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A framework for assessing the quality of aviation safety databases

Sabine Wilke *, Arnab Majumdar [1], Washington Y. Ochieng [2]

Imperial College London, Department of Civil and Environmental Engineering, Centre for Transport Studies, South Kensington Campus, Skempton Building, SW72AZ London, United Kingdom

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ABSTRACT

The quality of data analysis and modeling is dependent on its inputs and statistical analysis is of limited value with inappropriate data. This paper proposes a framework for assessing data quality using the example of airport surface safety, i.e. runway/taxiway safety. The nature of airport surface safety is such that there is a need to account for data from a number of stakeholders, who may possess databases differing in quality, and aggregate this data for subsequent analysis to provide robust safety assessment and mitigation. To address these issues, this paper proposes a framework for the validation of external data quality based on the underlying data collection and investigation processes. Multi-Criteria Decision Analysis (MCDA) using a linear model is applied to derive quantitative weights for twelve safety databases based on the quality of the underlying organizational data collection and investigation processes. The model takes eleven criteria in relation to possible error sources during data gathering and pre-processing, organizational safety culture, data accessibility, and the consistency of the reporting system over time into account. These weights combined with an internal data quality validation and an indication of the reporting level of an organization can give a robust indication of the quality of a database. This method is recommended for use for data quality assessments in aviation safety.

1. Introduction

The safety of the airport surface, i.e. the runways and taxiways is an area of great concern (ICAO, 2010). Whilst addressed extensively, an integrated approach to assessing surface safety is missing, i.e. aviation stakeholders focus on those accidents and incidents (occurrences) of their particular interest and immediate responsibility. To overcome this practiced piecemeal approach, the incorporation of all relevant stakeholders (regulators, Air Navigation Service Providers (ANSPs), airport authorities, airlines, ground handling companies) is essential. Only an integrated approach can provide a holistic understanding of the subject matter and can be the basis for effective safety mitigation strategies (Wilke and Majumdar, 2012).

This is particularly the case for safety assessments. To ensure that safety risks (including e.g. accidents/incidents) are identified, assessed and appropriately mitigated, aviation stakeholders are required to implement a Safety Management System (SMS). This is a systematic approach to managing safety, including policies and objectives, operational risk management, and adequate control mechanism. A SMS is a framework that provides an organization with the adequate tools to ensure that any drift by the organization towards a lower safety performance is prevented. At the heart of a SMS is the operational safety management (safety risk management), which supports the development of evidence-based measures for the overall safety management process. Safety risk management in practical terms is concerned with hazard and occurrence identification through reporting and data collection, investigation, and subsequent data analysis (ICAO, 2009).

Incident data is a key element of any SMS. Indeed, from the incident data, safety metrics can be derived and quantitative risk assessments conducted. However, the quality of incident data reflected in an organizational database can influence the results (i.e. the output of any data analysis is limited to the quality of its underlying data sets). This problem is magnified when attempting to aggregate databases across organizations.

An integration of different stakeholder viewpoints, in particular across national boundaries, has to account for differences in both the organizational characteristics and the national Air Traffic Management (ATM) systems. Particularly, when aggregating safety databases, differences in data quality have to be addressed and corrected, as variable data quality will greatly affect risk assessments in an organization. Three aspects of data quality need to

* Corresponding author. Tel.: +44 (0) 2075942705.
E-mail addresses: s.wilke09@imperial.ac.uk (S. Wilke), a.majumdar@imperial.ac.uk (A. Majumdar), w.ochieng@imperial.ac.uk (W.Y. Ochieng).
[1] Tel.: +44 (0) 2075946037.
[2] Tel.: +44 (0) 2075946104.

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be considered: external factors (i.e. how accurately does the database reflect occurrences), internal factors (i.e. how precise is the data), as well as the reporting level. Whilst the internal aspects of data quality have been addressed elsewhere (e.g. Dupuy, 2012), this paper proposes an external data validation framework using Multi-Criteria Decision Analysis (MCDA). Weights for twelve safety databases representing the viewpoints of all relevant aviation stakeholders are derived, based on the quality of the underlying data collection and investigation processes (reporting systems). In addition, the reporting levels of the twelve databases are analyzed.

This paper is outlined as follows. The next section introduces the concept of data quality and the importance of external data validation. Section 3 derives the methodology for the development of an external data validation framework and Section 4 discusses the influence of reporting levels on data quality. The results are subsequently discussed, including the importance of data quality in extracting causal factors, prior to the conclusion of the paper.

