



Australian Government

Australian Transport Safety Bureau

ATSB TRANSPORT SAFETY RESEARCH REPORT

Aviation Research and Analysis Report – AR-2007-053

Analysis, Causality and Proof in Safety Investigations



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and Proof in Safety Investigations**

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Abstract

The quality of a safety investigation's analysis activities plays a critical role in determining whether the investigation is successful in enhancing safety. However, safety investigations require analysis of complex sets of data and situations where the available data can be vague, incomplete and misleading. Despite its importance, complexity, and reliance on investigators' judgements, analysis has been a neglected area in terms of standards, guidance and training of investigators in most organisations that conduct safety investigations.

To address this situation, the Australian Transport Safety Bureau (ATSB) developed a comprehensive investigation analysis framework. The present report provides an overview of the ATSB investigation analysis framework and concepts such as the determination of contribution and standard of proof. The report concludes by examining the nature of concerns that have been raised regarding the ATSB analysis framework and the ATSB's consideration of these concerns.

The ATSB believes that its investigation analysis framework is well suited to its role as an independent, no-blame safety investigation body. It is hoped and expected that ongoing development and provision of information about the framework can help the safety investigation field as a whole consider some important issues and help develop the best means of conducting safety investigations to enhance future safety.

THE AUSTRALIAN TRANSPORT SAFETY BUREAU

The Australian Transport Safety Bureau (ATSB) is an operationally independent multi-modal bureau within the Australian Government Department of Infrastructure, Transport, Regional Development and Local Government. ATSB investigations are independent of regulatory, operator or other external organisations.

The ATSB is responsible for investigating accidents and other transport safety matters involving civil aviation, marine and rail operations in Australia that fall within Commonwealth jurisdiction, as well as participating in overseas investigations involving Australian registered aircraft and ships. A primary concern is the safety of commercial transport, with particular regard to fare-paying passenger operations.

The ATSB performs its functions in accordance with the provisions of the *Transport Safety Investigation Act 2003* and Regulations and, where applicable, relevant international agreements.

Purpose of safety investigations

The object of a safety investigation is to enhance safety. To reduce safety-related risk, ATSB investigations determine and communicate the safety factors related to the transport safety matter being investigated.

It is not the object of an investigation to determine blame or liability. However, an investigation report must include factual material of sufficient weight to support the analysis and findings. At all times the ATSB endeavours to balance the use of material that could imply adverse comment with the need to properly explain what happened, and why, in a fair and unbiased manner.

Developing safety action

Central to the ATSB's investigation of transport safety matters is the early identification of safety issues in the transport environment. The ATSB prefers to encourage the relevant organisation(s) to proactively initiate safety action rather than release formal recommendations. However, depending on the level of risk associated with a safety issue and the extent of corrective action undertaken by the relevant organisation, a recommendation may be issued either during or at the end of an investigation.

The ATSB has decided that when safety recommendations are issued, they will focus on clearly describing the safety issue of concern, rather than providing instructions or opinions on the method of corrective action. As with equivalent overseas organisations, the ATSB has no power to implement its recommendations. It is a matter for the body to which an ATSB recommendation is directed (for example the relevant regulator in consultation with industry) to assess the costs and benefits of any particular means of addressing a safety issue.

About ATSB investigation reports: How investigation reports are organised and definitions of terms used in ATSB reports, such as safety factor, contributing safety factor and safety issue, are provided on the ATSB web site www.atsb.gov.au.

EXECUTIVE SUMMARY

The ultimate purpose of a safety investigation is to enhance safety, and it is not the purpose to apportion blame or liability. A safety investigation into an occurrence (accident or incident) can enhance safety by identifying safety issues and communicating these issues to relevant organisations. It can also enhance safety by providing information about the circumstances of the occurrence and the factors involved in the development of the occurrence to the transportation industry.

The quality of a safety investigation's analysis activities plays a critical role in determining whether the investigation is successful in enhancing safety. However, safety investigations require analysis of complex sets of data and situations where the available data can be vague, incomplete and misleading. Despite its importance, complexity, and reliance on investigators' judgements, analysis has been a neglected area in terms of standards, guidance and training of investigators in most organisations that conduct safety investigations.

To address this situation, the Australian Transport Safety Bureau (ATSB) developed a comprehensive investigation analysis framework. The framework consists of: a defined process or workflow for conducting analysis activities; standardised terminology and definitions; an accident development model (termed the ATSB 'investigation analysis model'); and policies, guidelines, tools and training for investigators.

As with all analysis approaches, some concerns have been raised regarding aspects of the ATSB framework, particularly regarding the standard of proof used to determine contribution to the development of an occurrence and the nature of the ATSB investigation analysis model. In terms of standard of proof, the ATSB framework defines a 'contributing safety factor' as a safety factor that, if it had not occurred or existed at the relevant time, then either the occurrence would probably not have occurred, adverse consequences associated with the occurrence would probably not have occurred or have been as serious, or another contributing safety factor would probably not have occurred or existed. The term 'probably' was defined as being equivalent to 'likely' and meaning more than 66 per cent likelihood (a definition used by the Intergovernmental Panel on Climate Change).

Because of its focus on future safety, the ATSB definition adopts a 'link-by-link' approach, where the judgement about whether a safety factor contributed to the development of an occurrence is made in terms of its relationship to another contributing safety factor. In contrast, other types of investigations (particularly those whose purpose is to determine responsibility) generally use a 'relative-to-occurrence' approach. With the relative-to-occurrence approach, judgements of contribution are made in terms of the safety factor's relationship to the occurrence itself. The ATSB analysis framework will involve a higher standard of proof than in Australian coronial inquests or civil legal proceedings for factors relatively close in proximity to the occurrence (that is, more than 66 per cent versus more than 50 per cent). But as an ATSB safety investigation proceeds to identify contributing safety factors more remote from the occurrence, the degree of relationship of the factors to the occurrence itself will generally decrease using the ATSB framework.

Associated with the concept of standard of proof is the concept of standard of evidence, or the quantity or quality of evidence required before a decision maker can be satisfied that the relevant standard of proof has been met. In the Australian

legal system, the ‘Briginshaw scale’ is used when making judgements about the standard of evidence. The scale involves considering the seriousness of a finding, the inherent unlikelihood of a finding, and the gravity of consequences that flow from a finding for the party or parties involved. The Briginshaw scale is not routinely incorporated into safety investigation methods. The scale is used to some extent in ATSB safety investigations, but there are several reasons to consider that it is not required or beneficial for the ATSB to apply the scale more broadly.

The differences between the ATSB approach to determining contribution and other approaches may be a matter of nuance in many situations, and similar findings may result regardless of the approach being used. Nevertheless, there is also the potential for different sets of findings to be produced. More specifically, the ATSB’s link-by-link approach together with a ‘probable’ standard of proof has the following advantages over many other investigation analysis approaches:

- It better enables the search for potential safety issues, particularly those more remote from an occurrence. The enhanced searching will result in more safety issues being identified and communicated to relevant organisations to enhance safety.
- It has greater potential for providing a richer or more detailed description of the factors involved in the development of an occurrence, which provides better learning opportunities for the transport industry.
- It is more distinct from the approach used in legal proceedings for determining blame or liability. Therefore, there is less potential for the existence of barriers to learning or safety action due to an investigation’s findings being associated with such legal proceedings, or interpreted with such proceedings in mind.

In terms of the ATSB investigation analysis model, it is based on the widely used Reason model of organisational accidents and consists of five levels of safety factors (occurrence events, individual actions, local conditions, risk controls and organisational influences). Concern has been raised that the model is biased towards finding problems at the higher levels of the model and that the pendulum has swung too far towards searching for organisational factors. The ATSB model does encourage investigators to look for problems with risk controls and organisational influences as, if there are problems in these areas, this is where significant safety enhancements can be made. However, the model is only used as one means to help identify potential safety factors. Before any findings are made about whether these potential factors contributed to the development of the occurrence, or were otherwise important, they need to be tested or verified. In the ATSB analysis framework, this involves using a structured process to examine the available evidence and conducting tests for existence, influence and importance.

The ATSB believes that its investigation analysis framework is well suited to its role as an independent, no-blame safety investigation body. It is hoped and expected that ongoing development and provision of information about the framework can help the safety investigation field as a whole consider some important issues and help develop the best means of conducting safety investigations to enhance safety. Accordingly, any feedback or comment that any individual or organisation has regarding the ATSB analysis framework, ways to enhance the framework, ways for the ATSB to better communicate its findings, or any other matters discussed in this report would be gratefully received.

1 INTRODUCTION

1.1 Purpose of this report

While the ATSB is well respected in the field of safety investigation¹, it has recognised a need to continually improve its processes over time. As part of this continual improvement, it recently developed an enhanced and more transparent framework for conducting analysis activities during a safety investigation.

The purpose of this report is to present some key aspects of the ATSB analysis framework. The report also outlines some of the concerns that have been expressed with the ATSB framework and similar approaches, and the ATSB's consideration of these concerns.

In addition to helping communicate important information about the framework and related issues to relevant organisations, it is hoped and expected that this report will solicit constructive dialogue and suggestions to enhance the framework. Further discussion of methodology in this important area could also help improve analysis activities conducted in the field of transport safety investigation.

1.2 Overview of the report

The remainder of Section 1 of this report provides relevant background information concerning the purpose of safety investigations, the role of analysis, and an overview of the development and components of the ATSB analysis framework. The last part of the section provides an overview of the concerns that have been expressed regarding the ATSB framework and similar approaches. These concerns have primarily been associated with the standard of proof used to determine contributing safety factors, and the accident development model used by the ATSB.

Section 2 of the report discusses the new safety analysis terminology being used by the ATSB (such as 'contributing safety factor' and 'safety issue'). Section 3 outlines the accident development model used in the ATSB framework, and Section 4 provides an overview of the ATSB analysis process, focussing on areas related to the present report. Section 5 provides background on concepts such as contribution (or causation) and 'standard of proof', and how these concepts have been addressed by different investigation approaches, including the ATSB analysis framework. Section 6 then outlines concerns that have been expressed regarding the ATSB framework and similar approaches, and ATSB consideration of these concerns.

¹ For example, in 2003 the ATSB received the respected US-based Flight Safety Foundation (FSF) Cecil A. Brownlow award for its report on Ansett B767 aircraft maintenance deficiencies and ATSB investigation reports are frequently cited in FSF publications. In addition to within Australia, the ATSB is active internationally through the International Maritime Organisation (IMO), the International Civil Aviation Organization (ICAO), and in bodies such as the International Transportation Safety Association (ITSA), the Marine Accident Investigators International Forum (MAIIF), and the International Society of Air Safety Investigators (ISASI).

1.3 Purpose of safety investigations

1.3.1 Relevant international and national standards

A safety investigation is an investigation conducted with the purpose of enhancing safety (or preventing accidents), and not conducted for the purposes of attributing blame or liability. A safety investigation is generally conducted into a specific occurrence (that is, an accident or incident). Safety investigations can also be conducted into other matters, such as a specific part of the safety system or a series of events that may be of safety interest. The ATSB terms such investigations as 'safety issue investigations'. Although much of the ATSB analysis framework is applicable to both types of safety investigation, the focus of the present report is on occurrence investigations.

The purpose of safety investigations is clearly stated in relevant standards for different transportation modes. More specifically, the International Civil Aviation Organization (ICAO) outlines international standards and recommended practices for aircraft accident and incident investigation in *Annex 13 to the Convention on International Civil Aviation*.² Annex 13 defines an investigation (Chapter 1) as:

A process conducted for the purpose of accident prevention which includes the gathering and analysis of information, the drawing of conclusions, including the determination of causes and, when appropriate, the making of safety recommendations.

Annex 13 also states the following (paragraph 3.1):

The sole objective of the investigation of an accident or incident shall be the prevention of accidents and incidents. It is not the purpose of this activity to apportion blame or liability.

Further, paragraph 5.4 states:

The accident investigation authority shall have independence in the conduct of the investigation and have unrestricted authority over its conduct, consistent with the provisions of this Annex.

The International Maritime Organisation (IMO) outlines a code for the investigation of marine casualties and incidents in an annex to Resolution A.849(20) (27 November 1997). This document states the following (Section 2):

The objective of any marine casualty investigation is to prevent similar casualties in the future. Investigations identify the circumstances of the casualty under investigation and establish the causes and contributing factors, by gathering and analysing information and drawing conclusions. Ideally, it is not the purpose of such investigations to determine liability, or apportion blame. However, the investigating authority should not refrain from fully reporting the causes because fault or liability may be inferred from its findings.

On 16 May 2008, the IMO adopted the new *Code of the International Standards*

² ICAO, *Annex 13 to the Convention on International Civil Aviation: Aircraft Accident and Incident Investigation*, 9th edition, July 2001 (including Amendment 11 and supplement, 23 November 2006).

and Recommended Practices for a Safety Investigation into a Marine Casualty or Marine Incident (Casualty Investigation Code). The IMO has also adopted amendments to the International Convention on the Safety of Life at Sea (SOLAS) to annex the Casualty Investigation Code to SOLAS. The Casualty Investigation Code and SOLAS amendments are expected to enter into force on 1 January 2010. In the interim the IMO has issued a circular encouraging States to implement the Code's provisions, which confirm that marine safety investigations are to be conducted with the objective of preventing future occurrences, and that marine safety investigations do not seek to apportion blame or determine liability.

There is no equivalent international instrument regarding investigations of rail occurrences. *Australian Standard 4292.7-2006 (Rail Safety Management Part 7: Railway safety investigation)* provides guidance on processes to use for any organisation investigating rail safety occurrences in Australia. The standard states the following (in the foreword):

The requirements specified in this document for investigating an occurrence has as its primary objective the enhancement of safety through the discovery of any systemic problems and deficiencies which may have led to the occurrence, or any latent safety issues the investigation might reveal. As such, it needs to be clearly differentiated from other kinds of investigation that might arise from the same occurrence, such as police, OHS authority and coronial investigations.

It is important that in order to meet the kind of objective set out above, the investigation is designed to support a 'just culture' approach...

Section 1.8 also states:

An investigation conducted in accordance with this Standard will have as its prime objective the discovery of systemic safety deficiencies rather than to apportion blame or liability to any person or organization.

1.3.2 Australian legislation

International requirements for transport safety investigation are enacted into Australian law through regulations pursuant to Section 17 of the *Transport Safety Investigation Act 2003* (TSI Act) as well as directly in the TSI Act itself. The objects clause (Section 7) of the TSI Act reads:

- (1) The main object of this Act is to improve transport safety by providing for:
 - (a) the reporting of transport safety matters; and
 - (b) independent investigations into transport accidents and other incidents that might affect transport safety; and
 - (c) the making of safety action statements and safety recommendations that draw on the results of those investigations; and
 - (d) publication of the results of those investigations in the interests of transport safety.

- (2) Another object of this Act is that, during the investigation of a transport safety matter under this Act, there be co-operation between the Executive Director and any other Commonwealth agency or person having powers under another law of the Commonwealth to also investigate the matter.
- (3) The following are not objects of this Act:
 - (a) apportioning blame for transport accidents or incidents;
 - (b) providing the means to determine the liability of any person in respect of a transport accident or incident;
 - (c) assisting in court proceedings between parties (except as expressly provided by this Act);
 - (d) allowing any adverse inference to be drawn from the fact that a person is subject to an investigation under this Act.

In other words, ATSB conducts ‘no blame’ safety investigations, consistent with the requirements of ICAO and IMO, rather than so-called ‘just culture’ safety investigations as specified by AS4297.7. Although the two types of investigation have the same primary purpose, there can be some important differences:

- Just culture investigations focus on enhancing safety, and promoting the full reporting of safety-related information. However, they may also involve making judgements regarding the suitability or acceptability of the actions of individuals (including managers). Where such actions are judged to be clearly unacceptable (such as deliberately ignoring hazards or intending to cause damage), then sanctions may be imposed. Just culture investigations are generally conducted by operational organisations or regulatory authorities.
- No-blame investigations do not attempt to make judgements about the suitability or acceptability of individual actions as part of assessing blame or liability. This approach is taken to maximise the ability to obtain relevant information during an investigation. No-blame investigations are generally conducted by independent safety investigation organisations, such as the ATSB.

Even though the ATSB conducts no-blame investigations, a just culture approach is preserved through the ATSB taking a cooperative approach to any required parallel investigations by regulators, police or other bodies. However, these investigations are independent of the ATSB investigation and must gather their own evidence.

1.3.3 Means by which safety investigations can enhance safety

In simple terms, a safety investigation into an occurrence enhances safety by determining what happened, how it happened and why it happened. More specifically, the information obtained from an investigation can be used to enhance safety in several ways:

- Identifying safety issues that could adversely affect the safety of future operations, and encouraging or facilitating safety action by relevant organisations to address these issues. An ATSB safety investigation encourages or facilitates safety action by relevant organisations by communicating the safety issues to them, either through confidential briefings or through formal means such as a safety recommendation. Depending on the seriousness of the

safety issue, this communication can occur prior to finalising the investigation report.

- Providing information about the circumstances of the occurrence, and the factors involved in the development of the occurrence, to the transportation industry. This is done through the public release of an investigation report, and in some cases through industry presentations and safety magazine articles. Communicating information about the occurrence provides valuable learning opportunities to members of the industry, regardless of whether or not they were involved in the occurrence.
- Providing information for an occurrence database, which can then be combined with information from other occurrences and used for research and trend analysis purposes.

The most important safety outputs arising from a safety investigation are what the relevant organisations actually do to enhance the safety of their operations. As with equivalent overseas organisations, the ATSB has no power to require other organisations to make safety enhancements. However, it can facilitate such changes through its safety communication activities. The effectiveness of these communication activities will increase when the investigation provides a relatively detailed or rich picture of the factors involved in the development of the occurrence, and when findings about factors are based on a rigorous analysis process and compelling arguments.

1.4 The analysis phase of an investigation

A safety investigation involves a number of different activities. These can be summarised as shown in Figure 1. After a transport safety matter (accident, incident or other matter) has been notified to the ATSB, an assessment is made as to whether a safety investigation is desirable. The investigation itself involves data (or evidence) collection, analysis, safety action and report preparation phases, as well as project management activities.

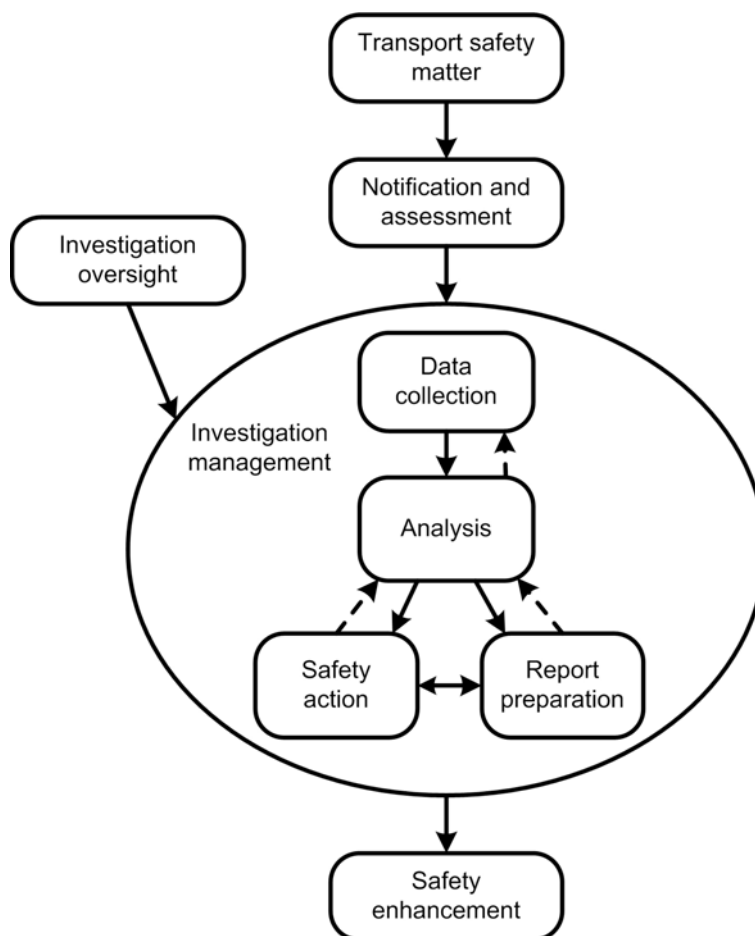
As shown in the figure, a key component of the safety investigation process is the analysis phase. This phase involves reviewing and evaluating the available data, and converting it into a series of arguments to produce a series of relevant findings. The quality of an investigation's analysis activities obviously plays a critical role in determining whether the investigation's findings are respected and successful in enhancing safety.

As shown in Figure 1, there is a greater focus on analysis activities after most of the data has been collected. However, analysis occurs throughout the investigation. It starts at the beginning of an investigation, when decisions are needed to ensure efficient data collection (for example, evidence needs to be examined and decisions made when inspecting an accident site to determine which components may or may not require further examination). Analysis also continues until the end of the investigation, as the investigation report may need to be modified to address relevant concerns raised regarding factual accuracy or findings during internal and external reviews of a draft report.

The analysis phase is rarely easy. Safety investigations require analysis of complex sets of data, and situations where the available data can be vague, incomplete and misleading. There are no detailed, prescriptive rules that can be applied in all

situations and provide guaranteed success, and analysis activities ultimately rely on the judgement of safety investigators.

Figure 1: Overview of safety investigation activities



1.5 Need for an enhanced analysis framework

Despite its importance, complexity, and reliance on investigators' judgements, analysis has been a neglected area in terms of standards, guidance and training of investigators in most organisations that conduct safety investigations. Many investigators (from most safety investigation organisations) seem to conduct analysis activities primarily using experience and intuition which is not based on, or guided by, a structured process. It also appears that much of the analysis is typically conducted while the investigation report is being written. As a result, the writing process can become inefficient, supporting arguments for findings may be weak or not clearly presented, and important factors can be missed.

