Methodologies used by ITSA accident investigation authorities

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Abstract

Investigation analysis methodology is a current lying beneath final accident reports because it is rarely mentioned and not an ICAO USOAP requirement. Based on initial PhD research data, the reported 'what' practice by nine ITSA-member AIAs in using academic researcher and bespoke methodologies to understand 'why' is surfaced and outlined.

Background

One current lying beneath a comprehensive systemic understanding of more complex aviation accidents and serious incidents is the use of safety/accident models (SAMs) and theories of 'causality' (here collectively termed investigation 'methodologies') by Accident Investigation Authorities (AIAs), particularly during analysis. These include technical and engineering, sociological, socio-technical, systemic, and human and organisational factors methodologies across decades of research literature, both academic and practice-based. Last year Karanikas (2022) noted 161 SAMs in the NLR database (Everdij and Blom, 2020).

It has been argued that 'what you look for is what you find' (Lundberg et al, 2009). Explicit or implicit methodologies chosen and used by AIAs can inform, constrain or broaden approaches to data collection and analysis of the 'why' beyond the 'what' and 'how' as well as any recommended safety action. At the ATSB, rigorous investigation and analysis methodology including evidence tables has been led by Dr Mike Walker (Walker and Bills, 2008). That paper has been cited and utilised by other AIAs (e.g., NSIA, 2021) and academic researchers (e.g., Underwood and Waterson, 2013, 2014; Hopkins, 2014). However, based on an initial scan of 20 AIAs, any use and documentation of methodology use is not obvious in published AIA investigation reports and elsewhere on AIA websites. Therefore, choice and use of methodologies can be considered a 'current which lies beneath' AIA reports.

Research and analysis comparing and evaluating accident investigation methodologies used by government bodies is patchy and it is rare for an International Transportation Safety Association (ITSA) AIA to be included. Most of the limited government investigation methodology research has involved regulatory bodies in various non-aviation high-risk industries. Some other researchers have analysed aviation accident investigation reports, and some have analysed data obtained from individual aviation safety investigators. However, directly obtaining information from aviation AIAs about their knowledge and use of researcher-based and bespoke methodologies is yet to be reported.

To dive into this current, all 17 ITSA AIAs were invited by the then ITSA Chair, to participate in the research. Seven members quickly agreed and by late 2022, nine had formally agreed: AAIB, ATSB, BEA, DSB, JST, JTSB, SIAF, TAIC and TSB. In a collaborative, qualitative multi-case study, they were asked what, if any, methodologies they used and to provide documentation including exemplar investigation reports. They responded to research questions with answers supported by internal methodology documentation and exemplar accident reports.

The data the nine participant AIAs provided was broader and more detailed but for the purposes of this paper, the focus is on answers to five exploratory questions:
(1) what are the ICAO requirements as reflected in USOAP audits of 'Accident Investigation'?
(2) have AIAs utilised academic researcher-based or bespoke methodologies in investigation and analysis? and if so,
(3) what methodologies have AIAs used?
(4) have multiple methodologies been utilised by individual AIAs? and
(5) how and where has AIA methodology usage been documented?
These five questions are addressed as steppingstones towards better understanding AIA practice in establishing the 'why' of accident causality. A draft paper covering this reported material was provided to participant AIAs to member-check accuracy, minimise researcher bias, and ensure no surprises or sensitivities.

Results

ICAO's Annex 13 investigation framework does not specify use of 'methodologies' for AIA accident investigation and analysis, nor does ICAO audit such methodology use in the 84 Accident Investigation questions in its Universal Safety Oversight Audit Programme (ICAO, 2020). Accordingly, any use of methodologies is another current which lies beneath. Some methodologies including SHEL(L) and those by Professor James Reason are discussed in guidance and other non-binding documentation such as the four editions of the ICAO Safety Management Manual that increasingly include more systemic approaches (ICAO, 2018).

Researcher-based and bespoke methodologies complement specialist insights by individual investigators developed from their technical disciplines and past generalist investigative experience. A summary of the initial research results is provided in Table 1 below.