2. Data quality

The quality of data analysis and modeling is dependent on the inputs, i.e. the quality of the underlying data sets, and statistical analysis is of limited value with inappropriate data. Both external factors (e.g. data collection and investigation process) and internal factors (e.g. data completeness, consistency) can influence the quality of the data. This paper assumes the following definitions:

- External validation refers to accuracy, i.e. how accurately the data reflects the truth of what happened, or how accurately the reporting and investigation process captures any occurrence.
- Internal validation refers to precision, i.e. whether a statistical model is able to predict the data well.

Furthermore, the reporting level plays a vital role when aggregating databases from diverse organizations. This reporting level is determined by the reporting scope (e.g. the collection of only high-severity occurrences versus all occurrences), the underlying definitions for accidents and incidents types, and the consistency of the reporting systems over time (e.g. change in definitions, data collection mechanisms).

Although acknowledged in aviation research (e.g. EUROCONTROL, 2011; United States Government Accountability Office, 2010; CAST/ICAO Common Taxonomy Team, 2006; Global Aviation Information Network, 2003; NTSB, 2002), data quality has rarely been taken into account and previous models for aviation safety fail to account for such quality issues. For instance, the European Organisation for the Safety of Air Navigation's (EUROCONTROL) Integrated Risk Picture (IRP) and the Causal Model for Air Transport Safety (CATS) developed by the Nationaal Lucht-en Ruimtevaartlaboratorium (NLR) are both models that quantify the risk of aviation occurrences. IRP represents the risk of aviation accidents with particular emphasis on ATM contributions, whereas CATS quantifies the risk for 33 separate accident scenarios. The IRP makes use of a total of 137 worldwide accidents involving large Western commercial jets during 1990–2002 and a selection of incidents involving commercial aircraft during 1998–2004 (EUROCONTROL Experimental Centre, 2006). NLR's model is based on Airclaims and accident data from the International Civil Aviation Organisation's (ICAO) Accident/Incident Reporting (ADREP) system from 1990–2003. To support the analysis, original accident investigation reports and other data sources (e.g. Flight Safety Foundation) have been used. Incident reports have also been used where available (Ale et al., 2009). Both models aggregate multi-national data from different sources, but do not account for differences in data quality.

Research on the generic management of data quality in a variety of industries has identified numerous data quality dimensions, including relevance, completeness, consistency, interpretability, accuracy, timeliness, and accessibility. These dimensions have been cited in various published studies relevant to the requirements of good data quality for generic systems or for statistical agencies (e.g. Wang and Strong, 1996; Lee et al., 2006).

A recent study by Dupuy (2012) addresses data quality issues for aviation safety databases by developing a framework for the analysis of loss of separation related incidents. The author analyses five safety databases and develops a data quality assessment framework in order to provide an indicator of the suitability of databases for certain types of analysis. Dupuy's data quality assessment framework considers the four metrics of relevance, completeness, consistency, and accessibility. Thus, it allows assessment of the quality of the data itself (i.e. internal validation). The author excludes factors related to 'trust', i.e. to as to whether the data reflects the truth of what happened. Dupuy's framework has been applied to the current research to check the data for internal consistency and the assessment concluded that all twelve databases are internally valid. However, this assessment did not proof to be sufficient. For instance, Dupuy defines completeness as 'the degree to which a database has values for all data fields that are supposed to have values.' An important issue with databases for airport surface safety occurrences is the large amount of textual data, i.e. descriptive narratives and investigation findings. In all twelve databases a descriptive narrative was given for each occurrence, a completeness rate of 100%. In such cases, it is essential to assess the quality of the narratives, i.e. is the narrative complete and does it accurately reflect the truth of what happened. This is known as external data validation.

This paper addresses the external aspects of data quality by developing an external data validation framework. In addition, the influence of the reporting level on data quality is discussed. A robust data quality assessment should take all three criteria (reporting level, external validation, internal validation) into account. The next section introduces the methodology.

3. Methodology

The proposed external data validation framework is based on Multi-Criteria Decision Analysis (MCDA), which is a technique that supports decision making by simplifying complex problems with several options assessed on multiple criteria. MCDA follows an 8-step process (Garoufalia, 2007):

(1) Definition of the decision context (study objective);
(2) Identification of options;
(3) Identification of criteria on which the options will be assessed;
(4) Scoring of the options on the criteria;
(5) Weighting of criteria according to their relative importance to the decision;
(6) Aggregation of scores and weights;
(7) Examination of results;
(8) Sensitivity analysis.

Different MCDA techniques are available and all follow the 8-step process; however, these techniques differ in their aggregation method. There are additionally means for scoring