The ATSB and its predecessor the Bureau of Air Safety Investigation (BASI)³ have for many years been examining ways to improve investigation processes. In terms

³ The Bureau of Air Safety Investigation (BASI) became part of the newly formed multi-modal Australian Transport Safety Bureau (ATSB) on 1 July 1999.

of analysis, this has involved developments such as the adoption of the Reason model as a basis for the analysis of an occurrence (see Section 3), and then further enhancements of that model over time.⁴ The ATSB believes that its past major investigations have generally been of high quality, with several receiving favourable recognition internationally.⁵ Nevertheless, the situation described above has meant that there was a potential for limitations to occur with the analysis processes used in ATSB investigations. Accordingly, the ATSB believed that it was appropriate to review its processes and develop a more comprehensive and explicit framework to guide and support the analysis activities of its investigators.

Development work commenced from mid 2004, after the ATSB was successful in obtaining substantial Australian Government funding to replace its existing occurrence database (OASIS) with a new Safety Investigation Information Management System (SIIMS) for its investigation activities. There were several drivers for the change, including the fact that OASIS was based on a very complex data model, which made trend analysis and research difficult. The previous system also had limited functionality beyond being an occurrence database. The ATSB wanted to take advantage of developments in information technology to build a system which could enhance the quality of the investigation process. The new system has several components, such as document management, project management and evidence tracking. A key component is a set of tools for the analysis phase of a safety investigation.

As part of the SIIMS project, the ATSB initially reviewed existing analysis frameworks and methods applicable to safety investigation. None of these were found to meet the ATSB's needs. Common limitations included:

- applicability to a narrow domain (for example, aircraft maintenance)
- focus on a limited part of the analysis process
- lack of flexibility to handle novel situations
- lack of flexibility to deal with both small and major investigations
- lack of guidance material about the process.

In addition, the review identified that there was minimal commonality in the terms, models, and processes used by various safety investigation organisations.

Consequently, the ATSB developed its own analysis framework, borrowing useful ideas from its existing processes and other organisations where appropriate, but also substantially adding to this material in many areas. The ultimate aims of the ATSB investigation analysis framework were to improve the rigour, consistency and defensibility of investigation analysis activities, and improve the ability of investigators to identify safety issues in the transportation system.

4 The first well-known example of BASI's use of the Reason model was BASI Investigation Report 199301743, Piper PA31-350 Chieftain, Young NSW, 11 June 1993.

5 Prominent early examples include (a) ATSB Investigation Report, Systemic Investigation into Fuel Contamination (published March 2001); (b) ATSB Investigation Report 199904538, Boeing 747-438, VH-OJH, Bangkok, Thailand, 23 September 1999 (published April 2001); (c) ATSB Aviation Safety Investigation BS/20010005, Investigation into Ansett Australia maintenance safety deficiencies and the control of continuing airworthiness of Class A aircraft (published November 2002).

1.6

Overview of the ATSB analysis framework

The resulting ATSB investigation analysis framework is described by several components, as outlined in Figure 2.⁶ The central component is a defined process or workflow for conducting analysis activities. This overall process is divided into five main sub-processes: preliminary analysis, safety factors analysis, risk analysis, safety action development and analysis review. A brief discussion of these processes is provided in Section 4.

Figure 2: Overview of the ATSB investigation analysis framework



Supporting and guiding the analysis process are the following components:

- Standardised terminology and definitions for analysis-related terms. This includes definitions for risk, hazard and safety, as well as terms to describe events and conditions that increase safety risk ('safety factors'), the events and conditions that contributed to the development of an occurrence ('contributing safety factors'), and the conditions that will have an influence on future safety unless addressed ('safety issues'). The terminology is discussed in Section 2.
- An accident development model. The ATSB 'investigation analysis model' incorporates an adaptation of the Reason model of organisational accidents, and involves a set of functional questions to help identify potential safety factors. The model is discussed in Section 3.
- Policies, guidelines, tools and training. These components assist investigators in conducting the analysis process. Some of the tools are included in SIIMS to

⁶ An overview of the framework is provided by M. B. Walker, 'Improving the Quality of Investigation Analysis', *ISASI Forum*, January-March 2007.

guide and document analysis activities. These tools include a sequence of events list, safety factors list, risk analysis form, and evidence tables. Evidence tables are discussed in Section 4.4.

- A strong emphasis in the guidelines and training on ensuring that teamwork and appropriate domain knowledge are used during analysis activities.

Many elements of the resulting framework are not new to the ATSB processes, but the development process has ensured that these elements have been more clearly defined and formalised.

1.7 Overview of concerns that have been expressed

Concerns have been expressed with all approaches to safety investigation analysis. There are many different viewpoints, and no analysis framework will ever be fully supported by all parties who may be associated with a safety investigation.

For example, some concerns have been expressed with the use of analysis methods based on the Reason model (see Section 6). There has also been much discussion and disagreement about the way findings of investigation reports should be organised. The ATSB analysis framework was developed with consideration of these various concerns and viewpoints in mind.

Prior to developing its enhanced analysis framework, concerns had occasionally been expressed regarding the analysis processes used in some ATSB investigations. In one high profile example, the coronial inquest into the VH-MZK Whyalla Airlines accident, the Counsel Assisting the then State Coroner for South Australia stated in his final oral submissions that aspects of the ATSB final report contained 'inaccurate factual findings' that were 'not backed up with good and reliable scientific analysis'. In addition, the Coroner's findings on 24 July 2003 (paragraph 13.5) stated that:

The overwhelming weight of the evidence before me suggests that these two engine failures were independent of each other, and it is not enough for the ATSB to simply dismiss that conclusion on the basis that its likelihood is too remote. If that conclusion is to be dismissed, it should be dismissed on a scientific basis rather than a statistical one. From that starting point, the ATSB has set out to establish that the failure of these two engines was a dependent failure.

However, the ATSB considered that these critiques were not well founded. Thus the ATSB's Supplementary investigation report of October 2003 stated (p.34):

the draft ATSB report had a very different failure sequence involving independent engine failures which was discarded when further evidence became available and additional analysis was undertaken. This shows that the ATSB had not set out to prove a single hypothesis (and, of course, in contrast to the Coroner's suggestion, utilising statistical analysis is a well-established tool in a scientific approach) ...

One of the first examples where the enhanced ATSB investigation analysis framework was utilised was in the ATSB's investigation into the fatal Metro 23

accident near Lockhart River on 7 May 2005.⁷ The ATSB's final report was released on 4 April 2007. During a subsequent coronial inquest into the accident, concerns were raised by one party regarding aspects of the methodology used by the ATSB. These mainly related to the Reason model approach and the standard of proof associated with the ATSB's definition of 'contributing safety factor'.

Overall, the Queensland State Coroner's findings on 17 August 2007 regarding the accident at Lockhart River were complimentary about the ATSB investigation and report, and the coroner's findings were generally consistent with the ATSB's findings. Although the party's concerns with respect to the ATSB methodology were not supported, the Queensland State Coroner stated the following⁸:

...The Bureau is to be commended for attempting to adopt a scientific approach to what has been, in many instances treated as an art form. However, there is, I would suggest, some basis for concern about aspects of the project's outcome. In view of its recency and importance to future investigations I consider it worthwhile to record some concerns about how it will be applied.

The analysis framework that was developed as part of that project is said to "improve the rigor, consistency, and defendability of investigation analysis activities and to improve the ability of investigators to detect safety issues in the transportations system." A key component of the new system, including the analysis framework, is the use of standardised terminology. A significant term, a "contributing safety factor," is defined as an event or condition that increases safety risk and which, if it had not occurred or existed, the occurrence under investigation or another contributing safety factor would "probably" not have occurred or would "probably" not have had such serious consequences. The Bureau settled on a 66% probability as a sufficient causal connection. CASA [Civil Aviation Safety Authority], in its submissions to this inquest suggested that this was too low a threshold; that it raises serious doubts as to whether the findings in the ATSB report regarding contributing safety factors can be relied upon.

In my view, the validity of such a benchmark can be challenged from at least two other perspectives. Firstly, to suggest that the accuracy of deductive reasoning or even speculative assessments to which the approach will be applied can be gauged with such precision is, in my view, misconceived. A calibration that may be ideally suited to measuring tangible items or the outcomes of chemical or physical processes may have no application to the vagaries of human behaviour.

Further, there seems no good basis for requiring the same level of certainty in relation to all possible contributing causes in all cases and seeking it solely from within the evidence gathered during an investigation. Lawyers apply what is referred to as the Briginshaw principle whereby the level of persuasion or conviction required and the evidence necessary to establish it may vary, having regard to the seriousness of the issue under consideration; the gravity of its consequences and inherent likelihood of it occurring. The

7 ATSB Transport Safety Investigation Report, Aviation Occurrence Report 200501977, Collision with Terrain, 11 km NW Lockhart River Aerodrome, 7 May 2007, VH-TFU, SA227-DC (Metro 23) (published April 2007).

8 Office of the State Coroner, Inquest into the Aircraft Crash at Lockhart River, Finding of Inquest delivered on 17 August 2007, pp.6-7. Finding obtainable from:
<http://www.justice.qld.gov.au/courts/coroner/findings.htm>

ATSB should perhaps heed the warning of Justice Dixon (as he then was) who, when discussing the level of persuasion necessary to find a fact proven said “It can not be found as a result of a mere mechanical comparison of probabilities independently of any belief in its reality.”

Issues for discussion arising from these comments include: the ATSB definition of contributing safety factor; the standard of proof (66 per cent probability threshold) associated with this definition; the role of judgement when considering probabilities; and the extent to which the ‘Briginshaw principle’ should be applied to safety investigations.

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2 KEY TERMS USED IN THE ATSB ANALYSIS FRAMEWORK

Section 2 outlines the definitions of key terms in the ATSB analysis framework, such as ‘safety factor’, ‘contributing safety factor’ and ‘safety issue’. The section also outlines the types of findings produced in ATSB investigations, and guidance on the meaning of verbal probability expressions used in investigation findings.

2.1 Safety factor

2.1.1 ATSB definition

A safety factor is an event or condition that increases safety risk.⁹ In other words, it is something that, if it occurred in the future, would increase the likelihood of an occurrence¹⁰, and/or the severity of the adverse consequences associated with an occurrence.

2.1.2 Key points to note

Key points to note in relation to the definition of safety factor include:

- The term ‘safety factor’ was selected after reviewing the terms used by other safety investigation organisations. It was found that many organisations did not have any specific term for the concept, or used multiple terms for the concept, such as ‘unsafe acts and unsafe conditions’. The term ‘safety factor’ was considered to be simpler than using multiple terms and less judgemental than terms such as ‘unsafe’.
- The term ‘event’ refers to something that happened at a specific point (for example, an engine failure), or something that did not happen at a time when it would have been appropriate or relevant to do so (for example, a pilot not lowering landing gear prior to landing). The term ‘condition’ refers to something that existed for a period of time (for example, a train driver’s fatigue), or something that did not exist at a time where it would have been appropriate or relevant to do so (for example, the absence of a procedure for a specific task).

⁹ Australian Standard 4360:2004 (*Risk Management*) defines risk as ‘the chance of something happening that will have an impact on objectives’. A note to the definition refers to International Standards Organisation / International Electrotechnical Commission (ISO / IEC) Guide 51 (*Safety aspects – Guidelines for their inclusion in standards*) for aspects related to safety. ISO/IEC Guide 51 defines risk as the ‘combination of the probability of occurrence of harm and the severity of that harm’, with harm defined as ‘physical injury or damage to the health of people, or damage to the property or the environment’. Safety was defined in ISO/IEC Guide 51 as ‘freedom from unacceptable risk’. A helpful discussion of the concept of ‘safety’ is provided in the ICAO *Safety Management Manual*, Doc 9859/AN460, 2006, p.1-1.

¹⁰ The term ‘occurrence’ is used by the ATSB and some other organisations to refer to either an accident or an incident.

- An event or condition does not have to contribute to an occurrence to be considered a safety factor, but it must have the potential to contribute to future occurrences if it existed in the future. An occurrence investigation may identify a range of events and conditions which increase safety risk, but only some of them will have actually contributed to the occurrence being investigated (see also Section 2.4).
- When deciding whether an event or condition is a safety factor, responsibility or blame for what has happened in the past should not be a criterion. Rather, consistent with the purpose of a safety investigation, the focus should be on identifying what can be learnt from the occurrence to enhance safety. Therefore, it is useful to consider whether, if a similar situation arose in the future, it is desirable (from a safety point of view) that the event or condition of interest be different from that which existed in the occurrence. For example, when considering the actions of individuals, it is useful to consider whether, if a similar situation arose again, it would be desirable for the individual's actions to be different. Similarly, when considering the characteristics of organisations, it is useful to consider whether, if a similar situation arose again, it would be desirable for the organisation's controls or processes to be different.
- The definition of safety factor needs to be interpreted realistically rather than pedantically. For example, simply starting the engine on a vehicle increases risk, but this would not normally be considered a safety factor unless the starting process was done in such a way that increased risk relative to normal operations. The definition also assumes that the increase in level of risk is greater than a trivial amount. Although this may seem a vague statement, the judgement is rarely difficult. There will usually be enough agreement within an investigation team to support the view that something is or is not associated with more than trivial risk.
- The term 'safety factor' is sometimes used for a different purpose in the field of engineering. In this context, the safety factor, more commonly known as the 'factor of safety', is defined as the designed strength of a component divided by the maximum expected load on the component. The higher the factor, the greater the margin over the theoretical design capacity to allow for various uncertainties in the design and manufacturing process. Although 'safety factor' sometimes has this alternative meaning, the term still appears to be the most meaningful label to apply to an event or condition that increases safety risk.

2.1.3 Types of safety factor

Safety factors can be categorised in a number of ways. For example:

- safety factors which contributed to the development of an occurrence ('contributing safety factors') versus safety factors which did not contribute (or 'other safety factors') (see Section 2.2)
- safety factors dealing with organisational or systemic aspects ('safety issues') versus safety factors dealing with individual or local aspects (or 'safety indicators') (see Section 2.3).

Safety factors can also be classified as belonging to one of the components or levels of an accident development model (see Section 3).

2.2 Contributing safety factor

2.2.1 ATSB definition

A contributing safety factor to an occurrence is a safety factor that, if it had not occurred or existed at the relevant time, then either:

- the occurrence would probably not have occurred, or
- adverse consequences associated with the occurrence would probably not have occurred or have been as serious, or
- another contributing safety factor would probably not have occurred or existed.

2.2.2 Key points to note

Key points to note in relation to the definition of contributing safety factor include:

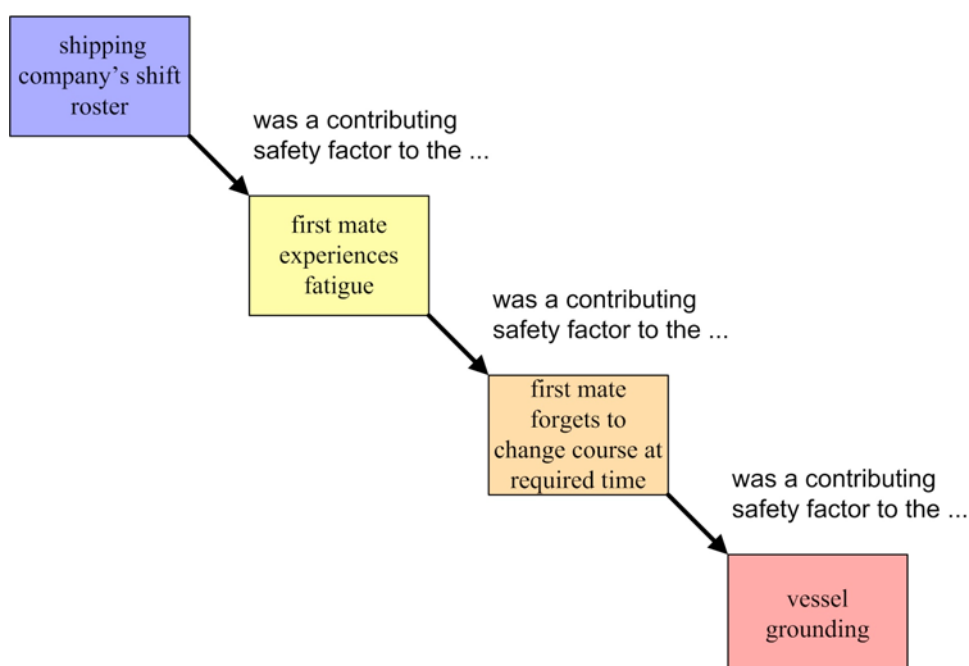
- The definition is written in the form of a ‘counterfactual condition’; that is, if A did not happen, then B would not have happened. Counterfactual conditionals are a common way of defining ‘cause’ and have gained widespread acceptance as a means of defining cause in the field of safety investigation (see Section 5.3.2). A counterfactual definition is also termed the ‘but for’ test and is widely used in legal proceedings (see Section 5.1.1).
- The ATSB does not normally use the term ‘cause’ due to potential difficulties associated with this term (see also Section 2.2.3 and Section 5.1.1). Most importantly, in legal contexts it is strongly associated with responsibility, blame or liability. There are also semantic difficulties, with many complicated philosophical arguments surrounding the issue of what constitutes a cause. To avoid these problems, some have argued that a term such as ‘explanations’¹¹ would be more appropriate rather than ‘causes’. However, the ATSB believes that ‘contributing safety factor’ provides a meaningful description and is also not associated with many of the problems inherent with the term ‘cause’.¹²
- Some organisations use two or more terms to differentiate factors in terms of their degree of connection or perceived importance in relation to the occurrence (for example, proximal cause and root cause; see also Section 5.3.1). The ATSB endorses a simple approach with only one term; either something is a contributing safety factor or it is not. Ranking factors in terms of their degree of contribution has practical difficulties, as it requires more decisions to be made by the investigation team. It can also be perceived by some parties as a way of differentiating the level of responsibility or blame for the occurrence (see Section 6.7). For safety enhancement purposes, differentiating the importance of safety factors is more appropriate in terms of the associated risk level for future operations (see Section 2.4).

¹¹ S. Dekker, *The field guide to understanding human error*, Ashgate: Aldershot UK, 2006, p.78.

¹² The term ‘contributing safety factor’ was considered preferable to ‘contributing factor’ as it emphasises the safety focus of an investigation. Although the term ‘contributing factor’ is widely used, it is associated with many different interpretations and is often not clearly defined.

- The definition emphasises the importance of minimising the consequences of an occurrence as well as minimising the likelihood of the occurrence. This is consistent with generally accepted safety management principles.
- The ‘probably’ qualifier in the definition is important because, in most situations, it is not possible to specify the contributing safety factors with absolute certainty. The only events and conditions that can usually be specified with certainty are those most closely connected to the occurrence in terms of time or physical proximity; that is, technical problems, individual actions and (less commonly) local conditions. By using the word ‘probably’, investigators can identify more contributing safety factors and provide a richer picture of how an occurrence developed. The term ‘probably’ is defined as meaning a likelihood of more than 66 per cent, or more than a two-in-three chance (see Section 2.6.3).
- The definition explicitly states that an event or condition is a contributing safety factor if it probably contributes to another event or condition that has already been found to be a contributing safety factor. For example, consider the simple situation outlined in Figure 3. It may be argued that, as there is some doubt with each link in the sequence, there would then be considerable doubt about stating that the shift roster contributed to the vessel grounding. However, the term ‘contributing safety factor’ is associated with the way the occurrence developed, rather than just explaining the final occurrence event or the consequences of the occurrence. This link-by-link approach to making judgements about contributing safety factors has advantages in simplifying the analysis process and providing a richer picture of how an occurrence developed (see Section 5.3.5).
- Only events and conditions that are safety factors should be identified as contributing safety factors. This means that the investigation focuses on events and conditions that are important for safety enhancement purposes.
 - Example: A train driver may arrive 10 minutes late for work, which leads to the driver’s train departing 10 minutes late. The train is later involved in a level-crossing accident with a bus. If the train had departed on time, the collision would not have occurred. However, the driver being late for work was not a safety factor, and it makes no practical sense to consider that it was a contributing safety factor to the occurrence.
- Although not explicitly stated in the ATSB definition, it is also important that a contributing safety factor is meaningfully related to the occurrence.
 - Example: An operator may have a procedure not to take off when crosswinds exceed 20 kts. The crosswinds are 25 kts and the crew decides to take off. During the takeoff the aircraft collides with objects left behind on the runway by maintenance workers. In pedantic terms, the crew’s decision to take off in contravention of the operator’s procedures could be regarded as contributing to the accident; that is, if it had not happened, the accident would not have happened. However, it is clear that the crew’s contravention of the crosswind procedure had no meaningful relationship to the accident, and therefore it should not be regarded as a contributing safety factor. Nevertheless, it can still be regarded as a safety factor, because it is an event that increased safety risk.

Figure 3: Simple occurrence with links between factors¹³



2.2.3 Comparison with previous BASI / ATSB approaches

Prior to 1983, BASI investigation reports provided a conclusions section and a 'cause'. During an Administrative Appeals Tribunal hearing in 1983¹⁴, BASI was criticised for only listing one cause (a pilot's action) for an accident instead of also listing other factors that played a causal role.

Subsequently, BASI and the ATSB generally used the term 'significant factors' for the findings of its aviation occurrence reports. A significant factor was defined as 'an element in the circumstances of an occurrence without which, the occurrence would not have occurred'. For some investigations, additional findings were also listed.