Table 1: ITSA AIA reported use of accident investigation and analysis methodologies

	Reason *	**Rasmussen ****	**Recent*** systemic**	**BowTie**	**Bespoke**	**Other**
AAIB	✓	✓	✓	✓		Multiple various incl. SHEL(L) & ATSB
ATSB	✓	✓		✓	SIIMS/AIMS	Multiple various including SHEL(L)
BEA		✓	✓		Gutter model (via Dédale MINOS)	
DSB	✓		✓	✓	Power & influence analysis	STEP; timeline analysis
JST	✓	✓		✓	Vortex model	Heinrich Domino
JTSB	✓					SHEL(L); 6M; 5 Whys; VTA; Fishbone; ATSB
SIAF		✓		✓		Engeström's activity theory/developmental work research method; power analysis; chain of events; grounded theory
TAIC						ATSB; mindmaps; timelines; human factors analysis
TSB	✓	✓			ISIM	

Note: columns are only ticked when explicit AIA mention made in responses or in open publications

*Including Tripod, HFACS, GEMS, Swiss Cheese Model (SCM) & updated systemic variants

** Including Accimap, Socio-technical hierarchy, & Migration to safety boundaries

*** Including Leveson's STAMP/CAST, and Hollnagel's FRAM and other models (eg by Salmon et al)

Most AIAs would be aware of the SHEL(L) model and the Reason model discussed for decades by ICAO and ISASI, and some were explicit about use in systemic investigations, including Reason's underpinning of Tripod, HFACS and GEMS and his SCM. Documentation supplied by three AIAs (AAIB, ATSB and JTSB) explicitly mentioned SHEL(L). Six AIAs cited Reason's models and six AIAs cited Rasmussen's models. Three AIAs documented use of

'recent' systemic models such as by Leveson and Hollnagel. Five AIAs documented use of BowTie analysis. Seven AIAs reported use of at least one 'other' methodology.

The TSB's bespoke 'ISIM' investigation methodology was integrated with IT systems to manage investigations, analysis, and potential safety recommendations. The ATSB built upon this with its bespoke 'SIIMS' methodology, recently revised and re-labelled 'AIMS', with detailed documentation and training related to analysis and testing of evidence, causality and significance and project management (ATSB, 2021, 2022). TAIC, JTSB and to an extent AAIB, reported use of the ATSB methodology dating from Walker and Bills (2008). Argentina's JST employed an in-house bespoke 'Vortex' model that drew upon Reason. The BEA used a bespoke 'gutter' model adapted from MINOS by the Dédale company to help understand systemic nonlinear complexity and indeterminacy and the circumstances in which this provides insightful systemic analysis (BEA, 2018; Choudet and David, 2017; Mumaw et al, 2018). DSB reported use of a bespoke form of power and influence analysis.

Some AIAs highlighted various other methodology use. The DSB used STEP and timeline analysis. The JTSB used a '6M' model based on Ishikawa's manufacturing industry 5Ms adapted for aviation investigation, a '5 Whys' type process, Variation Tree Analysis, and Fishbone diagrams. The JST cited the continuing relevance of linear reasoning based on Heinrich's Domino model. SIAF sometimes used Engeström's activity theory and developmental work research method, a form of power analysis, and grounded theory. TAIC used mindmaps, timelines and human factors analysis. The AAIB and ATSB had documented potential use of various other additional investigation methodologies.

Based on the data the answers to the five initial research questions are as follows.

(1) ICAO USOAP requirements for Accident Investigation do not include 'methodologies'.

(2) Notwithstanding the lack of requirements (SARPs) in ICAO Annex 13 and its USOAP audit, researcher-based and bespoke methodologies were found to have been used by all participant AIAs in investigation and analysis processes for major aviation investigations.

(3) The most commonly used methodologies were based on early systemic models by Professors James Reason and Jens Rasmussen. More recent systemic models such as by Professors Nancy Leveson and Erik Hollnagel were stated to have been used by three AIAs. Bespoke systemic methodologies had been developed and used by the ATSB (SIIMS/AIMS), BEA (Gutter model), JST (Vortex model) and TSB (ISIM). The DSB sometimes used a bespoke power and influence analysis model. A range of other methodologies was used by individual AIAs, sometimes depending on the type of investigation or stage of investigation as the JTSB emphasised.

