. It is becoming clear that traditional two-dimensional risk assessments to identify hazards and safety deficiencies lack the required sophistication to deal with increasingly complex airline operations (Rezai &Borjalilu,2018). This is further echoed by Mauro and Bashi (2009) who highlight that "many risk assessment heuristics and displays can yield misleading and sometimes mathematically incongruous assessments".

Airlines receive a lot of data from Flight Data Recorders (FDR) and Quick Access Recorders (QAR). In his research paper, "Estimating runway veer-off risk using a Bayesian network with flight data", Barry (2021) argues that risk assessments in airline operations are mostly qualitative in nature and this is despite the availability of large amounts of data from programmes such as Flight Data Monitoring (FDM), employee safety reporting systems and Flight Operations Quality Assurance (FOQA).

A number of risk assessment methods such as Bow tie diagrams, The Airline Risk Management Solutions (ARMS), Safety Issue Risk Assessment are being used by some airlines to improve risk assessment in Safety Management Systems. While they are an improvement to simple matrices, they unfortunately still rely on some subjective assessment.

The safety record of civil aviation is unrivalled but if it is to be improved, the airline industry should transition towards a more proactive and potentially predictive approach which anticipates and mitigates operational risks before unwanted events occur. It is the aim of this paper to explore statistical methods that can be used to determine the probability of safety occurrences and develop an algorithm that can be used by airlines using available safety data.

## 2. Novelty and significance relative to the state of the art

ICAO Safety Management Manual (2018) mentions that "the level of detail and complexity of tables and matrices should be adapted to the particular needs and complexities of each organisation". This guidance is vague and can be interpreted in various ways by airlines. The manual recommends organisations to include both quantitative and qualitative criteria but it only gives examples of the latter. Arguably, this is the reason why most organisations are using the qualitative criteria.

From the 1st of January 2005, airlines that operate aircraft with a maximum take-off mass in excess of 27 tonnes are required by ICAO to have a FDM program. This program is good in that it highlights occurrences of a non-standard, abnormal or unsafe nature. The biggest challenge that airlines are facing is the translation of information of these unsafe occurrences into a useful measure of risk. It is vital for researchers to come up with novel ways of detecting anomalies in data automatically without the need for predefinition.

Statistical techniques have a role to play here as they have a range of practical applications to detect unusual events and abnormalities in terms of pre-defined limits and randomness of occurrence data. A few tentative statistical suggestions are given in UK Civil Aviation Publication (CAP) 739 but no further explanation is given on how the statistical methodologies can be incorporated into risk management.

This research explores the potential of using statistical techniques to come up with an algorithm that can be used on FDM occurrence data to inform a quantitative approach of safety risk probability of operations. The algorithm will have the ability to accommodate other qualitative data available from airline data sources to complement quantitative FDM data. This should significantly increase the reliability of determining probabilities of occurrence in airline operations.

Existing risk assessment methodologies evidently show that there is a reluctance to use technology to enhance quantitative risk assessment. This research is going to be underpinned by the Technology Acceptance Model (TAM) shown in figure 2 to try and understand this reluctance. This theory was specifically designed to assess an individual's likelihood of accepting technology. This research will test whether the theory holds true in the use of data analytics in airline safety risk management processes. The fast speed of technology advancement in data analytics is challenging and its effects need to be explored. The research will also look into individual versus organisational (firm level) acceptance as well as velocity of the environment. The TAM model is going to be used as a general framework to investigate the factors that influence airlines to adopt data analytics in safety risk management of their SMS.

In their paper, "Understanding the usage, modifications, limitations and criticisms of Technology Acceptance

Model", Malatji, Van Eck and Zuva (2020) discuss a number of limitations of the model. This research will also endeavour to improve the model in light of the cited shortcomings and more.
The model is shown in figure 2 below:

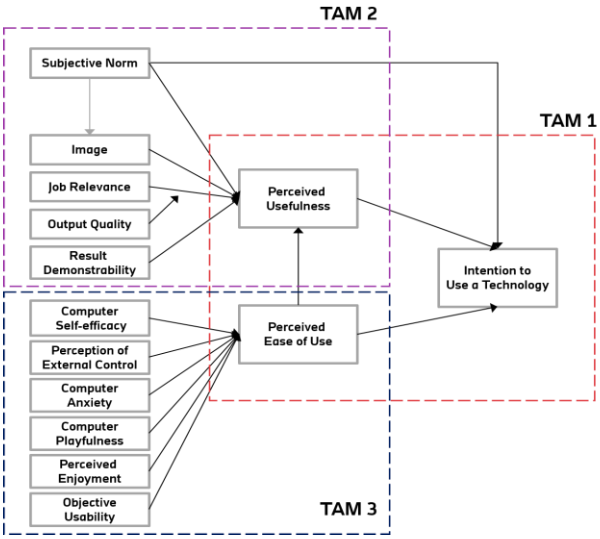


Figure 2. TAM 1, 2 & 3 – Simplified omitting moderators, Davis (1989) Venkatesh and Davis (2000) Venkatesh & Bala (2008). Source: Innovation Acceptance Lab

The novelty of this research is that it combines the exploration of use of statistical techniques to quantitatively assess risk using FDM and other data, with acceptability of SRM data analytics by operational personnel.

**3. Discussion of the applications and the contribution of the work**

The research will develop an algorithm that can be used by operational personnel to determine the probability of safety occurrence in airline operations. The study will also determine the factors which affect technology acceptance in an aviation industry which is highly dynamic and innovative.

**4. Approach and proposed experiments (where appropriate)**

A mixed methodology is proposed for this research. A quantitative approach is going to look into how occurrence data from a series of Airbus mid-range aircraft (A319, A320 and A321) flight data recorders and quick access recorders from the same operator. The data can be analysed and probabilities of occurrence determined using quantitative modelling. The resulting probabilities for significant events will be compared with those determined by the airline's safety management team in their safety reports. The above-mentioned aircraft were flying European routes and standard operating procedures were common across the different types. The flight recorder data and safety reports cover a 10-year period. The data analysis process will start in five months' time.

A qualitative approach will be primarily carried out to get a better understanding of the factors which contribute to technology acceptance and also the evidently reluctance of aviation safety specialists to use quantitative methods of risk assessment. Interviews and questionnaires will be used to gather information from safety personnel involved in safety risk analysis and mitigation.

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