The interpretation of 'significant factor' varied across investigations, although it was generally interpreted in a strict sense, meaning that there had to be a certain or near certain relationship to the occurrence before a safety factor could be listed as a significant factor. As a result, the significant factors reported for most investigations typically involved only events or conditions closely related in time to an occurrence, such as technical problems or pilot actions. Safety factors associated with organisations (or 'safety issues') were rarely identified as significant factors. As a consequence, the significant factors listed for many investigations provided a relatively shallow picture of why an accident or incident occurred. There was also a real potential for parties to pay less attention to other safety factors that may have

¹³ Most transport occurrences involve a complex combination of factors rather than a simple linear sequence of factors as depicted in Figure 3 (see Section 3.1).

¹⁴ *Jamieson and Department of Aviation*, Commonwealth Administrative Appeals Tribunal, No. V83/180.

been discussed in an investigation report because they were not listed as significant factors.

Another problem with the use of ‘significant factors’ was that different terms and definitions were used by ATSB investigation reports in other transport modes. When standardising its terminology across modes, the Bureau looked at the various options for terms and definitions to refer to the types of factors to be determined by an investigation, and decided to use the term ‘contributing safety factor’ for the reasons outlined in the previous section.

2.2.4 Comparison with some other definitions

The ATSB definition of contributing safety factor is consistent with the definitions used for similar concepts by relevant international and standards organisations for different transport modes. More specifically:

- ICAO Annex 13 (paragraph 5.4) requires investigations to determine the causes of an occurrence (if possible), with ‘causes’ defined as ‘actions, omissions, events, conditions, or a combination thereof, which led to the accident or incident’.¹⁵ The Annex also states that the final report should list ‘both immediate and deeper systemic causes’.
- The IMO currently uses a similar approach to ICAO. IMO Resolution A.849(20) defines causes as ‘actions, omissions, events, existing and pre-existing conditions or a combination thereof, which led to the casualty or incident’.¹⁶ The resolution states that the final report should include ‘a section, or sections, analysing and commenting on the causal elements, including both mechanical and human factors’.
- The Australian rail industry uses the term ‘contributing factor’ instead of ‘cause’ in AS4292.7-2006. It defines a contributing factor as ‘any element of an occurrence which, if removed from the sequence, would have prevented the occurrence or reduced the severity of the consequences of the occurrence’. This approach is consistent with that used by the ATSB. However, the ATSB definition provides more detail.

In summary, ICAO and IMO currently use the term ‘causes’ rather than ‘contributing factors’, and they define ‘causes’ broadly. Minimal guidance as to what is meant by the term is given in order to encompass a broad range of states’ arrangements. The ATSB approach is consistent with the ICAO and IMO requirements but uses a different term with a more detailed and practical definition.

Further discussion of other definitions and the ATSB definition are provided in Sections 5.3 and 5.4.

¹⁵ In October 2008, ICAO will be considering a proposal to replace the term ‘causes’ with ‘contributing factors’ in order to make investigation reports more consistent with safety management concepts.

¹⁶ The new IMO Casualty Investigation Code (see Section 1.3.1) adopts the term ‘causal factor’ and use a similar counterfactual definition as used by the ATSB for contributing safety factor. The Code also requires that reports contain analysis and comment on the causal factors, including mechanical, human and organisational.

2.3 Safety issue

2.3.1 ATSB definition

A safety issue is a safety factor that:

- can reasonably be regarded as having the potential to adversely affect the safety of future operations, and
- is a characteristic of an organisation or a system, rather than a characteristic of a specific individual, or characteristic of an operational environment at a specific point in time.

2.3.2 Key points to note

Key points to note in relation to the definition of safety issue include:

- Safety issues will usually refer to problems with an organisation's risk controls (see Section 3.4.5), or a variety of internal and external organisational influences that impact on the effectiveness of its risk controls (see Section 3.4.5). In other words, it is a factor for which an organisation has some level of control and responsibility and, if not addressed, will increase the risk of future accidents.
- Safety factors that describe problems associated with individual actions (see Section 3.4.3) or local conditions (see Section 3.4.4) are not generally safety issues themselves, but may provide indications that safety issues exist. For example, the fact that a train driver has a medical condition is not a safety issue itself, but it is a safety factor that may indicate that there is a safety issue associated with the rail operator's medical examination processes. Safety factors that are not safety issues can therefore be termed 'safety indicators'. In a sense, they are a means to an end, rather than being the end themselves.
- Safety issues describe conditions that should be rectified to enhance safety. They are conditions which, if serious enough, warrant an investigation making safety recommendations to relevant organisations.
- The term 'safety issue' is also analogous to the term 'safety deficiency' which was previously used for ATSB aviation investigations and is still incorporated in AS4292.7-2006 for rail investigations. The definition in AS4292.7-2006 is 'any situation related to the operation or management of the railway system that can reasonably be regarded as having the potential to adversely affect the safety of railway operations'. The ATSB started using the term 'safety issue' rather than 'safety deficiency' because the latter term was interpreted by some organisations as being undesirably pejorative.
- Although not explicitly stated in the ATSB definition of a safety issue, the concept of practicability needs to be considered when determining safety issues during a safety investigation (see Section 3.5).

2.3.3 Levels of risk associated with safety issues

Safety issues are a subset of ‘hazards’¹⁷, and as such have an associated level of safety risk for future operations. The ATSB analysis framework distinguishes between three levels of safety issue:

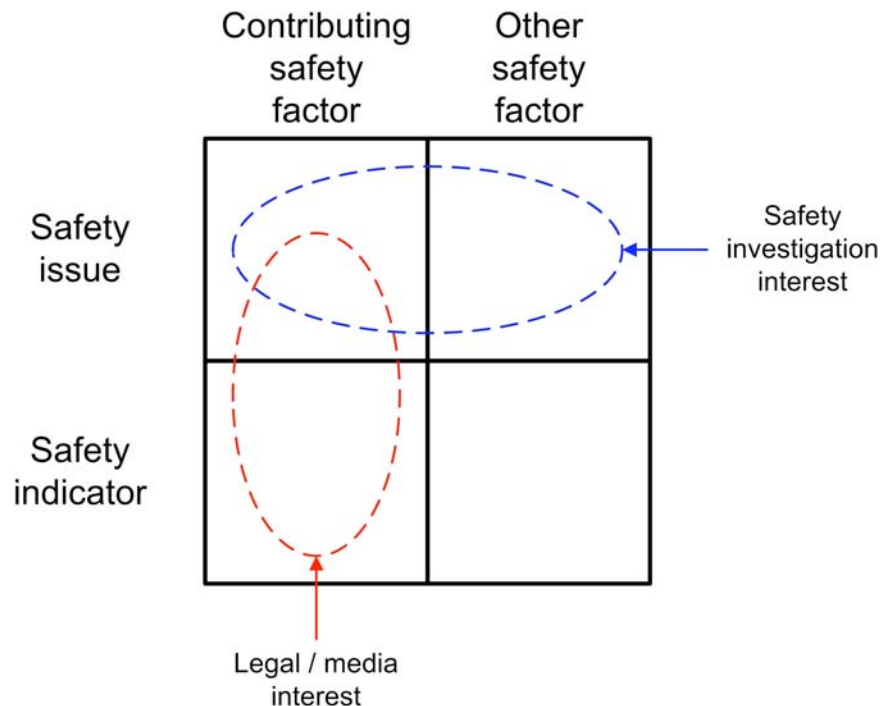
- Critical safety issues – associated with an intolerable level of risk. In other words, the risk level is regarded as unacceptable whatever the level of benefits associated with the activity.
- Significant safety issues – associated with a risk level in the ‘as low as reasonably practicable’ (ALARP) range. In other words, the risk level is regarded as acceptable if it is kept as low as reasonably practicable.
- Minor safety issues – safety issues associated with a risk level in the broadly acceptable range.

These categories are used by ATSB for internal purposes to determine the nature and timeliness of ATSB efforts to facilitate safety action by relevant organisations.

2.4 Contributing safety factors versus safety issues

Figure 4 summarises the types of safety factors using a matrix. It shows that a given safety factor can either contribute or not contribute to a particular occurrence, and it can be either a safety issue or a safety indicator.

Figure 4: Overview of types of safety factors



¹⁷ AS4360:2205 and ISO / IEC Guide 51 both define a hazard as a ‘source of potential harm’.

For example, in the Boeing 747-400 runway overrun at Bangkok in September 1999¹⁸, several factors were identified as being both contributing safety factors and safety issues (such as limitations with the operator's risk assessment processes and flight crew procedures and training for landing on water-affected runways). Factors were also identified which were safety issues but not considered to have contributed to the development of the occurrence (such as the runway not being grooved, and limitations with the operator's procedures and training for cabin crew in identifying and communicating relevant information during an emergency).

The same investigation also identified factors which were contributing safety factors but not safety issues (such as several flight crew actions and the heavy rain on final approach). Other safety factors were identified which considered to have not contributed to the occurrence, nor were they safety issues (such as the pilot in command probably experiencing a moderate level of fatigue). Even though the latter factors were neither contributing safety factors nor safety issues themselves, it does not mean that such factors are not important, as they may indicate the presence of safety issues in the system.

In other words, a safety factor that is found to be a contributing safety factor is not necessarily more important than other safety factors which were not found to have contributed. From a safety enhancement perspective, importance should reflect the degree of safety risk for future operations. Therefore, the most important safety factors for future transport operations are the critical and significant safety issues, and not all of these will be identified during an occurrence investigation as being contributing safety factors. It is therefore important that safety investigation reports discuss the safety issues that are identified during an investigation, regardless of whether they contributed or not.¹⁹

In summary, given that the purpose of safety investigations is safety enhancement (or accident prevention), their primary interest should be identifying safety issues (as shown in Figure 4). However, traditionally such investigations have focussed on identifying contributing or causal factors, and this is primarily the area where legal proceedings and media coverage relating to occurrences also focus their attention.

Although safety investigations should ideally focus on identifying safety issues, regardless of whether they were contributory or not, to purely do this is not possible for a variety of reasons:

- ICAO (aviation), IMO (marine) and AS4292.7-2006 (rail) require 'causes' or 'contributing factors' to be determined (where possible).
- The public, coroners and other stakeholders expect safety investigation reports to identify and discuss the factors involved in the development of an occurrence.
- Some organisations will unfortunately appreciate the importance of a particular safety issue only if it can be shown to have actually been involved in the development of an occurrence (see Section 5.3.4).

18 ATSB Investigation Report 199904538, Boeing 747-438, VH-OJH, Bangkok, Thailand, 23 September 1999 (published April 2001).

19 ICAO, *Manual of Aircraft Accident and Incident Investigation: Part IV- Reporting*, Doc 9786, 2003 (p.IV-1-15) stated 'During aircraft accident investigations, safety issues are often identified which did not contribute to the accident but which, nevertheless, are safety deficiencies. These safety deficiencies should be addressed in the Final Report'.

- The concept of contribution provides a central organising principle. Safety investigations are not broad audits or examinations of an organisation or safety system with unlimited resources. Although any safety factors that are identified during an investigation should be raised in an investigation report, regardless of whether they contributed or not, the search for potential safety factors needs to be pragmatically focussed in areas which are related to the circumstances of the occurrence, and the contributing safety factors that have already been identified. In other words, to be efficient and timely, safety investigations should not stray too far from the paths of contribution when searching for potential safety factors.

As a result, safety investigations need to focus on identifying both contributing safety factors and safety issues.

2.5 Arguments, premises and findings

2.5.1 Definitions

A safety investigation produces a series of findings or conclusions. To develop these findings, the investigation team needs to produce arguments. Arguments consist of a set of statements, one of which is the finding and the rest are premises.

Premises provide the reasons, grounds or justification for believing the finding, whereas the finding is the result of the argument. The premises may consist of items of evidence, as well as assumptions. Findings can also be termed ‘claims’ or ‘hypotheses’, although such terms are more useful when discussing proposed findings rather than verified findings.

2.5.2 Types of findings in safety investigation reports

During a safety investigation, the investigation team may develop many findings. The most important findings are those which appear in the findings section of the final investigation report; in the ATSB analysis framework these findings are known as ‘key findings’. In the process of developing these key findings, an investigation team may also need to develop a series of ‘intermediate findings’.

Developing a finding requires a detailed and structured examination of the available evidence. Aspects that should be considered when developing a finding are discussed in Section 4.4.

2.5.3 Key findings

In the ATSB analysis framework, there are three categories of key findings:

- **Contributing safety factors:** safety factors identified during an occurrence investigation which were considered to have had met the definition of ‘contributing safety factor’ (see Section 2.2). These may or may not be safety issues (see Section 2.4).
- **Other safety factors:** safety factors identified during the investigation which did not meet the definition of contributing safety factor but were still considered to be important. These also may or may not be safety issues. From a safety

enhancement perspective, they can also be as important as or even more important than contributing safety factors.

- Other key findings: any other finding considered relevant to include in the findings section of the final report. For example:
 - Findings to resolve significant ambiguity or controversy that occurred during the investigation which was not addressed by the safety factor findings.
 - Findings about possible scenarios or safety factors when firm safety factor findings were not able to be made.
 - Positive safety factors, or events or conditions which ‘saved the day’ or played an important role in reducing the risk associated with an occurrence.

These three categories used by the ATSB are based on the approach that has been used by the Transportation Safety Board of Canada (TSB) for several years.²⁰

2.5.4 Intermediate findings

As with a key finding, an intermediate finding is based on an argument with a set of premises. However, an intermediate finding is itself used as a premise to reach a more important finding (such as a contributing safety factor). In other words, prior to making a safety factor finding, investigators may need to do a lot of analysis work to convert the available information into meaningful pieces which can then be used in the argument for a safety factor finding.

An investigation team may need to make intermediate findings on a wide range of topics. Some intermediate findings concern the credibility or relevance of the available evidence, whereas others deal with the content of the evidence. For example, investigators may need to make findings to answer questions such as the following:

- What was the aircraft configuration at impact?
- What was the speed at impact?
- Who was the handling pilot?
- Was the driver appropriately qualified?
- When was the last maintenance of the engine performed?
- What was the wind speed at the time?
- Did the witness actually see the impact?
- How accurate is the radar data?

Intermediate findings will be included in the factual and analysis sections of an investigation report where required; they are not listed in the conclusions section of the report.

²⁰ The TSB uses the following headings for its findings: Findings as to causes and contributing factors; Findings as to risk; Other findings.

2.5.5 Types of arguments

Arguments can be broadly classified into two main types: deductive arguments and inductive arguments. A deductive argument is where the finding is claimed to follow from its premises with logical certainty; that is, the premises are claimed to provide conclusive or necessary grounds for the finding. An inductive argument is where the finding is claimed to be more or less probable, but not certain; that is, the premises provide sufficient reasons or grounds to conclude that the finding is supported to a certain level of likelihood, but not sufficient grounds to be absolutely conclusive.²¹

Some aspects of the technical or engineering side of an investigation involve deductive reasoning, particularly when reaching intermediate findings. However, the majority of the reasoning conducted in safety investigation involves inductive arguments, particularly when discussing safety factors. This applies to operational, technical and engineering aspects as well as human and organisational aspects.

Inductive arguments can take many forms, such as arguing from a specific instance to a general case, argument by analogy, or ‘inference to the best explanation’ (also known as ‘abduction’).

2.6 Uncertainty, probability and likelihood expressions

2.6.1 Probability and likelihood

Uncertainty is a key component of inductive arguments and reasoning in many fields, and it can be characterised in several ways. In the ATSB analysis guidelines, uncertainty is primarily discussed as the degree of probability that a particular statement is true, based on the available evidence.

In simple terms, probability is the degree of likelihood or chance of something being true. In mathematical terms, probability is usually represented on a scale of 0 to 1 (or 0 to 100 per cent). In the present report (and the ATSB analysis guidelines), the terms ‘probability’ and ‘likelihood’ are used interchangeably.

During safety investigations, investigators can rarely use mathematical probability as a basis for making findings. Instead, they use various terms (for example, ‘possible’, ‘probable’ or ‘very likely’) to represent their understanding of the level of likelihood. Such terms are known as ‘verbal probability expressions’.

2.6.2 Verbal probability expressions

A substantial amount of research has examined how people use and understand verbal probability expressions. General findings of this research are²²:

²¹ For a good introduction to critical reasoning and arguments, see T. Bowell & G. Kemp, *Critical thinking: A concise guide*, 2nd edition, London, Routledge, 2005.

²² K. H. Tieggen & W. Brun, ‘Verbal expressions of uncertainty and probability’, in D. Hardman & L. Machi (Eds.), *Psychological Perspectives on Reasoning, Judgement and Decision Making*, New York, Wiley, 2003, (pp.125-145).

- Although most individuals are relatively consistent in how they use verbal probability expressions, there is a relatively large difference between people in how they interpret what different expressions mean.
- People generally underestimate the extent to which others will have different interpretations of the same verbal probability expression.
- The context in which an expression is used can have a significant influence on how it is interpreted.
- People generally prefer using verbal rather than numerical expressions to describe probability, even though they prefer receiving numerical rather than verbal expressions from others.²³

These results show that a safety investigation organisation needs to have clear, consistent definitions of the verbal probability expressions it uses during investigation analysis activities and in investigation reports. Although there have been some attempts to develop defined scales of verbal probability expressions, none of these scales had been widely adopted until recently with the work of the Intergovernmental Panel on Climate Change (IPCC).

2.6.3 IPCC definitions

In recent years, the IPCC has developed standardised terminology to facilitate the communication of uncertainty regarding technical information in its field.²⁴ The IPCC guidelines cover several aspects of uncertainty, including the use of verbal probability expressions.

The IPCC definitions have been based on a substantial amount of discussion involving a range of different types of experts from many countries. The IPCC definitions are also broadly consistent with previous research into how people use different verbal probability expressions. Given that the IPCC definitions represent the most extensive and rigorous effort in this area from a range of international experts, the ATSB has adopted the definitions as the basis for communicating probability information during analysis activities and in its investigations reports.²⁵

Table 1 presents a list of verbal probability expressions produced by the IPCC in 2005. The ‘equivalent expressions’ in brackets are based on other research and are not included in the IPCC guidelines.

23 M. Kavana, D. T. Kennedy & B. Mohebbi, ‘An applied study using the analytic hierarchy process to translate common verbal phrases to numerical probabilities’, *Journal of Behavioural Decision Making*, vol. 10, 1997, pp.133-15.

24 Intergovernmental Panel on Climate Change, *Guidance Notes for Lead Auditors of the IPCC Fourth Assessment Report on Addressing Uncertainties*, July 2005.

25 The ATSB adopted the IPCC definitions in early 2007, following the IPCC’s release of some key reports. Prior to this time, the ATSB analysis guidelines had for a short period defined probable as meaning ‘75% or more’ rather than ‘more than 66%’ (see also Section 5.4.1).

Table 1: Verbal probability expressions (based on IPCC documents)

Terminology	Likelihood of the occurrence / outcome	Equivalent expressions
Virtually certain	> 99% probability of occurrence	Almost certain
Very likely	> 90% probability	Highly likely, very probable
Likely	> 66% probability	Probable
About as likely as not	33 to 66% probability	More or less likely
Unlikely	< 33% probability	Improbable
Very unlikely	< 10% probability	Highly unlikely
Exceptionally unlikely	<1% probability	

The IPCC has also specified some additional expressions in some of its other documents that may be useful.²⁶ These include:

- Extremely likely: > 95 per cent probability.
- More likely than not: > 50 per cent probability (equivalent terms would include ‘on the balance of probabilities’).
- Extremely unlikely: < 5 per cent probability.

2.6.4 ATSB approach to using verbal probability expressions

In addition to Table 1, Figure 5 provides the ATSB’s suggested verbal probability expressions for its investigation analysis activities. The graph is based on the IPCC guidelines, with additional expressions added which can be useful in some situations.

The purpose of the graph and the table is to improve the consistency in usage of verbal probability expressions, and thereby improve the communication of investigation findings. However, the expressions in the graph and the table only provide an indication of meaning, not a detailed prescription. In almost all situations, selecting the most appropriate expression is a matter of judgement, based on the available evidence, rather than a matter of precise measurement.

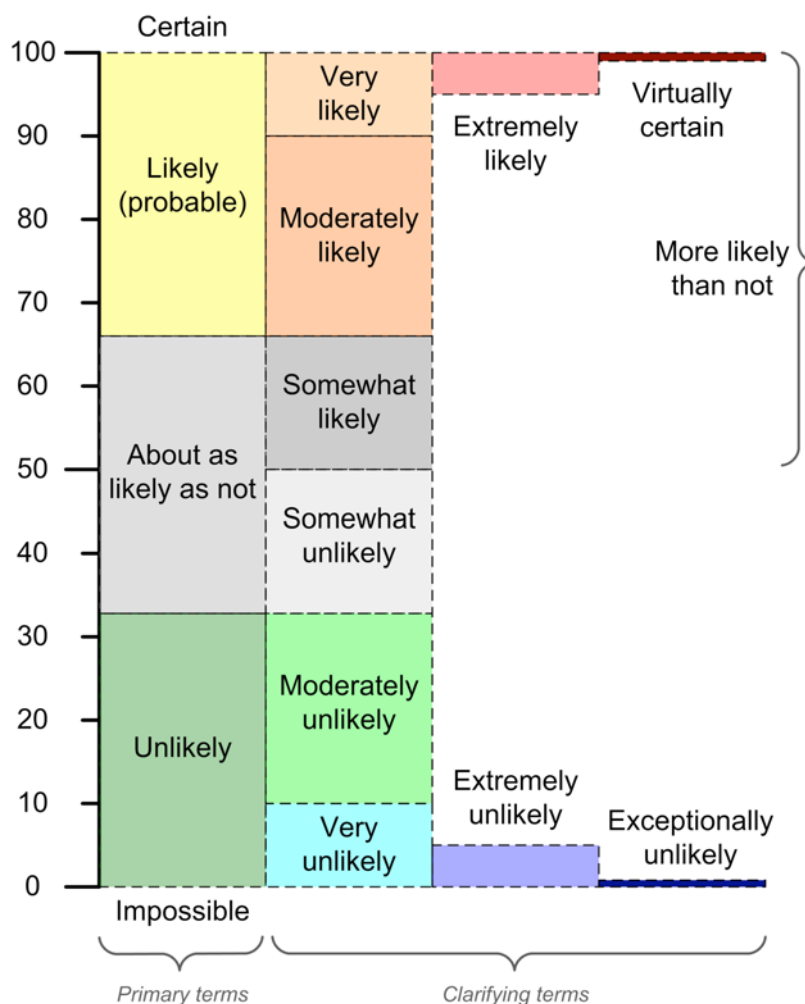
In other words, the graph and table provide indications of the relative meaning of various expressions. If an expression is required to indicate a degree of likelihood, it is best to use one of the terms provided. Where a particular expression is being used, it is best used in a manner consistent with the indicative meaning provided.