(4) All AIAs used multiple methodologies - in some cases several in the same investigation - depending on the investigation issues and context. This is consistent with research advice from Salmon and Read (2019) and Karanikas (2022). The AAIB notably stated in its research response that the various available: *"methodologies all have advantages and limitations; inspectors all think differently. A methodology needs to encourage creativity to allow thinking outside the box, while having the discipline to pull the multiple threads together"*.

(5) Among participating ITSA AIAs, the ATSB and DSB had made specific reference to methodology usage in material on their websites. All the AIAs provided general investigation

and analysis process material based on Annex 13. Some AIAs made reference to methodology use in particular accident investigation reports but this was not easy to find because of the typically hundreds of reports on each website. Such references, with various levels of detail, were found in some of the exemplar reports that participants drew attention to (e.g., ATSB, BEA, DSB and SAIF). There was also some methodology documentation at ICAO and ISASI investigator seminars around the world (e.g., by the ATSB, BEA and TSB) but this was not widely known and accessed by researchers or non-specialists. Participant AIA methodology was mostly documented internally. Such use as now been made available, with the AIAs' collaborative agreement, through this research project.

Next Steps

The next phase of the research will focus more on the 'why' of methodology choice and use. It will include completion and review of participant interviews as well as analysis of the more detailed written and documentary material already provided by ITSA AIA participants. The NTSB has recently agreed to participate and its data will be incorporated. In dialogue with key research literature, a detailed analysis of the different AIA methodology characteristics, and of their choice and how and why they are used will be undertaken. When this material is drafted and before any broader publication, there will be further opportunity for member-checking and sharing of results with participants. This is to enhance integrity and usefulness of the material to ITSA participants, other AIAs, ICAO, ISASI, researchers that may wish to have greater practical industry impact, and other high-risk industries and their investigators.

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Appendix of Key Acronyms

AAIB: Air Accidents Investigation Branch of the United Kingdom (its 'inspectors' are investigators)
Accimap: accident diagram mapping causal links & hierarchical causality (by Rasmussen & Svedung)
AIA: Aviation Investigation Authorities, ICAO terminology that includes multi-modal ITSA members
AIMS: ATSB Investigation Management System (replacement of SIIMS)
ATSB: Australian Transport Safety Bureau
BEA: Bureau d'Enquêtes et d'Analyses pour la sécurité de l'aviation civile (France's AIA)
BowTie: pictorial representation with precursors on left of accident top event & mitigators on right
CAST: Causal Analysis based on STAMP (by Leveson)
DSB: Dutch Safety Board
FRAM: Functional Resonance Analysis Model (by Hollnagel, initially termed an accident model)
GEMS: Generic Error-Modelling System (by Reason)
Gutter model: BEA's pictorial adaption of MINOS by the Dédale company to help understand systemic nonlinear complexity and indeterminacy
HFACS: Human Factors Analysis & Classification System (by Wiegmann & Shappell based on Reason)
ICAM: Incident Cause Analysis Method (based on Reason model)
ISIM: TSB's Integrated Safety Investigation Methodology
ITSA: International Transportation Safety Association
JST: Junta de Seguridad en el Transporte (Argentina's AIA)
JTSB: Japan Transport Safety Board
NSIA: Norway Safety Investigation Authority (Norway's AIA, formerly AIBN in English)
NTSB: National Transportation Safety Board of the United States of America
SAMs: Safety/Accident Models that may guide/underpin investigations & address types of causality
SCM: Swiss Cheese Model (pictorial analogy used for an early form of Reason's model)
SHEL(L): software, hardware, environment, liveware and liveware-liveware model (Hawkins & ICAO)
SIAF: Safety Investigation Authority Finland
SIIMS: ATSB's Safety Investigation Information Management System (now replaced by AIMS)
SMM: Safety Management Manual produced by ICAO in four editions from 2006 to 2018
STAMP: System-Theoretic Accident Model and Processes (by Leveson)
STEP: Sequentially Timed Events Plotting (see Herrera and Woltjer)
TAIC: Transport Accident Investigation Commission of New Zealand
Tripod (Beta): accident investigation and analysis model (by Hudson, Reason & Wagennaar)
TSB: Transportation Safety Board of Canada
USOAP: Universal Safety Oversight Audit Programme by ICAO
Vortex: Argentina JST (originally aviation) accident investigation model with a Reason basis
VTA: Variation Tree Analysis