The distinction between likely (or probable) and lower probability expressions is the crucial distinction in the graph because ‘probable’ is included in the definition

²⁶ For example, H. R. Le Treut et al., ‘Historical Overview of Climate Change’. In S. Solomon et al. (Eds.) *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge UK, Cambridge University Press, 2007, p.121.

of contributing safety factor. This level (more than 66 per cent likelihood or more than a two in three chance) was chosen as being the critical threshold as it appeared to represent an appropriate ‘standard of proof’ for safety investigations (see Section 5.4.1).

Figure 5: Graphical representation of verbal probability expressions



The ATSB analysis guidelines provide additional guidance for ATSB investigators regarding the use of the verbal probability expressions (as depicted in Table 1 and Figure 5). This guidance includes the following:

- During investigation activities, it will generally be appropriate to use the primary terms shown on the left side of the graph. Where there is sufficient information and it is useful to do so, more specific expressions or clarifying expressions could also be used. This approach is used to simplify the decision-making process regarding which expressions are appropriate.
- The different categories should be considered as having ‘fuzzy’ rather than absolute boundaries.
- The probability expressions will generally not be appropriate when assessing the likelihood of very low frequency events during risk analysis. Alternative terms, based on a frequency per year, are provided in the ATSB analysis guidelines for risk analysis purposes.

- The use of a negative term prior to one of the probability expressions is problematic. For example, the use of ‘not likely’ to indicate a likelihood of 66 per cent or less would be ambiguous, as it would also appear to be synonymous with ‘unlikely’.
- Phrases such as ‘the most likely explanation’ are not included in the table or graph. Such phrases indicate a relative likelihood between two or more explanations, and do not provide an indication of the estimated likelihood of any specific explanation.
- When using the table or graph, it will often be useful firstly to consider whether the finding being considered can be assessed as likely (or probable). When the decision appears to be difficult, it may be easier to ask whether the proposed finding of interest was more or less likely (that is, more than or less than 50 per cent). If it clearly seems to be much more than 50 per cent, then ‘likely’ would generally be a better expression. If it is a difficult decision, then ‘likely’ would generally not be the best expression.
- When the ‘likely’ range is appropriate, it will generally not be necessary to clarify the probability level with a more specific expression. However, in some situations, to emphasise a particular point, it may be useful to use a clarifying expression (such as very likely). Such expressions should be used conservatively and only when they can be supported by the available evidence.
- When the ‘likely’ range is not appropriate, it will often be useful to clarify the likelihood level with a more specific expression (such as very unlikely), particularly when the probability level is relatively low.
- The expressions ‘moderately likely’ and ‘moderately unlikely’ have been included for completeness. In general, it will be sufficient to use the expressions ‘likely’ and ‘unlikely’ respectively when dealing with such probability levels. However, the terms may be useful when trying to highlight distinctions in a series of findings.
- The expression ‘possible’ was not included as research shows that numerical estimates of ‘possible’ are more varied than most other probability expressions. In a pure logic sense, it can be taken to mean any probability level above zero. Given its level of imprecision, it is preferable that when using ‘possible’ to indicate a low level of likelihood, a clarifying expression is also used to ensure that appropriate weight is provided to a finding (for example, ‘it is considered possible though very unlikely that...’).
- The term ‘possibility’ is often used when raising alternative scenarios or points of view (for example, ‘another possibility is ...’). When someone is raising alternative explanations in this way, they are usually in the realms of what is technically possible but is realistically associated with a low likelihood. In such cases, a clarifying expression is useful to indicate the probability level.

2.6.5 The need for evidence

Estimations of probability or likelihood need to be based on evidence. In some situations, an investigation team will not have sufficient evidence to make a determination of the probability that a finding is true with an appropriate degree of confidence, even in terms of which of the primary terms is most appropriate. In such cases, verbal probability expressions towards the lower end of the scale should not be used to reflect a lack of evidence or a lack of knowledge. Rather, the finding

should be written to indicate that a reliable estimation of the probability level could not be determined (for example, ‘there was insufficient evidence available to determine the extent to which this occurred...’).

The term ‘standard of evidence’ can be used to refer to the quantity and quality of the evidence required before being satisfied that a potential finding has been proven to a specified level of probability. The standard of evidence required before an investigation team can be satisfied that a particular safety factor ‘probably’ contributed to another safety factor is discussed further in Section 5.4.2.

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Section 3 briefly discusses some general aspects of how accidents develop, and the role that accident development models can play in safety investigations. The section then reviews the most widely used model in safety investigations (the Reason model of organisational accidents), and how the ATSB has adapted this model to better suit its requirements.

3.1 General comments on accident development

A large number of different theories and models have been proposed about ‘accident causation’ or how accidents develop.²⁷ These models vary greatly in terms of their approach and the types of issues considered. Some of the difference has arisen because of the different types of accidents being explained (such as occupational accidents, motor vehicle accidents or high-capacity public transport accidents).

For example, in complex and ‘ultra safe’ systems, such as commercial high-capacity air transportation, accidents usually involve combinations of many factors. In other words²⁸:

It is now broadly recognized that accidents in complex systems occur through the concatenation of multiple factors, where each may be necessary but where they are only jointly sufficient to produce the accident. All complex systems contain such potentially multi-causal conditions, but only rarely do they arise thereby creating a possible trajectory for an accident. Often these vulnerabilities are “latent”, i.e. present in the organization long before a specific incident is triggered. Furthermore, most of them are a product of the organization itself, as a result of its design (e.g. staffing, training policy, communication patterns, hierarchical relationship,) or as a result of managerial decisions.

In simpler systems, such as private road transport and aviation operations, many accidents are relatively simple in nature and are usually a repetition of previous occurrences.²⁹ Accidents in transportation systems between these two extremes can vary widely in nature and complexity.

Safety investigations conducted by the ATSB and similar agencies focus on commercial transportation. Although the complexity of such operations can vary,

²⁷ The term ‘accident causation’ is not used in this report due to semantic difficulties associated with terms such as ‘cause’ and ‘causation’. The term ‘accident development’ also reflects the fact that the factors involved in many accidents develop over a period of time prior to the accident.

²⁸ J. Reason, E. Hollnagel, & J. Paries, *Revisiting the “Swiss Cheese” model of accidents*, EEC Note No. 13/06, Eurocontrol Experimental Centre, 2006.

²⁹ R. Amalberti, ‘The paradoxes of almost totally safe transportation systems’, *Safety Science*, vol. 37, 2001, pp. 109-126.

there are a number of general statements that can be made regarding accidents in such operations³⁰:

- The development of an accident is a process that involves a number of different contributing factors. These factors can vary greatly in terms of their type or nature.
- The manner in which the different factors combine and relate to each other during the events leading up to an accident can be complex and dynamic.
- Common factors involved in most accidents are individual actions (errors and violations) by operational personnel. However, most of these actions are the result of other factors that need to be determined to fully describe the accident.
- Most accidents involve factors associated with how one or more organisations manage safety, through the use of risk controls and higher-level safety management processes.
- With each accident, there is a point in time at which control is lost or damage becomes inevitable. Events after this point can modify the level of damage associated with the accident, but cannot prevent the accident from occurring.

3.2 The role of accident development models in safety investigation

A model of accident development can serve a number of useful roles in safety investigation. These roles include:

- Providing an approach for identifying potential safety factors during an occurrence investigation.
- Providing a framework for communicating the results of an occurrence investigation in an investigation report.
- Providing a taxonomy for classifying factors found during occurrence investigations, and then using that taxonomy for trend analysis and research purposes.

It is important to emphasise that an investigation analysis framework needs much more than an accident development model. Such a model can only provide guidance in identifying potential safety factors. It cannot prove that such factors either existed or had an influence during an occurrence. In other words, in addition to an accident development model, an analysis framework needs (amongst other things) clear definitions of key terms, guidelines for critical reasoning, and a structured process for identifying, defining and testing safety factors.

There is no accident development model that explicitly and comprehensively encapsulates all of the complexities of how accidents develop, and the suitability of some models varies greatly depending on the nature of the occurrence. As a result, many safety investigation agencies do not use any explicit model when conducting occurrence investigations.

30 Useful discussions of the nature of accident development are provided by (a) E. Hollnagel, *Barriers and accident prevention*, Aldershot UK, Ashgate, 2004; (b) J. Reason, *Managing the risk of organizational accidents*, Aldershot UK, Ashgate, 1997.

However, given the benefits of using a model, the ATSB (and its predecessor BASI) have often used the Reason model of organisational accidents as an underlying framework to help guide investigation analysis. The Reason model has also been widely adopted by many other safety investigation organisations, although the ATSB has probably utilised the model for longer and more frequently for its larger investigations than most organisations.

3.3 The Reason model

3.3.1 Overview of the model

According to the Reason model³¹, widely known as the ‘Swiss cheese’ model, accidents rarely result solely from the actions of operational personnel (such as pilots, drivers, masters, engineers, or controllers). Rather, most accidents are due to a combination of problems originating at all levels of the organisation. More specifically³²:

...a number of sentinel events in various domains – Tenerife, Mt Erebus, Chernobyl, Zeebrugge, King’s Cross, Clapham, to name but a few – soon made it clear that those people at the “sharp end” in direct contact with each system were not so much the instigators of bad events as the inheritors of an “accident in waiting” that had, in some cases, been lying dormant within the system for many years.

Much as it was (and still is) managerially and legally convenient to blame those on the front line, it was gradually becoming apparent that accidents in well-defended systems arose from a concatenation of many different factors arising from all levels of the organisation. The defining feature of such an “organisational accident” was that these latent systemic conditions, in combination with local triggers, opened up a brief window of accident opportunity through which the system’s barriers, controls and safeguards, allowing the local hazards to come into damaging contact with people or assets.

The more common form of the Reason model is shown in Figure 6.³³ In simple terms, the accident sequence begins with the negative consequences of organisational processes (for example, management decisions associated with planning, scheduling, designing, specifying, communicating, and regulating). These ‘organisational conditions’ are transmitted to the workplace in which the relevant operational tasks are performed. They can result in ‘local conditions’ that have a negative impact on an individual’s performance (for example, fatigue, high

31 An overview of the evolution and different versions of the model is provided by J. Reason et al., 2006. More detailed descriptions of various versions are provided in (a) J. Reason, *Human error*, Cambridge UK, Cambridge University, 1990; (b) D. Maurino et al., *Beyond aviation human factors: Safety in high technology systems*, Aldershot UK, Ashgate, 1995; and (c) J. Reason, *Managing the Risks of Organizational Accidents*, Aldershot UK, Ashgate, 1997.

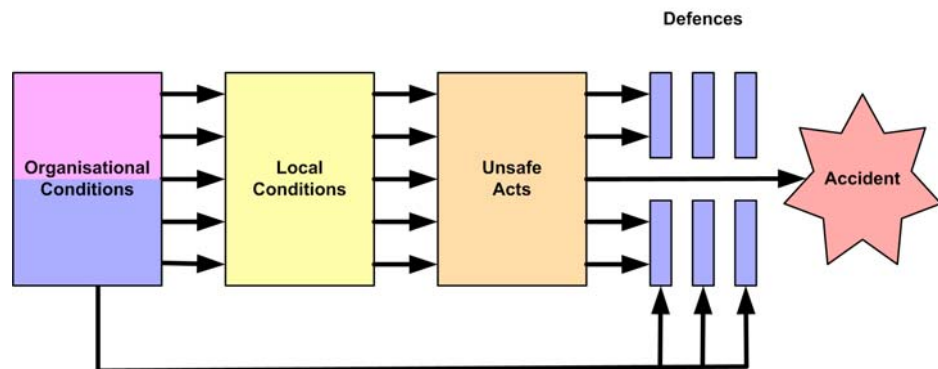
32 J. Reason, Foreword to A. Hopkins, *Safety, culture and risk: The organisational causes of disasters*, Sydney, CCH Australia, 2005.

33 J. Reason, ‘A systems approach or organizational error’, *Ergonomics*, vol. 38, 1995, pp.1708-1721. The colours on the diagram show how the various components of the model relate to the ATSB adaptation of the model.

workload, lack of skills) and set the conditions for ‘unsafe acts’ (errors and violations).

According to the model, these unsafe acts can have consequences that are not identified or controlled by the ‘defences’ or safety net built into the system (for example, warnings and emergency procedures). Therefore, local conditions and inadequate defences can facilitate or not adequately control unsafe acts, and these local conditions and inadequate defences can be symptoms of wider systemic issues or organisational conditions, such as poor communication.

Figure 6: The Reason model of organisational accidents



In other words, the system’s defences (or barriers, safety guards or controls) can be absent or have limitations (that is, they can have gaps or holes). These limitations can result from unsafe acts of operational personnel (sometimes termed ‘active failures’). Alternatively, they can originate from management decisions and organisational processes. These longer lasting gaps in the defences have been termed ‘latent failures’ or ‘latent conditions’.

In summary, the Reason model emphasises that unsafe acts have a key role to play in the development of accidents. However, the origins of unsafe acts often lie in management systems, not within the individuals who made the unsafe acts. In other words, the model emphasises a ‘system’ approach to improving safety rather than an approach focussing on the individuals who initiate or undertake unsafe acts.

3.3.2 Some general points

The Reason model provides a useful framework for identifying and organising safety factors during the analysis phase of a safety investigation. When considering the Reason model, it is also worth noting the following³⁴:

- The model is relatively simple and does not attempt to represent the full complex, dynamic nature of accident development. Such a representation is beyond the scope of any one model and was never the original intention of the model.

³⁴ These observations are based on the ATSB’s experience. Other observations, many of which are similar, are provided by J. Reason et al., 2006.

- Although the model was originally intended to explain large-scale accidents in complex, high reliability systems, the model can also be usefully applied to less complex systems. In such cases, there will generally be fewer factors involved, particularly in terms of organisational conditions.
- Since 1990 there has been much work done in using the model as a basis for measuring and managing safety performance as well as conducting safety investigations.
- In addition to the Reason model, there are many other models of accident development that have emphasised the importance of management systems and organisational conditions. Although there would be advantages for all safety investigation organisations to use the same accident development model with the same terms, ATSB experience in consulting with other organisations has shown, thus far, that it is not possible to get agreement in this area.
- A range of versions of the Reason model with different terms have been used by the safety industry for investigation. There are no necessarily ‘right’ or ‘wrong’ versions of the model, as long as the definitions being used are clearly understood by the users and consistently applied. The use of different interpretations of the model during an investigation has resulted in communication issues and problems in the past.
- A pedantic interpretation of the model can lead to difficulties when trying to classify specific events or conditions to fit into one of the boxes (for example, problems with training could be considered an organisational condition, an inadequate defence or a local condition). There can sometimes be significant disagreement between different investigators or parties involved in an investigation. In such situations it is usually better to consider the general concepts behind the model, rather than worry about specific classifications.
- The Reason model focuses on human factors and organisational issues, which are obviously of great importance. However, technical problems are not specifically dealt with in the model, which can make it difficult to incorporate them into the analysis of an occurrence.
- The concept of defences is now often considered to be much broader than the ‘last-line’ defences described in early versions of the model. This can also create a degree of confusion as to whether some issues are best classified as defences, organisational conditions or local conditions.

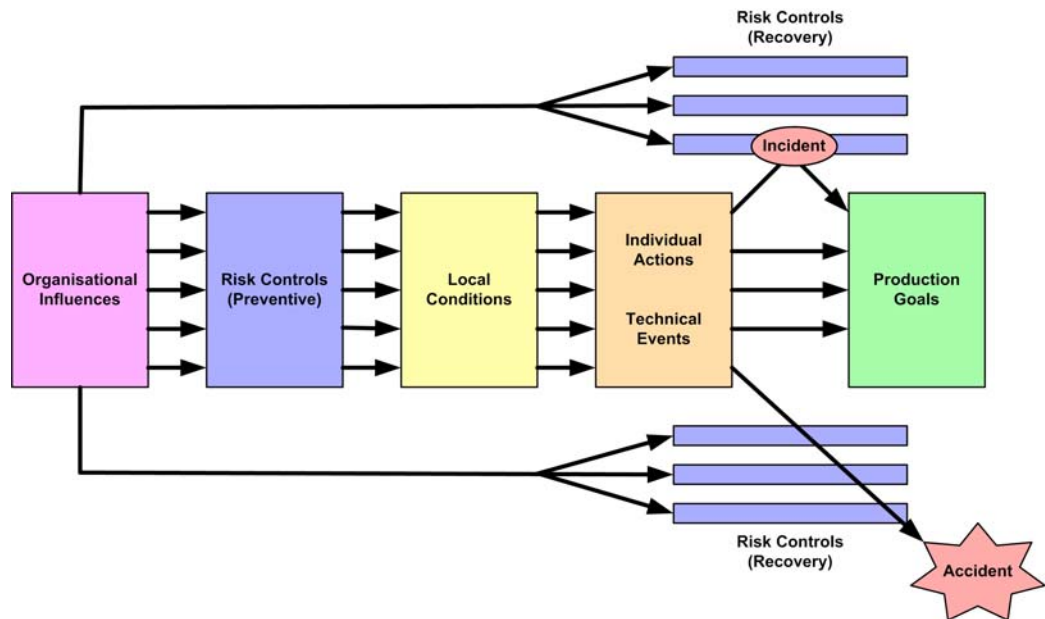
3.4 The ATSB investigation analysis model

3.4.1 Introduction

Although the Reason model, in its various forms, provides a widely accepted and useful approach for assisting occurrence investigation, there are some features of the model that the ATSB has found limit its usability in some situations (see Sections 3.3.2 and 3.7). In order to provide a more generic model that would be more applicable to a wider range of investigations, and better fulfil the role of identifying potential safety factors, the ATSB has modified some aspects of the model.

The ATSB adaptation of the model is shown in Figure 7. As this figure shows, an organisation achieves its production goals through the combination of various events and conditions. Different types of organisations have different production goals. For example, the production goal of a transport operator is to transport people or cargo from one location to another location in an efficient manner. The goal of a maintenance organisation is to conduct maintenance activities to a certain standard in an efficient manner.

Figure 7: ATSB adaptation of the Reason model



In most situations, the production goals will be achieved. In some situations, various events and conditions will combine to produce occurrence events (where the system ‘goes off track’) and risk controls are required to ensure that an accident does not occur or to minimise the severity of the accident’s consequences. In some situations these ‘recovery’ risk controls will not be effective in preventing an accident or minimising its consequences.

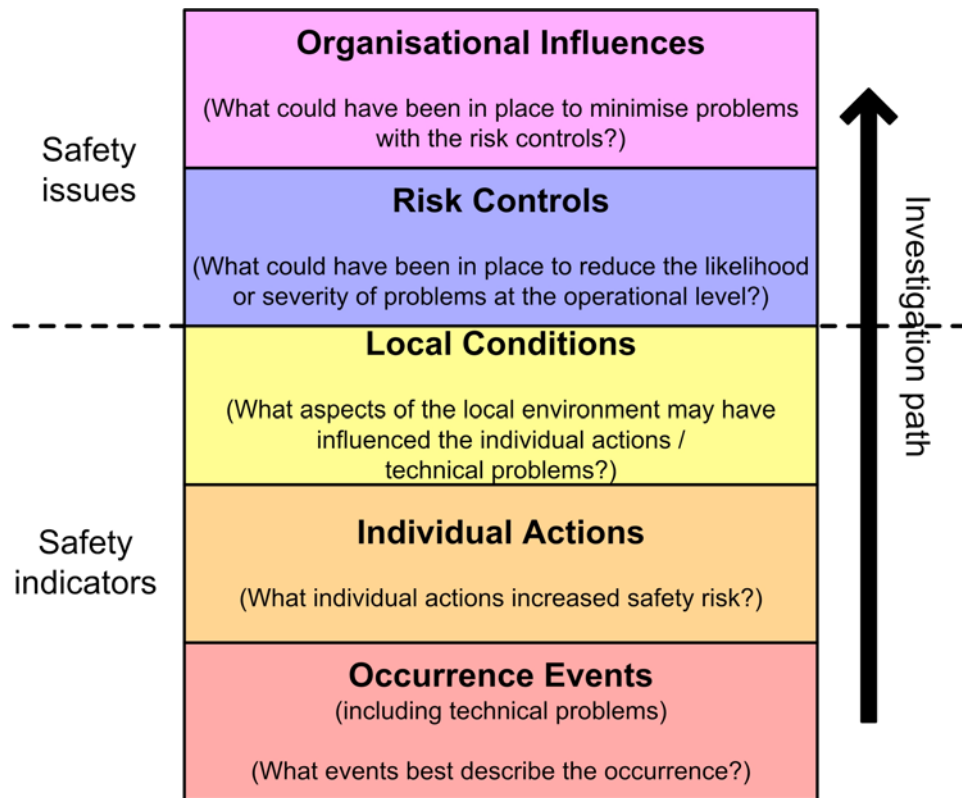
In addition to the recovery risk controls, there is also a range of other (‘preventive’) risk controls that minimise the likelihood of deviations from normal system performance. Problems with the design or suitability of the risk controls can arise due to a range of factors, which can be termed ‘organisational influences’.

As with the Reason model, the ATSB model also does not attempt to describe all of the complexities involved in the development of an accident, but attempts to provide a general framework that investigators can use to help guide data collection and analysis activities during an investigation.

The representation of the model shown in Figure 7 is used primarily to show some differences between the Reason model and the ATSB version. The representation which is used during investigations, known as the ATSB ‘investigation analysis model’, is presented in Figure 8. This figure shows that the components of the model can be presented as a series of levels of potential safety factors:

- occurrence events (including technical problems)
- individual actions
- local conditions
- risk controls (including preventive and recovery controls)
- organisational influences.

Figure 8: ATSB investigation analysis model



From an investigation viewpoint, the most useful way of using the model to identify potential safety factors is to start at the bottom and work up, asking a series of strategic questions. Broad questions for each level are shown in brackets in the relevant level in Figure 8. The ATSB investigation analysis guidelines provide a more detailed set of generic, functional questions to consider when identifying potential factors at each of the levels.

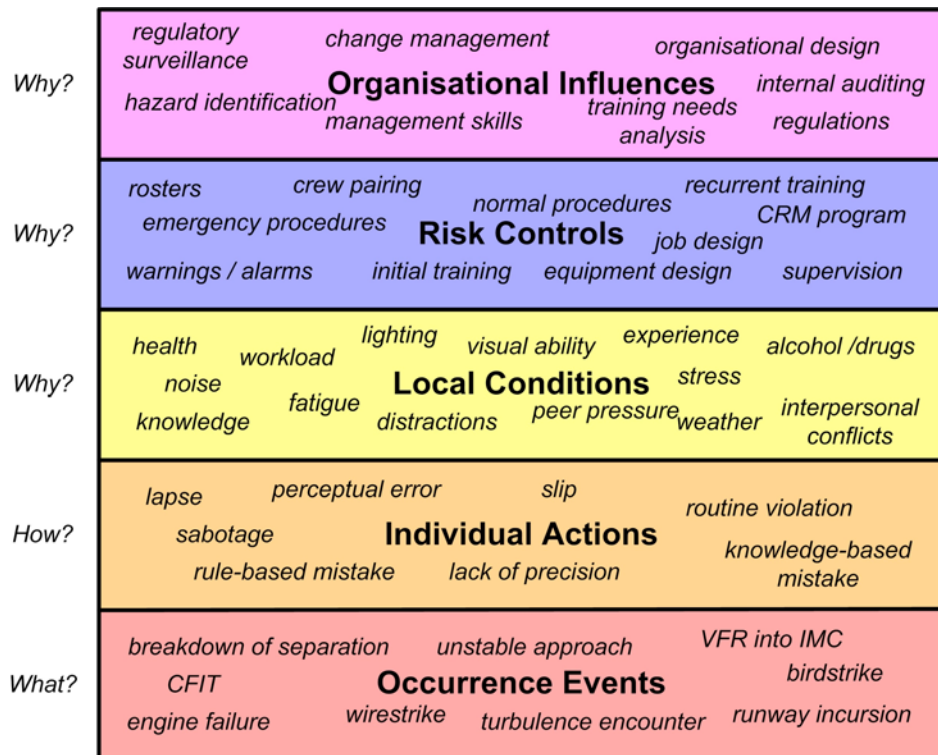
The basic format of the ATSB model (with different terminology) was used in the ATSB investigation report 199904538 of the Boeing 747-400 runway overrun at Bangkok, published in April 2001.³⁵ The model has since been used in a number of other investigations. The format of the model, as described in this report, has been presented the ATSB Human Factors for Transport Safety Investigators course and a number of other forums since 2002. ATSB investigators have been encouraged to use this model or other versions of the Reason model as the underlying framework

³⁵ ATSB Investigation Report 199904538. The terminology used for some elements in the model has been modified since that report.

for their investigation activities for several years. However, in 2006 it became ATSB policy to standardise the terms used to describe analysis-related concepts, including the various elements of accident development models, to improve the consistency of ATSB analysis and communication activities. Other models will have relevance for describing specific events and conditions in some situations, and these models can be used where ATSB investigators think they are useful.³⁶ However, where terminology in these other models is referring to a concept referred to in the ATSB model, it is ATSB policy to use the terminology associated with the ATSB model.

The following sections provide a brief overview of each of the levels of the model. Only a brief overview of the elements of the model can be provided in this report. Further details are provided to investigators during the ATSB human factors course. To assist the presentation, Figure 9 includes some typical aviation examples of safety factors that can be found at each of these levels.

Figure 9: Examples of safety factors



3.4.2 Occurrence events

Occurrence events are the key events which describe an occurrence (accident or incident), or the events which ultimately need to be explained by an occurrence investigation. In other words, occurrence events are the safety factors that describe 'what happened'. Examples of types of occurrence events used in ATSB databases for different transport modes are presented in Table 2.

³⁶ ATSB investigator training also includes coverage of other theoretical models that can be used to explain occurrences, such as the SHELL model and threat and error management (TEM) model.

Important aspects to note about occurrence events include:

- Occurrence events are represented in Figure 7 by the arrows diverging off the straight left to right path as well as any of the technical events which increase risk.
- Occurrence events generally refer to what a transport vehicle was doing or how it was being adversely influenced rather than the actions of any specific individual. For example, an ‘abrupt manoeuvre’ refers to what happened to an aircraft rather than the actions of the pilot, even though the pilot’s actions may have produced the manoeuvre.
- Many occurrences will only have one occurrence event, but many of those that the ATSB investigates will have multiple occurrence events in a sequence (for example, birdstrike leading to engine failure; signal passed at danger leading to collision).
- For an accident, there may be a series of occurrence events leading up to the accident event, or the point at which adverse consequences occur. There may also be occurrence events following the accident event (for example, failures of safety equipment designed to minimise the consequences of an accident).
- For occurrences subject to a safety investigation, identifying the occurrence events provides a platform on which to build the analysis of potential contributing safety factors.

Table 2: Examples of occurrences events

Aviation	Marine	Rail
birdstrike	grounding	derailment
engine failure	collision	collision
fuel starvation	fire	level crossing occurrence
unstable approach	equipment failure	signal passed at danger

‘Technical events’ (see Figure 7) refer to the performance of equipment and components involved in the conduct of a transport activity, such as vehicles and their associated parts and systems, as well as supporting facilities (for example, navigational aids, lighting and communication facilities). When equipment does not perform as required, the resulting event can be termed a ‘technical problem’, ‘technical failure’ or ‘technical malfunction’. In other words, technical problems are those technical events which are safety factors.

In many ways, technical problems can be considered as being similar to individual actions which increase safety risk, as they are both describing events which occur at an operational level. Similarly, they can both be influenced by a range of local conditions and risk controls. However, they are better classified as occurrence events in the model as in some cases a technical problem may be the occurrence event which is the subject of the safety investigation. Technical problems are also generally considered to be occurrence events in many occurrence databases. In addition, they are often considered at an earlier stage than individual actions in the investigation analysis process.

3.4.3 Individual actions

Individual actions are observable behaviours performed by operational personnel. The term ‘operational personnel’ refers to any person that can have a relatively direct impact on the safety of a transport activity; for example, flight crew, locomotive drivers, ships’ masters, cabin crew, controllers, maintenance personnel, and dispatch and loading personnel.

To achieve production goals, certain tasks have to be performed by operational personnel. Most of the time these individual actions are conducted in a manner consistent with that needed to achieve the production goals. On some occasions, one or more individual actions will result in the achievement of the production goals being threatened.

Although individual actions can both reduce or increase risk, when the term is used in this report it can be taken to refer to individual actions that are safety factors (unless otherwise noted). The terms ‘active failure’ or ‘unsafe act’ are commonly used to refer to such actions. However, such terms can be perceived as being unnecessarily negative and judgemental. Therefore, the ATSB prefers to use the neutral term ‘individual actions’ to refer to such actions.

Important aspects to note about individual actions include:

- Individual actions will contribute to many but not all occurrence events (for example, some technical problems will occur which were not influenced by the actions of any operational personnel).
- Many accidents and serious incidents involve a number of individual actions. It is important to view such actions as events that should not be reproduced under similar conditions in the future, rather than consider them ‘failures’ of the individual(s) involved. When considering the actions of individuals, it is useful to consider whether, if a similar situation arose again, it would be desirable for the individual’s actions to be different.
- There will generally be a clear distinction between occurrence events and individual actions, as the former refers to what happened to the vehicle or the system, whereas the latter refers to a specific individual’s action. However, there is often a close mapping between a specific occurrence event and a specific individual action (for example, ‘signal passed at danger’ compared with ‘the train driver did not detect the red signal’).
- Occurrence events are safety factors that describe ‘what’ happened, and local conditions, risk controls and organisational influences can be considered to represent ‘why’ the occurrence happened. Individual actions should not be viewed as the focus, a starting point, or the end point of a safety investigation. Therefore, they sit between what and why. Some investigators may find it useful to consider that individual actions explain ‘how’ rather than ‘why’ some of the occurrence events happened.
- It is important that the analysis phase of an investigation clearly identifies the individual actions and uses them as a platform to identify any underlying safety issues which may exist. A fundamental principle of safety investigation and human factors is to encourage managers, regulators, designers and investigators to look beyond the individuals and examine the system and the underlying reasons for the individual actions.

3.4.4 Local conditions

Local conditions are those conditions which exist in the immediate context or environment in which individual actions or technical events occur, and which can have an influence on the individual actions or technical events. Local conditions include characteristics of the individuals and the equipment involved, as well as the nature of the task and the physical environment.

Local conditions can increase the likelihood of individual actions which increase safety risk (for example, fatigue, insufficient knowledge, high workload). A range of terms have been used for such conditions, such as 'task and environmental conditions', 'preconditions' and 'antecedents'.

Local conditions can also increase the likelihood of technical problems which increase safety risk (for example, local conditions that can be associated with an engine failure could include pre-existing material defects or high operating temperatures).

3.4.5 Risk controls

Risk controls are the measures put in place by an organisation to facilitate and assure safe performance of the operational components of the system (that is, operational personnel and equipment). They can be viewed as the outputs of the organisation's safety management system. Risk controls are sometimes termed 'defences', 'safeguards' or 'barriers', although some definitions of these terms can vary in scope.

There are two main types of risk controls:

- Preventive controls, or control measures put in place to minimise the likelihood of undesirable local conditions, individual actions and occurrence events. These controls facilitate and guide performance at the operational level to ensure individual actions and technical events are conducted effectively, efficiently and safely. Such controls include procedures, training, equipment design and work rosters.
- Recovery controls, or control measures put in place to detect and correct or otherwise minimise the adverse effects of local conditions, individual actions and occurrence events. Such 'last line' controls include warning systems, emergency equipment and emergency procedures. On rare occasions, these risk controls will be breached and an accident will result, or the consequences associated with an accident will become more severe.

The term 'Bow-tie analysis' is often used to refer to a risk analysis method which aims to identify risk controls that can be put in place to prevent or reduce the likelihood of an undesirable event occurring (that is, preventive controls), and risk controls that can be put in place to minimise the consequences of the undesirable event (that is, recovery controls). Both types of controls are important for maximising safety.

The terms 'defences-in-depth' or 'lines of defence' are used to refer to the notion that there are generally a number of risk controls providing layers of protection in a transport operation. Each layer of risk controls provides assurance against the

possible breakdown in the preceding layer. Reason³⁷ noted that deficiencies in defences or risk controls can occur due to individual actions or to systemic problems (for example, being poorly designed in the first place). At any particular time in any safety system, there will be weaknesses in some risk controls, and these weaknesses will change over time. These holes or weaknesses can occasionally align, leading to serious consequences. As noted above, this concept has led to what is known as Reason's 'Swiss cheese' model.

Some risk control problems can also be described as local conditions. For example, an important warning alarm that sounds the same as other alarms may be a safety factor because it may be difficult to identify. This factor is a risk control because it is something put in place by an organisation to help ensure safe performance. However, the same factor can also be considered to be a local condition because it exists in the immediate context and can have a relatively direct influence on a driver's performance. Conditions which can often be considered to be both risk controls and local conditions include equipment design, procedures and supervision.

3.4.6 Organisational influences

Organisational influences are those conditions that establish, maintain or otherwise influence the effectiveness of an organisation's risk controls. There are two main types of organisational influences: internal organisational conditions and external influences.

Organisational conditions are the safety management processes and other characteristics of an organisation which influence the effectiveness of its risk controls. Safety management processes include activities such as hazard identification, risk assessment, change management and training needs analysis.

External influences are the processes and characteristics of external organisations which influence the effectiveness of an organisation's risk controls and organisational conditions. These influences include the regulatory standards and surveillance provided by regulatory agencies. It also includes a range of pressures, standards and other influences provided by organisations such as industry associations and international standards organisations.

3.5 How far should an investigation go?

The most important safety factors to identify in a safety investigation are those that occur at the risk control and organisational influence levels. These are the levels where changes can be made which can have a meaningful influence on safety. Safety factors which occur at these levels are generally safety issues (see Section 2.3). As shown in Figure 8, safety factors at the occurrence event, individual action and local condition levels can be viewed as being 'safety indicators', or indicators of the real problems rather than being the real problems themselves.

However, many investigations will not identify problems at the organisational influences level, or perhaps even the risk control level. This is due to a number of reasons, including:

³⁷ J. Reason, 1997, p.9.

- The presence of problems at lower levels does not always mean there is a problem in the way an organisation manages its safety activities. In other words, the reasons for the problems at lower levels may be adequately explained by individual actions and local conditions, or there may be nothing that various organisations could practicably have done to have minimised the safety risk.
- Collecting and interpreting information about organisational influences, and to some extent risk controls, can be time consuming and difficult, the problems (if there are any) are often hard to clarify, and investigations have limited time and resources.
- There may be insufficient evidence available to make any findings at these levels.

In terms of practicability, a finding (or an associated recommendation) about a safety issue generally should not be made if it is not reasonable or practicable for the relevant organisation(s) to address the issue. For example, it may not be practicable for a small rail operator to install automatic train protection, or may not be practicable for an aviation aerial work operator to use two flight crew on all of its operations. However, there will be some situations where it would be appropriate for an investigation to identify safety issues in its findings, even if they were not practicable for the relevant organisation to address. These would include situations where the level of risk was considered intolerable. They would also include situations where the reason why addressing the safety issue is impracticable is due to the existence of other safety factors which could be addressed or where an alternative means for addressing the safety issue may be available.

According to the ATSB analysis guidelines, the concept of practicability should be considered by investigators when identifying potential safety factors dealing with organisational or system conditions, testing these potential safety factors, and /or conducting a risk analysis (see Section 4 for a brief overview of the ATSB analysis process).

Judgements about practicability need to be based on the concept of acceptable risk. Therefore, the risk associated with a safety issue needs to be considered, but considered in terms of the extent to which the risk could have been reduced and how easy or how costly it was to achieve this reduction. More specifically, a test for practicability involves considering:

- The level of risk associated with the safety issue.
- The state of knowledge about the safety issue and the ways it can be removed, mitigated or otherwise addressed.
- The availability and suitability of ways to remove or mitigate the safety issue.
- The cost of removing or mitigating the safety issue.

It is a matter for the organisation(s) responsible for (or associated with) a safety issue to assess the costs and benefits of any particular means of addressing the issue. The role of ATSB investigations is to help identify safety issues, not conduct detailed cost-benefit analyses. Therefore, it can be expected that the ATSB may be 'risk conservative' or 'safety focussed' when determining the existence of safety issues.

Related to the concept of practicability is the issue of how far back into a system does an investigation need to look for potential safety factors; in other words, what

is the 'stop' rule?³⁸ The ATSB analysis guidelines advise investigators that if the investigation is still identifying safety issues that are significant and could practicably be addressed, then (subject to any budget constraints) the investigation should continue. However, if the investigation is focussing on factors that no organisation could reasonably be expected to address, then (subject to the exceptions discussed above) the investigation should be finalised.

However, even when the investigation has reached this 'stop' rule, it can sometimes be useful to try to explain why the highest level safety issue(s) occurred; not only in terms of identifying additional safety issues, but in terms of providing information on the context in which the issues occurred. Such an approach can provide balance, and also help minimise the natural tendency of some parties, such as the media, to allocate blame to a particular organisation. For example, a shortage of training and checking pilots across the aviation industry may help explain why a particular airline may have had limitations in its training and checking processes. Discussing the industry-wide shortage in the investigation report may be useful to help explain the operator's safety issue. However, making a finding that the shortage is a safety issue would have minimal benefit unless it is practicable for an organisation or group of organisations to address the problem.

3.6 Use of charts to show relationships

Many investigators have found it useful to use charts of various forms when identifying potential safety factors. By representing the identified factors in a graphical format, it can be easier to see the potential relationships between various factors. It can also be easier to identify gaps in the list of potential factors that have been identified, or factors that have not been adequately explained. In addition, charts can also be useful for communicating the findings of complex investigations.

A major problem with using charts is that they can appear more impressive than what the underlying analysis work has suggested. Most analysis methods based on charting techniques are not associated with detailed guidance on identifying potential safety factors, and few provide any guidance on testing the relationships between safety factors. With some analysis methods the focus of an analysis can become the development of a chart rather than the process of identifying potential safety factors and testing (or verifying) that they were influential.

One form of charts that is compatible with the ATSB investigation analysis model is an AcciMap.³⁹ An AcciMap shows the events involved in the development of the occurrence from left to right, and then adds the contributing factors to these events in a series of hierarchical layers. The types of layers used vary from one user to the next, with many applications extending to government policy or national culture levels. Hopkins has noted that the use of such diagrams helps show that there are multiple factors involved in an occurrence, and that 'viewing matters in this way

³⁸ See also A. Hopkins, 2000, pp.22-23, 134-138.

³⁹ AcciMaps were originally developed by Jens Rasmussen and subsequently used and refined by others such as Andrew Hopkins. See A. Hopkins, 'Fault Trees, ICAM & Accimaps: A Methodological Analysis', *Safety in Australia*, vol. 25(2), 2003, pp.13-23. See also A. Hopkins, 2000, Chapter 10. Other types of charts with similarities to AcciMaps have been developed and used in safety investigation, both prior to (and since) Rasmussen's work.

reveals the truly systemic nature of the accident and the inappropriateness of singling out any one factor or person as the primary cause'.⁴⁰

In recent years, the ATSB has been using a form of AcciMap (or safety factors map) in conjunction with its investigation analysis model to assist with the identification of potential safety factors during an investigation. A major benefit of using this type of chart is that investigators can maintain awareness of their progress during an investigation, in terms of how far into a safety system they have progressed and whether there are potential gaps that need to be explained further.

AcciMaps can also provide a useful summary of the findings of an investigation in investigation reports. The first ATSB investigation report to include an AcciMap was the ATSB's final report on the Lockhart River Metro 23 accident (see Figure 10).⁴¹ When examining this chart, the following should be noted:

- The chart reflects the complex nature of this occurrence, and it needs to be examined in conjunction with the analysis section of that report to fully understand the nature of the factors and the relationship between them.
- As is often the case with safety investigations into significant accidents, some of the parties associated with the occurrence did not agree with some of the findings of the ATSB investigation.
- Because of the analysis approach being used, the inclusion of factors in the AcciMap (or in the contributing safety factors of an investigation) does not mean that these factors should be considered as being equivalent to 'causes' of the accident in a legal sense, or reflect what the findings of a legal proceedings would produce (see Section 5). ATSB investigations use a different methodology and will often produce different findings compared with legal proceedings or other types of investigations.

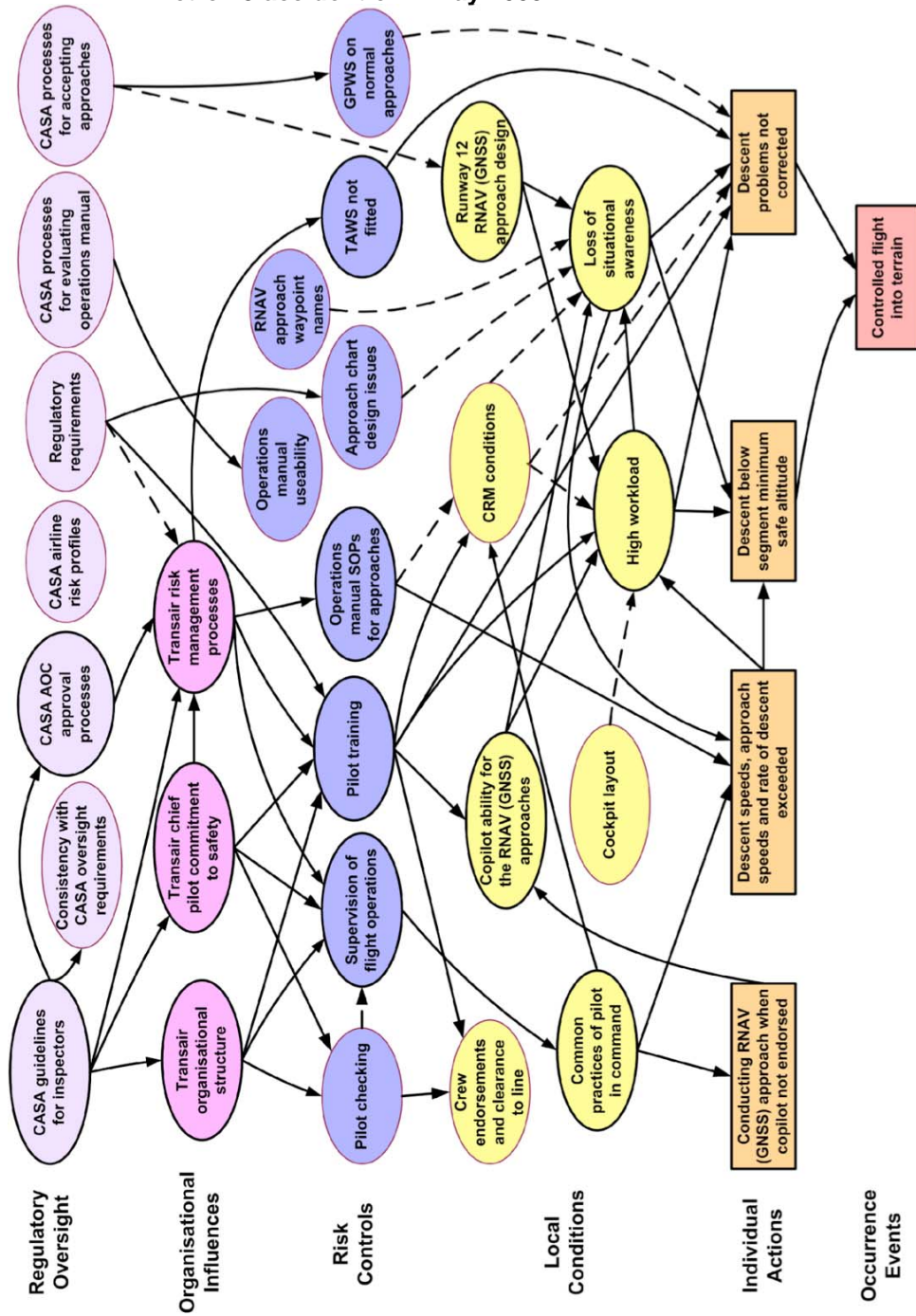
In the ATSB's experience, the use of AcciMaps has considerably helped the explanation of complex occurrences to industry personnel during presentations and courses. In addition, preliminary research commissioned by the ATSB has shown that such charts are favourably received by laypersons and can aid their comprehension of the findings of an investigation report.⁴² Where necessary for explaining a complex occurrence, such charts will be included in future ATSB investigation reports.

40 A. Hopkins, *Safety, culture and risk: The organisational causes of disasters*, Sydney, CCH Australia, 2005, p.78.

41 See page 227 of the ATSB Transport Safety Investigation Report, Aviation Occurrence Report 200501977, Collision with Terrain, 11 km NW Lockhart River Aerodrome, 7 May 2007, VH-TFU, SA227-DC (Metro 23) (published April 2007).

42 M. Wiggins & R. Glass, *The utility of safety factor maps in accident/incident communication*, paper presented at the 8th International Symposium of the Australian Aviation Psychology Association, Sydney, April 2008.

Figure 10: Chart showing safety factors associated with the Lockhart River Metro 23 accident on 7 May 2005⁴³



43 Dashed lines indicate a possible but not probable relationship. Black borders indicate contributing safety factors while purple borders indicate other safety factors.

3.7

Comparison of the ATSB model with other models

There are some important differences in terminology and concepts between the ATSB investigation analysis model and the basic form of the Reason model. These differences include the following:

- The ATSB model uses the term ‘risk controls’ instead of the term ‘defences’. It also uses the term to refer to a broader range of issues than was the case in early versions of the Reason model. That is, the term does not refer to only ‘recovery’ defences but also to preventive measures such as training, procedures and equipment design which reduce the likelihood of problems occurring in the first place. The change of name was introduced to help avoid confusion regarding the scope of the term ‘defence’. The name also more correctly represents the range of issues covered, and helps integrate the analysis model with risk management concepts. The combination of recovery controls and preventive controls also recognises that these issues are at a similar level of management control and are typically considered at the same time during an investigation analysis.
- The ATSB model places a greater emphasis on the distinction between the things an organisation puts in place at the operational level to minimise risk (that is, risk controls such as training and procedures), and the aspects of an organisation which influence the effectiveness of these measures (that is, organisational influences such as hazard identification and training needs analysis processes).
- The ATSB model uses neutral terms. Specific labels for problems or safety factors at each level are not generally used. The Reason model is often associated with terms that can be perceived as being unnecessarily negative and judgemental when referring to the performance of individuals or organizations (for example, terms such as: failed or absent defences, unsafe acts, active failures, latent failures).
- The ATSB model better enables the analysis of technical problems to be integrated with the analysis of other safety factors.

Many other accident development models can also be reduced to a series of hierarchical levels, similar to that shown in Figure 8. For example, the Human Factors Analysis and Classification System⁴⁴, which is based on an early version of the Reason model, has four levels: unsafe acts, preconditions for unsafe acts, unsafe supervision and organizational influences. Although the unsafe acts and preconditions levels are broadly similar to the ATSB model’s individual actions and local conditions, the top two levels of the two models have differences in scope.

Like all models of accident development, the ATSB model has limitations. Many safety factors can be proposed which do not neatly fall into one of the levels, and the limited nature of the model does not fully explain the complex, dynamic nature of accident development. Nevertheless, ATSB experience has shown that the model provides an appropriate balance between ease of use and full realism when identifying potential safety factors and communicating the findings of safety investigations.

44 D. A. Wiegmann & S. A. Shappell, *A human error approach to aviation accident analysis: The human factors analysis and classification system*, Aldershot UK, Ashgate, 2003.

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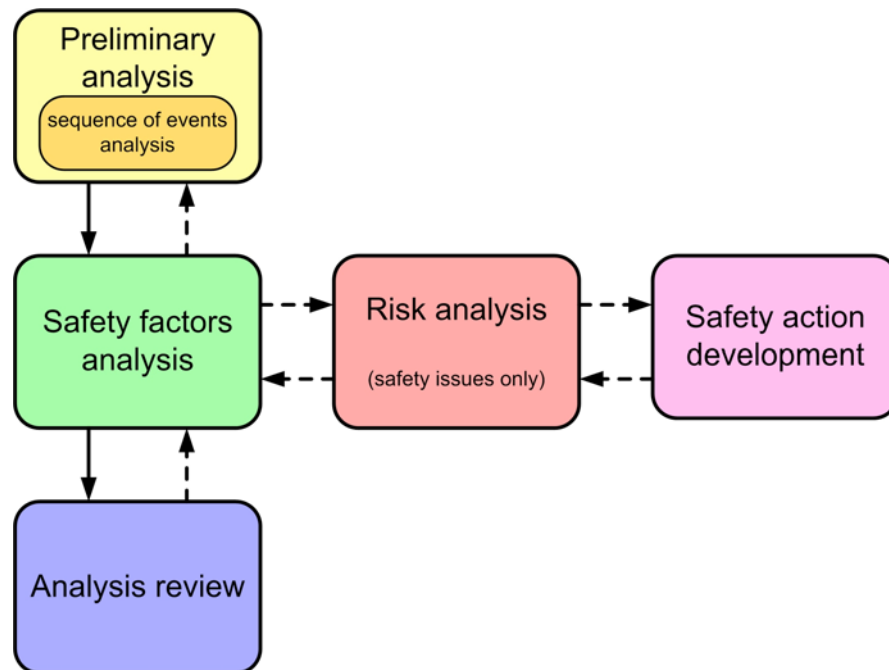
ATSB ANALYSIS PROCESS

Section 4 briefly overviews the process involved in conducting ATSB investigation analysis activities. The section then focuses on safety factors analysis, particularly that part of the process where proposed safety factors are tested to determine whether they are contributing safety factors or otherwise important.

4.1 General description

A major part of the ATSB analysis framework is a defined process or workflow to be used when conducting analysis activities. The overall process is divided into five separate processes, each of which is further broken down into a set of stages. The relationship between the five processes is shown in Figure 11.

Figure 11: Overview of ATSB analysis process



The five processes can be briefly described as follows:

- Preliminary analysis: A range of activities to convert data into a format suitable for the analysis of safety factors. This involves the use of techniques to interpret and organise data, including the systematic review of the sequence of events associated with an occurrence. Preliminary analysis may require the development of arguments to support intermediate findings on a range of topics (see Section 2.5.4).
- Safety factors analysis: A structured process to determine which events and conditions were safety factors, with an emphasis on determining the contributing safety factors and safety issues.
- Risk analysis: A structured process to determine the risk level associated with any verified safety issues. The ATSB process involves determining the worst

feasible scenario that could arise from the safety issue, and ranking the consequence and likelihood levels associated with such a scenario. The resulting risk level is classified for internal purposes as ‘critical’, ‘significant’ or ‘minor’.⁴⁵

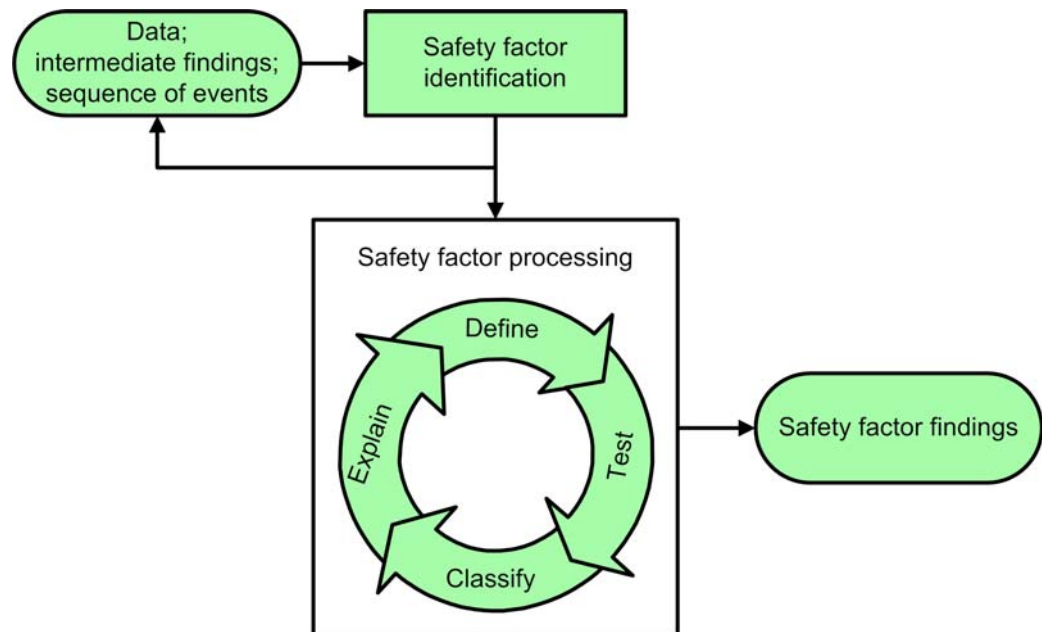
- Safety action development: A structured process of facilitating safety action by communicating safety issues to relevant organisations. The nature and timeliness of the ATSB communication is determined by the risk level associated with the safety issue.
- Analysis review: A review of the analysis results to identify gaps or weaknesses. This process involves checking the investigation findings for completeness and fairness. It also involves reorganising the findings into a more coherent format and sequence (if required).

The overall process provides a structured means of conducting analysis tasks and producing a set of findings. The ATSB analysis guidelines emphasise the importance of using a team-based approach and knowledge about the domain(s) being investigated when conducting the analysis tasks.

4.2 Overview of safety factors analysis

As indicated in Figure 11, safety factors analysis is the heart of the analysis process. It has two main components: safety factor identification and safety factor processing. An overview of safety factors analysis is presented in Figure 12.

Figure 12: Safety factors analysis process



⁴⁵ Although the ATSB’s risk analysis process is for internal purposes, it is compatible with AS4360:2004 and the *Common Risk Management Framework for New and Changed Operational Requirements within Aviation* developed by the Department of Transport and Regional Services, Department of Defence, CASA and Airservices Australia in 2007.

During safety factor identification, potential safety factors are identified by using a variety of techniques. These techniques can be divided into three approaches:

- A generic approach, which involves asking a set of generic questions about the occurrence (based on each of the levels in the ATSB investigation analysis model outlined in Section 3.4).
- A focussed approach, which involves asking a set of focussed questions to clarify and explain specific factors already identified.
- Specialised techniques to help identify explanations for specific types of factors, particularly when the other two approaches have not been successful (for example, barrier analysis, problem analysis, failure mode effects analysis).

Safety factor identification activities start early in the investigation, and are repeated at regular intervals until there is sufficient data available to conduct safety factor processing. The ATSB analysis guidelines encourage investigators to use charting techniques when identifying potential factors and display the possible relationships between the factors. Investigators are also encouraged to regularly review the list of potential factors to determine if there may be critical safety issues that need to be urgently addressed, as well as to determine needs for additional data collection.

Safety factor processing focuses on each potential safety factor that has been identified and selected for further analysis. This further analysis involves defining and testing the factor (see Section 4.3). Each verified factor is then classified in the occurrence database. The final stage is to ensure that, where possible, the factor being processed has been adequately explained by other factors (that is, a revision and extension of safety factor identification).

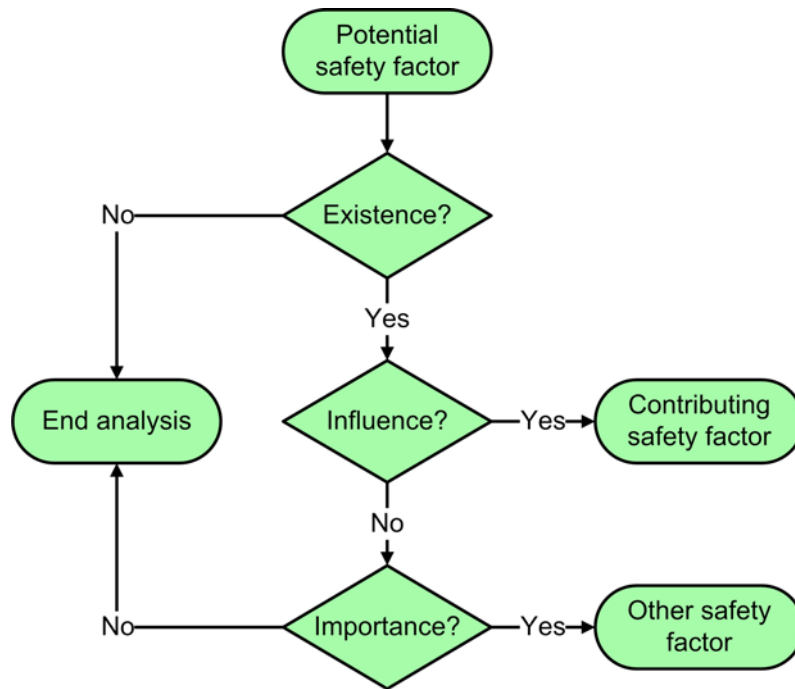
4.3 Testing potential factors

The ‘test’ stage of safety factor processing is an area where the ATSB framework has placed substantially more emphasis than other safety investigation methods. For every potential safety factor that is identified as needing further analysis, a series of tests are performed to determine whether the factor can be ‘verified’. These tests include the test for existence, test for influence, and test for importance.

An overview of the flow of the testing process is presented in Figure 13. As shown in the figure, the testing process will determine whether a potential safety factor is a contributing safety factor (existence plus influence), another safety factor of interest (existence plus importance), or of no consequence to the investigation.

The ATSB guidelines for conducting the tests for existence, influence and importance have three main components: background information on critical reasoning (for example, the nature of evidence and fallacies of reasoning), a process for developing and evaluating arguments (known as an evidence table, see Section 4.4), and criteria for evaluating existence, influence and importance (see Section 4.5).

Figure 13: Overview of the testing process



4.4 Evidence tables

4.4.1 Description of evidence tables

In the past, investigators in most safety investigation organisations have not always clearly presented the supporting arguments for their findings, other than in paragraph form in an investigation report. This format can be ambiguous, incomplete and time consuming to finalise. As part of its analysis framework, the ATSB wanted investigators to present their supporting arguments in a more structured and understandable way prior to writing the analysis section of a report.

The traditional way of presenting arguments in the field of critical reasoning is to use a series of statements; premises followed by the finding. Developing an argument in this format can be a difficult process, particularly when dealing with complex sets of data, or situations where there are concerns regarding the credibility or relevance of items of evidence.

The ATSB developed the evidence table to be a more flexible and easier-to-use format. The evidence table format also encourages a detailed and structured examination of the available evidence related to a proposed finding. It is an ATSB policy that all of the key findings in an ATSB safety investigation report will be supported or verified by an evidence table. In addition, each evidence table will include all relevant items of information, and appropriate qualifications regarding each item of information.

The ATSB analysis guidelines outline two types of evidence table:

- basic evidence tables, used for ‘other key findings’ and intermediate findings
- safety factor evidence tables, used for testing potential safety factors.

A basic evidence table consists of three columns: a column for the items of evidence or information that may be relevant to the finding; a column to provide comments on the strengths and weaknesses of each item; and a column for rating how the item may impact on the finding (supports, opposes, no effect, or unsure). Based on the information in the three columns, an overall assessment can be made as to whether the proposed finding is supported. Table 3 provides a hypothetical example of a basic evidence table.

Safety factor evidence tables are an extended version of a basic evidence table, with separate parts for the test for existence, test for influence and test for importance. The existence and influence parts are essentially the same as a basic evidence table. The importance part (if required) is simply a free text box allowing investigators to justify why they think the safety factor should be analysed further.

Table 3: Example of a basic evidence table (hypothetical)

Title

Description

Item	Comments	Supports?
Regulator's annual medical records indicated no ongoing or potential medical fitness concerns	Records not always reliable indicators of existing problems – but do contain some medical testing	supports
Interviews with pilots revealed no indications of ongoing or recent medical problems likely to influence performance	Crews typically unlikely to volunteer such information during investigation interviews – no overt indications	unsure
Doctor who interviewed crew 2 days later concerned re pilot in command's concentration	Problems likely due to trauma of accident – no problems encountered in subsequent interviews	no effect
Operator arranged for crew to undertake eyesight tests – no problems identified	Results not actually sighted firsthand. However, no reason to doubt operator	supports

Summary

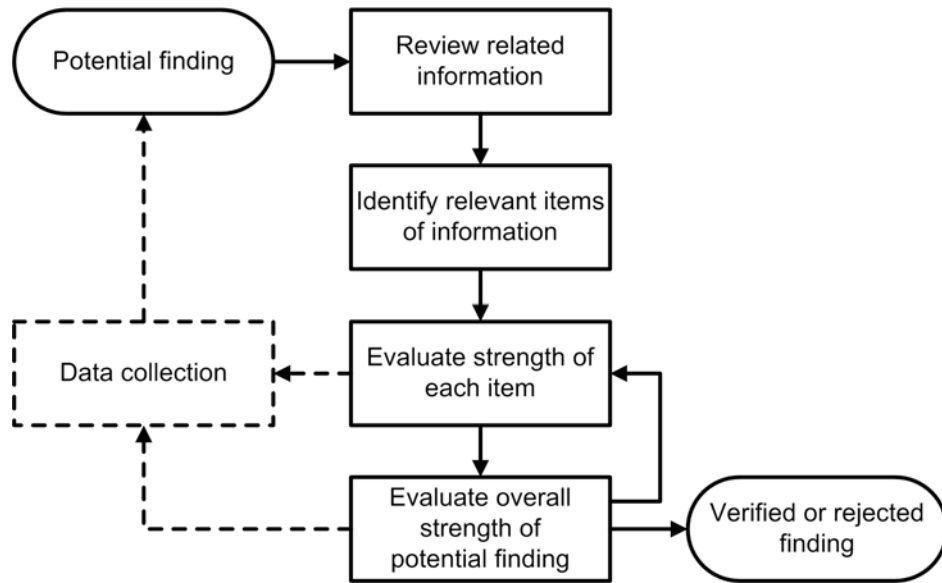
Supported? Add to key findings?

4.4.2 Process for developing an evidence table

The general process for developing an evidence table is summarised in Figure 14. The ATSB analysis guidelines provide advice for conducting each of the steps involved.

The steps of reviewing the available information and identifying items of information or evidence are relatively straightforward. When conducting these steps, the ATSB guidelines emphasise the importance of reviewing the available evidence and not relying on investigator memory of the evidence.

Figure 14: Process for developing an evidence table



In terms of identifying items of information for evaluating a proposed finding, the ATSB guidelines ask investigators to identify items of evidence which appear to support the proposed finding, items of evidence which appear to oppose the proposed finding, and any other types of evidence which would normally be considered relevant to the type of finding of interest. The guidelines also ask investigators to consider what items of evidence would be expected for the proposed finding but were not seen, what items of evidence were observed but would not be expected, and any alternatives to the proposed finding that could account for the pattern of evidence.

A key point of emphasis throughout the ATSB guidelines is to ensure that all evidence that is contrary to a proposed finding is included and evaluated in the evidence table. This approach is consistent with the notion of favouring the ‘null hypothesis’ that the proposed finding is not proven unless and until there is sufficient evidence to do so.

After identifying all the potentially relevant evidence, investigators are asked to evaluate each of the items of evidence individually in terms of their credibility and relevance to the proposed finding. This involves considering a range of criteria, such as validity, reliability, bias or objectivity, sensitivity, and the scope or power of the test when ‘there was no evidence that...’ statements are used. Any concerns, limitations or salient features of the item of evidence can then be placed in the comments column of the evidence table.

After each of the items of evidence has been evaluated, the overall pattern of evidence is then considered. This involves considering another range of criteria, such as the quantity of evidence, consistency of evidence, independence of sources of evidence, extent to which opposing evidence can be explained, extent to which evidence is converging or merely corroborating, and the extent to which there is direct evidence available. Based on the whole pattern of evidence, the investigation team can make overall judgements as to whether the proposed finding is supported or not supported, whether it can be supported if it is appropriately qualified, or

whether further data collection is required. Any pertinent comments regarding the overall assessment are placed in the summary box.

Evidence tables are analysis tools to assist the investigation team, and they are not included in final investigation reports. However, the contents of the evidence tables will be reflected in the contents of the analysis section of the final report. In addition, completing the tables prior to writing the analysis helps ensure that the final report will be focussed and organised. In addition to assisting the investigation team, evidence tables also enhance the ability of the ATSB process for reviewing investigation reports prior to releasing draft reports to external parties for comment.

4.5 Criteria for evaluating existence, influence and importance

The tests of existence and influence are based on concepts presented in an ICAO human factors advisory document.⁴⁶ However, the ICAO document provided minimal detail regarding how to assess existence and influence, and there has been surprisingly little discussion in the safety investigation field regarding such matters.⁴⁷ To overcome this problem, the ATSB developed a list of criteria or questions to consider when conducting the tests. This guidance was based on investigator experience, as well as to some extent on discussions of causation in fields such as epidemiology and toxicology.⁴⁸

The aim of the test for existence is to answer the following question: *Did the potential safety factor exist?* In other words, the hypothesis or proposed finding being evaluated is that the event or condition (as defined by the factor description) actually existed. The test can be conducted using the process as outlined in Figure 14. However, a range of criteria can be considered when identifying items of evidence, evaluating these items and evaluating the overall set of evidence. These criteria include the symptoms or effects of the proposed factor, the sources or reasons for the factor, and whether there is a known history of existence. Further details of these criteria from the ATSB analysis guidelines are provided in Appendix A.

⁴⁶ ICAO, *Human factors digest No. 7: Investigation of human factors in accidents and incidents*, Circular 240-AN/144, 1992. This was later incorporated into the ICAO *Human Factors Training Manual*, Doc 9683, 1998.

⁴⁷ One exception is I. Rimson, *Investigating 'causes'*, paper presented at the 29th Annual Seminar of the International Society of Air Safety Investigators Annual Symposium, Barcelona, October 1998. This paper referred to 'constraints of legitimate reservation' associated with Goldratt's theory of constraints (see H. W. Dettmer, *Goldratt's Theory of Constraints: A Systems Approach to Continuous Improvement*, Milwaukee, Wisconsin: ASQ Quality Press, 1997). The eight categories of legitimate reservation provide relatively basic aspects to consider when evaluating whether one event or condition influenced another.

⁴⁸ For example: (a) A. Bradford Hill, 'The Environment and Disease: Association or Causation?', *Proceedings of the Royal Society of Medicine*, vol. 58, 1965, pp.295-300; (b) M. D. Green et al., 'Reference guide on epidemiology', in Federal Judicial Centre's *Reference manual on scientific evidence* (2nd edition), 2000, pp.333-400; (c) B. D. Goldstein & M. S. Henefin, 'Reference guide on toxicology', in Federal Judicial Centre's *Reference manual on scientific evidence* (2nd edition), 2000, pp.401-437.

The aim of the test for influence is to answer the following question: *Did the proposed safety factor have an influence on the occurrence or a known contributing safety factor?* In other words, does it meet the requirements of being a contributing safety factor? Only those potential safety factors that have passed the test for existence are considered for the test for influence. The test is also conducted using the process outlined in Figure 14. However, the first step is to clearly determine what the proposed factor influenced (that is, the occurrence, the severity of the consequences associated with the occurrence, or another contributing safety factor). A range of criteria are used when conducting the test for influence, such as relative timing, plausibility, known history of influence, required assumptions, and alternative explanations. Further details are provided in Appendix B.

Only those potential safety factors that have passed the test for existence and then failed the test for influence are subjected to a test for importance. The aim of the test for importance is to answer the following question: *Is the proposed factor worth analysing further (even though it cannot be demonstrated to have had an influence on this occasion)?* Relevant criteria to consider when doing this test are outlined in Appendix C.

In addition to the tests for existence, influence and importance, a test for practicability is also conducted when dealing with safety issues (see Section 3.5).

Not all of the criteria for the tests of existence, influence or importance will be relevant for every situation, and different criteria will produce the same answers in some situations. However, together with the evidence table, the criteria provide a systematic means of reviewing available information, identifying potential safety factors, and then evaluating these potential safety factors to determine whether they were involved in the development of the occurrence (that is, contributing safety factors) or otherwise considered important (that is, other safety factors).

5 STANDARDS OF PROOF AND RELATED CONCEPTS

Section 5 examines how different types of investigations into occurrences define causation (or a similar concept such as contribution), and how they determine whether causation has been proven. The investigation approaches examined are legal proceedings generally (in relation to accidents), coronial inquests, and safety investigations generally.⁴⁹ This review helps provide context to explain why some aspects of the ATSB analysis framework were developed. The final part of this section revisits the ATSB framework to show some key differences between the ATSB framework and other approaches.

5.1 Legal proceedings

5.1.1 Causation in legal proceedings

The interpretation and determination of causation in the fields of philosophy and law has been a matter of significant debate and disagreement. However, there does appear to be a widely held view that what is determined as being a cause of a particular event (or occurrence) depends on the purpose of the inquiry. Chief Justice Mason of the Australian High Court stated⁵⁰:

It has often been said that the legal concept of causation differs from philosophical and scientific notions of causation. That is because "questions of cause and consequence are not the same for law as for philosophy and science", as Windeyer J. pointed out in *The National Insurance Co. of New Zealand Ltd. v. Espagne* [1961] HCA 15; (1961) 105 CLR 569, at p 591. In philosophy and science, the concept of causation has been developed in the context of explaining phenomena by reference to the relationship between conditions and occurrences. In law, on the other hand, problems of causation arise in the context of ascertaining or apportioning legal responsibility for a given occurrence.

When discussing the High Court's approach, Justice Doyle observed⁵¹:

What this seems to mean is that the law determines causation for a particular purpose, namely the attribution of legal responsibility. The reason or purpose for attributing responsibility should therefore shape the approach to the concept of causation.

⁴⁹ Another type of investigation that may be conducted following an occurrence is an administrative or regulatory investigation. Such investigations focus on determining the suitability of the activities of individuals or organisations, or the compliance of these activities with relevant standards. Such investigations are not necessarily concerned with the concept of causation or contribution (of the occurrence), and are therefore not considered in this report.

⁵⁰ *March v E & MH Stranmere Pty Ltd* (1991) 171 CLR 506.

⁵¹ J. Doyle, 'Causation in the context of medical practitioners' liability for negligent advice', in I. Freckelton & D. Mendelson (Eds), *Causation in law and medicine*, Aldershot UK, Ashgate, 2002, p.385. The reference to the High Court was to Chief Justice Mason's comments in *March v E & MH Stranmare Pty Ltd*.

The legal approach to causation is likely to differ from the medical approach. A doctor looks for causes in the interests of prevention and cure. The law looks for a cause, or the cause of an event, with a view to attributing liability for the event...

Wright also noted that it is generally agreed that the purpose and context of an inquiry determines which of the many contributing factors will be selected as “the cause”.⁵² Furthermore he stated (p.1012):

“The cause” is merely an elliptical way of saying “the (most significant for our purpose) cause”. Sometimes even the phrase “a cause” is used in this elliptical manner. All the contributing conditions are causes, but one or more are selected as being the most significant for a particular purpose, using noncausal criteria relevant to that purpose.

In terms of how the determination of causes fits within legal proceedings, Wright stated (p.1004):

...under the traditional view as implemented by the courts, a defendant’s tort liability depends on the answers to three distinct but interconnected inquiries. The first inquiry is the tortious-conduct inquiry: Did the defendant behave tortiously - for example, intentionally, negligently, or by creating an ultrahazardous situation or a defective product? The second inquiry is the actual-causation inquiry: Did the tortious aspect of the defendant’s conduct contribute to an injury to the plaintiff’s person or property? The third inquiry is the so-called proximate-cause inquiry: Are there any policies or principles that absolve the defendant of liability despite her tortious causation of the injury? Only the second inquiry, the actual-causation inquiry, is a causal inquiry. In the first and third inquiries, noncausal principles are used to select the *responsible* causes from all the other causes.

He further noted that:

Despite the lack of an explicit comprehensive definition of causation, people from time immemorial have shown remarkable agreement in their causal judgements, at least once they are clearly focussed on the causal issue rather than on some noncausal inquiry regarding the (most significant for some purpose) cause.

Many legal theorists have agreed with the view that the determination of causes should be separated from the policy and judgemental aspects of determining which of the causes (if any) should be held to be legally responsible or liable. For example, Stapleton has proposed that the term ‘historical involvement’ is used for the inquiry to determine the causes, and ‘relevance to purpose’ as the inquiry to determine which of those causes is selected for the purpose of the inquiry.⁵³ The latter (responsibility) inquiry involves concepts such as ‘remoteness’, and whether any intervening acts (after the cause of interest) break the ‘chain of causation’, as well as the notion of the extent to which the damage was foreseeable.

⁵² R. W. Wright, Causation, responsibility, risk, probability, naked statistics, and proof: Pruning the bramble bush by clarifying the concepts, *Iowa Law Review*, vol. 73, 1988, p.1001-1077.

⁵³ J. Stapleton, Unpacking causation, in P. Cane & J. Gardner (Eds.), *Relating to responsibility*, Oxford UK, Hart Publishing, 2001, pp.145-185. Wright, 1988, also provides a review of various proposals along these lines.

However, Wright noted (p.1013) that this distinction between determining causes (without policy judgements) and then determining responsibility (using policy judgements) has often not been reflected in practice, with much confusion in the use of causal language. Many also hold the view that policy and judgement issues are necessary for the causation inquiry as well as the determination of responsibility. Part of this view appears to be associated with the lack of agreement on the appropriate test to determine causes.

A number of different tests or approaches have been proposed and used for legal proceedings. The most common approach is the use of the 'but-for' test, which states that an event or condition (usually an individual's or organisation's conduct) is a cause of the damage of interest (for example, injury, death or other loss) if, but for the act or condition, the damage would not have occurred. The 'but for' test is effectively the same as the counterfactual conditional discussed in Section 2.2.2.

The but-for test is widely acknowledged to be simple and work well in most situations.⁵⁴ However, difficulties have been raised regarding the test's usefulness for legal purposes in some situations. Honore summarised the most commonly discussed problems as follows:

There are however cases in which the but-for test is difficult to reconcile with our intuitive judgements of responsibility. These concern two types of case in particular, those of over-determination and of joint determination. If two huntsmen independently but simultaneously shoot and kill a third person, or two contractors independently fail to deliver essential building supplies on time, it is intuitively clear that each should be held responsible for the death or building delay. Yet the but-for test seems to yield the conclusion that neither has caused the harm.

Various solutions have been proposed to overcome such problems. For example, based on the work of Hart and Honore⁵⁵, Wright proposed the use of a 'necessary element of a sufficient set' (NESS) test. Under this test, a particular condition is 'a cause of (contributed to) a specific result if and only if it was a necessary element of a set of antecedent actual conditions that was sufficient for the occurrence of the result'.⁵⁶ Although that test is more complex, it does not solve all the problems associated with the but-for test, and has not been widely used to date.⁵⁷

The Australian High Court has determined that the but-for test should not be the exclusive test of factual causation. More specifically, Chief Justice Mason stated⁵⁸:

54 See (a) A. M. Honore, 'Causation in the law', in *Stanford Encyclopedia of Philosophy*, 2001; (b) R. W. Wright, 'Causation in tort law', *California Law Review*, vol. 73, 1985, p.1775. Both of these papers review different approaches to determining causation in law.

55 H. L. A. Hart & T Honore, *Causation in the law*, 2nd edition, Oxford UK, Oxford University Press, 1985.

56 R. W. Wright, 1988, p.1019. See also Wright, 1985, pp.1788-1791.

57 D. Hamer, "'Chance would be a fine thing': Proof of causation and quantum in an unpredictable world", *Melbourne University Law Review*, vol. 23, 1999, pp.557-634.

58 *March v E & MH Stranmere Pty Ltd* (1991) 171 CLR 506. Justice McHugh provided an alternative view that the 'but for' test should be the exclusive test of causation, and other matters should be dealt with as part of the concept of 'remoteness'. The High Court has reaffirmed its majority view in subsequent cases. For example, see *Roads and Traffic Authority v Royal* (2008) HCA 19 (May 2008).

Commentators subdivide the issue of causation in a given case into two questions: the question of causation in fact - to be determined by the application of the "but for" test - and the further question whether a defendant is in law responsible for damage which his or her negligence has played some part in producing: see, for example, Fleming, *The Law of Torts*, 7th ed. (1987), pp 172-173; Hart and Honor, *Causation in the Law*, 2nd ed. (1985), p 110. It is said that, in determining this second question, considerations of policy have a prominent part to play, as do accepted value judgments: see Fleming, p 173. However, this approach to the issue of causation (a) places rather too much weight on the "but for" test to the exclusion of the "common sense" approach which the common law has always favoured; and (b) implies, or seems to imply, that value judgment has, or should have, no part to play in resolving causation as an issue of fact. As Dixon C.J., Fullagar and Kitto JJ. remarked in *Fitzgerald v. Penn* (at p 277): "it is all ultimately a matter of common sense" and "(i)n truth the conception in question (i.e., causation) is not susceptible of reduction to a satisfactory formula": at p 278.

Freckelton similarly observed that causation is routinely described in the legal field as 'a matter of common sense'. He also concluded⁵⁹:

Proof of causation therefore is dominated by considerations of likelihood and chance, as well as being dependent upon experts' capacity to make such notions accessible. As already described, legal tests for causation and its proof remain in a considerable state of flux and by reason of their ambiguity are difficult of practical exegesis and application...

In summary, the 'but for' test is widely used to help determine the 'causes' of an occurrence in legal proceedings. However, in practice, a variety of policy and 'common sense' judgement aspects are often involved in determining the causes, as well as in determining whether these causes should be associated with responsibility or liability.

5.1.2 Standards of proof

In the legal system, the term 'standard of proof' is used to refer to the degree of certainty with which a contested fact (or a case as a whole) must be established in order to be accepted or proven. Contested facts would include determinations of the cause(s) of an occurrence.

Different standards of proof are applied depending on the implications associated with an erroneous decision for the parties involved. In other words, the more significant the consequences of an erroneous decision will be for a defendant, the higher the standard of proof required for the other party to justify its case.

In Australia, the UK and many other countries, there are two primary standards of proof:

- proof on the balance of probabilities (for civil proceedings)
- proof beyond reasonable doubt (for criminal proceedings).

'Beyond reasonable doubt' is a much higher standard, where the risk of an erroneous decision (that is, conviction) for a defendant can have severe

⁵⁹ I. Freckelton, 'Epilogue: Dilemmas in the proof of causation', in I. Freckelton & D. Mendelson (Eds), *Causation in law and medicine*, Aldershot UK, Ashgate, 2002, p. 481.

consequences and the defendant therefore needs a very high level of protection from such errors. It is accepted that some guilty parties will not be convicted as a result. There has been much legal controversy regarding the nature of ‘beyond reasonable doubt’.⁶⁰ However, as the standard is generally not applied in safety-related investigations, it is not discussed further in the present report.

‘On the balance of probabilities’ (generally known as preponderance of evidence in the US) is a lower standard, with the general view being that the risk of an erroneous decision should be the same for both parties in civil proceedings, although only one party will have the ‘burden of proof’. The standard is generally interpreted to mean that the matter of interest has to be found to have ‘more likely than not’ occurred. However, as Redmayne stated, the standard is not that straightforward⁶¹:

It is well known that the standard of proof in a civil case is proof on the balance of probabilities, and that this means that the party bearing the burden of proof must prove her case is more probable than not. Indeed, the civil standard of proof appears to be one of the simplest concepts in the law of evidence, requiring little explanation or illustration. But scratch the surface of this most basic of evidentiary notions and an altogether more complex picture is revealed: the case law provides a range of conflicting interpretations of what the civil standard of proof requires in different contexts.

In discussing standards of proof in the US and the UK, Anderson et al. stated⁶²:

It is commonly said that it would be unreasonable to expect the trier of fact to demand the same level of proof for a minor traffic violation as for a conviction for murder and that in civil cases involving allegations of dishonesty or adultery or illegitimacy for example, a higher degree of probability is required than mere preponderance of evidence. That some such deviations are and should be applied is generally acknowledged, but there is a remarkable lack of clarity about the rationale(s) for such deviations and about the degree of deviation that is indicated in each kind of case.

Similarly to Anderson et al., in relation to civil proceedings in the UK, Redmayne noted (pp.174-175):

The development of variations in the basic civil standard of proof has been driven by the fact that certain civil cases involve serious issues. Some involve serious allegations (of criminal conduct, for example); some have serious outcomes (a parent losing custody of her child); and some involve both. In such cases, the courts are reluctant to find a claim proved on the simple balance of probabilities, without at least noting the gravity of the case requires some deviation from the normal approach to proof on this standard. When it comes to describing the modification of approach that is required, however, we find that judges adopt different approaches and their explanations are sometimes unclear.

⁶⁰ For example, see C. Hemmens, K. E. Scarborough & R. V. del Carmen, ‘Grave doubts about “reasonable doubt”’: Confusion in state and federal courts’, *Journal of Criminal Justice*, vol. 25, 1997, pp.231-254.

⁶¹ M. Redmayne, ‘Standards of proof in civil litigation’, *The Modern Law Review*, vol. 62, 1999, p.167.

⁶² T. Anderson, D. Schum, & W. Twining, *Analysis of evidence* (2nd edition), Cambridge UK, Cambridge University Press, 2005, p.243-244.

Redmayne noted (p.176) that there were two main approaches used in the UK to deal with the situation: varying the standard of proof depending on the circumstances, and varying the amount of evidence that is needed to satisfy the standard. He argued that both types of approach were limited as they led to inconsistencies in the approach used by individual judges.

Redmayne also noted (p.187) that, in the US, the situation is partly dealt with through the use of a third primary standard of proof, generally termed 'clear and convincing evidence'. This standard sits between the preponderance of evidence standard and the beyond reasonable doubt standard, and is used in some types of civil proceedings where it is believed defendants need a greater level of protection from erroneous decisions than that provided by the balance of probabilities standard. Given the limitations of using variable approaches, Redmayne advocated that a fixed intermediate standard such as that used in the US was the preferable option for dealing with situations where the normal civil standard was considered to be inadequate.

The Australian approach to applying a civil standard of proof to a wide range of situations is to use what is known as the 'Briginshaw scale'.

5.1.3 The Briginshaw scale

As noted in Section 5.1.2, making judgements in relation to the balance of probabilities standard can be a complex matter, and various factors may need to be considered. In Australia, the most commonly cited reference in this regard is High Court Justice Dixon's comments in relation to the *Briginshaw v Briginshaw* case⁶³:

The truth is that, when the law requires the proof of any fact, the tribunal must feel an actual persuasion of its occurrence or existence before it can be found. It cannot be found as a result of a mere mechanical comparison of probabilities independently of any belief in its reality. Except upon criminal issues to be proved by the prosecution, it is enough that the affirmative of an allegation is made out to the reasonable satisfaction of the tribunal. But reasonable satisfaction is not a state of mind that is attained or established independently of the nature and consequence of the fact or facts to be proved. The seriousness of an allegation made, the inherent unlikelihood of an occurrence of a given description, or the gravity of the consequences flowing from a particular finding are considerations which must affect the answer to the question whether the issue has been proved to the reasonable satisfaction of the tribunal. In such matters 'reasonable satisfaction' should not be produced by inexact proofs, indefinite testimony, or indirect inferences. Everyone must feel that, when, for instance, the issue is on which of two dates an admitted occurrence took place, a satisfactory conclusion may be reached on materials of a kind that would not satisfy any sound and prudent judgment if the question was whether some act had been done involving grave moral delinquency.

The 'considerations' outlined by Justice Dixon have become known as the 'Briginshaw scale', 'Briginshaw test' or 'Briginshaw principle'. Despite a widespread usage of the scale in Australia, there appear to be differences in

⁶³ The case involved a dispute between a Mr and Mrs Briginshaw concerning adultery. For the classic comments by Justice Dixon see *Briginshaw v Briginshaw*, (1938) 60 CLR 336, 361-2.

interpreting its nature.⁶⁴ Some discussions imply that the standard of proof should vary according to the factors mentioned by Dixon, whereas other interpretations are that the standard of proof should remain the same, but the robustness or overall merits of the required evidence should vary. The latter view appears to be the more widely accepted view in recent times.

For example, in 1992 members of the High Court stated⁶⁵:

The ordinary standard of proof required of a party who bears the onus in civil litigation in this country is proof on the balance of probabilities. That remains so even where the matter to be proved involves criminal conduct or fraud. On the other hand, the strength of the evidence necessary to establish a fact or facts on the balance of probabilities may vary according to the nature of what it is sought to prove. Thus, authoritative statements have often been made to the effect that clear or cogent or strict proof is necessary 'where so serious a matter as fraud is to be found'. Statements to that effect should not, however, be understood as directed to the standard of proof. Rather, they should be understood as merely reflecting a conventional perception that members of our society do not ordinarily engage in fraudulent or criminal conduct and a judicial approach that a court should not lightly make a finding that, on the balance of probabilities, a party to civil litigation has been guilty of such conduct.

Williams has stated that the 'standard of proof does not change, but the quantum or quality of evidence required to meet the standard may'.⁶⁶ De Plevitz stated that the Briginshaw scale is based on the principle that 'a court in a civil action should not lightly find that a party has engaged in criminal conduct'. She also stated that the 'standard of evidence' should vary when using the Briginshaw scale, not the standard of proof. In addition, the *Commonwealth Evidence Act 1995* states (s.140):

- (1) In a civil proceeding, the court must find the case of a party proved if it is satisfied that the case has been proved on the balance of probabilities.
- (2) Without limiting the matters that the court may take into account in deciding whether it is so satisfied, it is to take into account:
 - (a) the nature of the cause of action or defence; and
 - (b) the nature of the subject-matter of the proceeding; and
 - (c) the gravity of the matters alleged.

⁶⁴ See (a) L De Plevitz, 'The Briginshaw 'standard of proof' in anti-discrimination law: 'Pointing with a wavering finger'', *Melbourne University Law Review*, vol. 38, 2003, pp.308-333; (b) Australian Law Reform Commission, *Evidence (Interim)*, Report 26, 1985, Appendix C-16.

⁶⁵ Joint judgement of Mason CJ, Brennan, Deane and Gaudron JJ in *Neat Holdings Pty Ltd v Karajan Holdings Pty Ltd* (1992) 110 ALR 449, 449-50.

⁶⁶ C. R. Williams, 'Burdens and standards in civil litigation', *Sydney Law Review*, vol. 25, 2003, p.185. In applauding Briginshaw, he also agrees (pp 180-181) that a requirement of satisfaction requires something more than an estimate of probabilities; it requires a subjective belief in a state of facts on the part of the body charged with determining the facts. Williams states that the courts have had regard to 'the nature and consequence of the fact or facts to be proved' in determining whether they 'feel an actual persuasion' of those facts in a variety of circumstances.

In summary, it is generally understood that the civil standard of proof in Australia is based on the concept that the party making the decision has to be 'satisfied' that the available evidence has met the balance of probabilities standard. It is also generally understood that, in order to be satisfied, the decision maker needs to consider the aspects associated with the Briginshaw scale. What seems less clear is what exactly does 'satisfied' mean, and when should the Briginshaw scale be applied.

In terms of how 'satisfied' or 'reasonably satisfied' is defined, a precise specification is difficult and it seems to rely on the judgement of the decision maker. However, it does appear that it needs to be based on more than simply an estimate of probabilities.⁶⁷ In safety investigations for example, knowing that 51 per cent of failures of a particular type of engine resulted from a specific manufacturing problem would not (by itself) be sufficient to conclude that the next failure of the same engine type would be due to the same problem. More evidence would be required to demonstrate that there was a link between the manufacturing problem and the engine failure in the particular situation of interest.

In terms of when the Briginshaw scale should be used, there seem to be different views. De Plevitz noted that the scale appeared to be applied as a matter of course in anti-discrimination cases, but in relation to other matters it was used more selectively. More specifically:

...it can be said that Briginshaw is enlivened where there are serious accusations (murder, sexual abuse of children, corruption, undermining the very business of your employer, adultery prior to the Family Law Act 1975 (Cth), gross medical negligence or fraud) or where the effect of the finding would be permanent and damaging to the respondent's future (loss of liberty, racial identity, sexual functioning or profession). These are clearly issues of gravity and importance that warrant a closer scrutiny of the evidence before a decision adverse to the respondent is made.

De Plevitz concluded that the trigger for applying the Briginshaw scale, according to High Court and other appellate court authority, was the possibility that an adverse finding 'will produce a grave consequence' for the defendant. She also quoted High Court Justice McHugh who stated in *Witham v Holloway* (1995):

I know Briginshaw is cited like it was some ritual incantation. It has never impressed me too much. I mean, it really means no more than, 'Oh, we had better look at this a bit more closely than we might otherwise', but it is still a balance of probabilities in the end.

The Briginshaw scale has been applied to situations involving both individuals and organisations. However, the extent to which the consequences of an adverse finding produce grave consequences for an organisation is perhaps less clear than for individuals. For example, De Plevitz noted that the most common consequence an employer is likely to face in anti-discrimination cases is a modest sum in compensatory damages.

As highlighted by Williams and DePlevitz, 'standard of evidence' is different from standard of proof. Standard of evidence refers to characteristics such as the quantity, reliability and consistency of the available evidence. When deciding whether a finding has been proven to the required standard of proof, the Briginshaw scale implies that a relatively high standard of evidence may be acceptable if the

⁶⁷ C. R. Williams, 2003, p.180.

proposed finding has significant consequences for those involved (for example, direct evidence, multiple witness statements, and expert opinions with a large degree of consistency). However, for findings which may have minimal consequences, it may be appropriate to have a lower standard of evidence (for example, one witness statement).

5.1.4 Relationship between probability and standards in legal settings

In order to make judgements with regard to standards of proof, it is necessary to use some concept of uncertainty or probability. Anderson et al. noted (p.246):

There are no conclusions reached in legal disputes that can be stated with absolute certainty. Consequently, the use of probabilistic concepts is as common in inferences in law as it is in inferences in other contexts. Probabilistic judgements concerning various matters in law are usually made verbally. For example, forensic standards of proof involve verbal probabilistic hedges such as “beyond reasonable doubt”, “clear and convincing evidence,” and “probable cause”. In some contexts it is supposed that probabilistic judgements will always be stated numerically either using numbers on the conventional zero-one probability scale or in terms of odds. But in other contexts, law for example, such numerical judgements are quite difficult to make and justify because the events of concern either happened or did not happen on exactly one occasion...

Anderson et al. also state that the reasons why conclusions in fields such as law are necessarily probabilistic in nature include that the evidence is always incomplete, commonly inconclusive, often ambiguous, commonly dissonant (in that some parts favour one proposition while other evidence favours another proposition), and comes from sources with ‘every graduation of credibility shy of perfection’. The same situation applies to the field of safety investigation.

In terms of the relationship between probability and standards, some research in the US has found that the ‘preponderance of the evidence’ standard was generally associated with a likelihood at about or just above 50 per cent. The ‘clear and convincing’ standard was generally regarded to be about 66 per cent likelihood, and the ‘beyond reasonable doubt’ standard was generally regarded as being a likelihood of 90 per cent or more, with some believing it was much higher than 90 per cent.⁶⁸ Research has also shown difficulties with the way that jury instructions for the three primary standards are defined in the US, and that jurors cannot reliably distinguish between the different standards when using only verbal descriptions. However, the use of numerical probabilities was found to be helpful in distinguishing between the standards.⁶⁹

There has been great reluctance within the legal field to define the standards of proof using conventional numerical probabilities on a scale between 0 and 1 (or 0 to

68 The most detailed comparison was provided by C. M. A. McCauliff, ‘Burdens of proof: Degrees of belief, quanta of evidence, or constitutional guarantees?’, *Vanderbilt Law Review*, vol. 35, 1982, pp. 1293-1335. See also E. Stoffelmayr & S. S. Diamond, ‘The conflict between precision and flexibility in explaining “beyond reasonable doubt”’, *Psychology, Public Policy, and Law*, vol. 6, 2000, pp. 769-787.

69 D. K. Kagehiro, ‘Defining the standard of proof in jury instructions’, *Psychological Science*, vol. 1, 1990, pp.194-200.

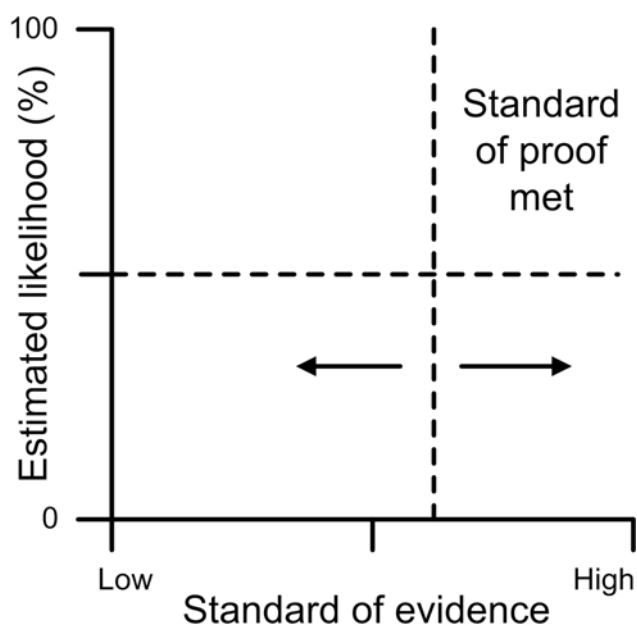
100 per cent). Anderson et al. stated (p.249) that there has been considerable debate for over thirty years concerning how the probative weight, force or strength of evidence should be assessed in probabilistic terms. Several approaches have been proposed, with no clear resolution. Redmayne commented (pp.167-168):

The concept of probability is the first important component of proof. It happens, though, that there are a number of different conceptions of probability and that there is disagreement about precisely what probability means in the legal context. This is not, however, a serious stumbling block for present purposes: whether forensic probability is cardinal or ordinal, objective or subjective, Pascalian or Baconian there is little doubt that it comes in degrees. This is certainly the accepted understanding of the difference between the criminal and civil standard of proof: in order to win a criminal case, the prosecution must prove its case to a higher degree of probability than need the plaintiff in a civil case.

In summary, to determine whether a fact is proven (such as whether one event or condition contributed to another event or condition), involves using a standard of proof and making various judgements. To some extent, estimation has to be made, based on the available evidence and on some form of scale, as to the probability or likelihood that a proposed finding was true. This estimation needs to be compared with the relevant standard of proof to determine whether the standard has been met. In the Australian legal system, the extent to which the decision maker can be satisfied that the standard of evidence was sufficient to meet the balance of probabilities standard of proof may vary according to various factors, as suggested by the Briginshaw scale.

Figure 15 provides a simplified representation of the relationship between probability, standard of evidence and standard of proof. The perceived likelihood that a proposed finding is true is represented by the vertical axis, and the horizontal axis represents the standard of evidence deemed acceptable for the situation (based on considerations such as those associated with the Briginshaw scale). For the balance of probabilities standard of proof to be met, and the finding considered proven, the perceived likelihood has to be higher than 50 per cent, and the standard of evidence has to be above a nominated level. Although the perceived likelihood and standard of evidence are represented on different axes, the two concepts would generally be closely related.

Figure 15: Simplified representation of the civil standard of proof



5.2 Coronial inquests

5.2.1 General aspects of coronial inquests

The main type of legal process that investigates fatal transportation accidents in Australia and many other countries is a coronial inquest. In a comprehensive discussion of the nature of coronial inquests in Australia, Freckelton and Ranson noted that⁷⁰:

The most significant role of the modern coroner in Australia and New Zealand is to investigate death and determine who died, when they died, how they died and what constituted their cause of death.

In addition to making findings on these important issues, a coronial inquest can serve many other purposes. A key role is the prevention of future deaths through the use of recommendations. The former Victorian State Coroner, Graeme Johnstone, has stated that ‘the value of the coroner’s recommendations (riders) and comments, which has been limited in the traditional case-by-case “legally based” investigatory system, is beginning to be more widely appreciated.’⁷¹ However, Freckleton and Ranson⁷² outlined limits to the coroner’s scope as indicated by Justice Nathan in *Harmsworth v State Coroner*:

⁷⁰ I. Freckelton & D. Ranson, *Death investigation and the coroner’s inquest*, Melbourne, Oxford University Press, 2006, p.62.

⁷¹ G. Johnstone, ‘Coronial inquiries and recommendations’ in H. Selby (Ed) *The Inquest Handbook*, Annadale, NSW, The Federation Press, 1998, p.40.

⁷² I. Freckelton & D. Ranson, p.548, citing *Harmsworth v State Coroner* [1989] VR 989 at p.996.

The power to comment is incidental and subordinate to the mandatory power to make findings related to how the deaths occurred, their causes and the identity of any contributory persons.

As with safety investigations, a key aspect of coronial inquests is that they are not conducted for the purpose of apportioning blame or liability. However, there can be an inevitable link between coronial proceedings and other legal or disciplinary proceedings. Selby has observed that⁷³:

At the hearing the inquisitorial coroner is often faced by adversarial parties. This reflects a search for blame and the parties' desire to push the responsibility and the financial costs on to one party rather than the other. It also gives notice that though the coroner may wish to arrive at the truth, that will not be the aim of some of those represented at the inquiry.

Similarly, Freckelton and Ranson commented (p.117):

Although the coroner's investigation is not aimed at determining civil liability, in practice the inquest is an ideal forum for the discovery of information that could be useful to a plaintiff in preparing for a civil claim. While coroners regularly emphasise that the jurisdiction is not blame-based, but rather prevention-based, this is of little comfort to witnesses who find that the inquest has been used by one party to gather and test the evidence of witnesses who might be valuable in a future civil action. It could be said that this is an inevitable risk of the inquest process and that the benefit of the inquest for future risk reduction outweighs any increase in litigious activity.

Johnstone stated (p.42):

Coroners' procedures, in an attempt both to establish a sound structure for a public investigatory process and to provide procedural fairness, is helped and hindered by the adversary system. The system's focus on blame means that often the real issues are hidden or diminished. ... Experience of a large number of coronial investigations shows that "accident" causes are multifaceted.

Although generally coroners' findings do not make explicit findings relating to blame, they often discuss issues such as responsibility. In other words⁷⁴:

... the reality of coroner's findings is that they generally do make a factual determination about the cause of death in terms that enable an inference to be drawn about blameworthiness in the circumstances leading to a death.

In all jurisdictions, though, regardless of the exact phraseology of coroners' findings, the allocation of fault to one or more parties to an inquest enables informed decision-making as to whether civil proceedings, which also have to be determined on the balance of probabilities, should be instituted. Although a coroner's findings or comments are not admissible as proof of negligence in subsequent civil proceedings, they are a useful guide to how an independent fact-finder is likely to view the relevant factual matrix. For this reason, the agenda of many parties to coroners' inquests is to explore the feasibility, or reduce the likelihood, of the institution of subsequent civil proceedings.

Freckelton and Ranson stated (p.619) that coroners are generally precluded from making any finding that a person is or may be guilty of a criminal offence. They

⁷³ H. Selby, in H. Selby (Ed.), *The inquest handbook*, Sydney, Federation Press, 1998, p.xxi.

⁷⁴ I. Freckelton & D. Ranson, p.562.

also noted (pp.557-560) that, in most jurisdictions, where a coroner believes that a criminal offence has been conducted associated with a death, coroners are required to pass that information on to the Director of Public Prosecutions.

5.2.2 Determination of causes in coronial inquests

Freckelton concluded that the manner in which causation is determined in coronial inquests is not clear, although the 'common sense' test advocated by the High Court (and involving the use of the but-for test) had been explicitly applied in some cases.⁷⁵ There are no indications that coronial inquests use a different approach to causation than that used in civil legal proceedings.

In terms of the range or types of causal factors identified by coroners, Freckelton and Ranson commented (pp.638-639):

Difficult legal and medical issues often arise in the context of coroners' hearings in determining how far into the chain of causation a coroner should inquire to ascertain the 'real cause' of death...

...Clearly, a limit has to be imposed in terms of the remoteness of a factor's impact upon the occurrence of a death. However, this does not assist the assessment very far in terms of how far a coroner or coroner's jury is entitled to go beyond a proximate cause of death or other phenomenon. It is clear that in practice coroners regularly inquire into and make findings on matters that are anterior to the proximate cause of death and that contextualise that cause. As yet there is little helpful superior court authority in respect of the degree of remoteness of inquiry and findings permissible for coroners.

They also noted (p.641) that the extent to which a coroner proceeds away from the accident when determining causes is a matter of common sense, and therefore will vary from inquest to inquest.

Historically, in some jurisdictions in Australia, coroners were required to find the identity of any individuals who contributed to a death. Although not specifically required anymore (except in Tasmania), Freckelton and Ranson (p.645) stated that an integral part of an inquiry into how a death came about 'involves assessment of whether it occurred through the agency, intervention or involvement of another person or entity'. They concluded (p.648), that assessment of whether a person or entity contributed to a death generally involved consideration of appropriate or reasonable standards of behaviour. They also noted that, when making assessments in this area, judgements of fault and blameworthiness are unavoidable.

Freckelton and Ranson stated that an important decision on the subject of contribution in coronial inquests was that of Justice Hedigan of the Supreme Court of Victoria in the context of an application to declare void findings of the State coroner in one of a series of seven inquests into fatal shootings by police.⁷⁶ They noted that his Honour's guidance conformed with the practice within the Victorian Coroner's Court of finding contribution only where blameworthiness could be

⁷⁵ I. Freckelton, 'Causation in coronial law', in I. Freckelton & D. Mendelson (Eds), *Causation in law and medicine*, Aldershot UK, Ashgate, 2002, pp. 331-354. See also Freckelton and Ranson, p.641.

⁷⁶ I. Freckelton & D. Ranson, pp.645-646, discussing *Chief Commissioner of Police vs Hallenstein* [1996] 2 VR 1 (SCVic).

established.⁷⁷ His Honour held that “It is preferable to leave evaluation of contribution to be made on a common sense, case by case basis” guided by the general principles attaching to civil liability.

5.2.3 Standard of proof and standard of evidence in coronial inquests

With regard to the standard of proof used in Australian coronial inquests, Freckelton and Ranson stated (pp.554-555)⁷⁸:

Coroners can only make findings on the basis of the proof of the relevant facts on the balance of probabilities in Australian and New Zealand inquests. However, where the matters that are the subject of the coroner’s findings are very serious or approximate criminal conduct, the finding will be on the upper end of the balance of probabilities, in accordance with the scale postulated in *Briginshaw v Briginshaw*...

Coroners should be mindful of the deleterious effect that a finding of contribution to cause of death may have on a person’s character, reputation and employment prospects, as well as the gravity of such a finding. While allegations of matters of assault need to be proved only on the balance of probabilities before a coroner, their criminal nature is one of the factors to be taken into account in determining whether the requisite level of ‘comfortable satisfaction’ exists as to the matters alleged... The result is that the distinction between the criminal and civil standards in such matters may not be of major consequence.

As with the interpretation of the *Briginshaw* scale generally (see Section 5.1.3), some descriptions of applying the *Briginshaw* scale in coronial inquests have implied that the standard of proof should be varied, whereas others have stated that the standard of evidence should be varied. Consistent with the latter approach, the Queensland State Coroner stated the following in his findings related to the Lockhart River inquest (p.5):

A coroner should apply the civil standard of proof, namely the balance of probabilities, but the approach referred to as the *Briginshaw* sliding scale is applicable. This means that the more significant the issue to be determined, the more serious an allegation or the more inherently unlikely an occurrence, the clearer and more persuasive the evidence needed for the trier of fact to be sufficiently satisfied that it has been proven to the civil standard.

A significant difference between coronial inquests and other legal proceedings is that coroners are not bound by rules of evidence limiting what types of evidence are admissible. However, Freckelton and Ranson commented (p.573) that the evidence which is used as the basis of findings needs to be reliable, and that the rules of evidence applicable to civil proceedings provide guidance as to the reliability of different types of evidence.

⁷⁷ I. Freckleton, ‘Inquest law’ in H. Selby (Ed) *The Inquest Handbook*, Annadale, NSW, The Federation Press, 1998, pp.5-6.

⁷⁸ I. Freckleton & D. Ranson, pp.554-555.

5.3 Safety investigations

In legal proceedings, it is more common to discuss ‘causation’ rather than ‘contribution’ to accidents, although coronial inquests often make reference to contributing factors as well as causes. In safety investigations, the use of ‘contributing factors’ or similar terms is more common. This subsection examines some of the definitions that have been used in the safety investigation field. It then outlines two different approaches that have been used to determine contribution (or causation) in safety investigations: the ‘relative-to-occurrence approach (which is used in legal proceedings), and the ‘link-by-link’ approach.

5.3.1 Contributing factors versus causal factors

Organisations that conduct safety investigations use a variety of terms to describe the factors involved in the development of an occurrence, and often these terms are not clearly defined. However, when organisations do use ‘contributing factors’ or some analogous term together with ‘causes’ or some similar term, the contributing factors are generally described as having a lower degree of relationship to the actual occurrence than causes.⁷⁹

For example, the US National Aeronautics and Space Administration (NASA) uses the following terms⁸⁰:

Proximate cause(s): The event(s) that occurred, including any condition(s) that existed immediately before the undesired outcome, directly resulted in its occurrence and, if eliminated or modified, would have prevented the undesired outcome. Also known as the direct cause.

Root cause(s): One of multiple factors (events, conditions or organizational factors) that contributed to or created the proximate cause and subsequent undesired outcome and, if eliminated, or modified would have prevented the undesired outcome. Typically multiple root causes contribute to an undesired outcome.

Contributing factor: Any event or condition that may have contributed to the occurrence of an undesired outcome but, if eliminated or modified, would not by itself have prevented the occurrence.

Similarly the US Department of Energy (DOE) stated the following⁸¹:

There are three types of causal factors: direct, contributing, and root causes. Direct cause is defined as the immediate events or conditions that cause the accident. Contributing causes are conditions or events that collectively increase the likelihood of an accident but that individually did not cause the accident. Root causes are conditions or events that, if corrected or eliminated, would prevent recurrence of the accident.

79 The generic term ‘contributing and causal factors’ is used in this report to refer to a range of specific terms used by different organisations.

80 NASA, *NASA Procedural Requirements for Mishap and Close Call Reporting, Investigating, and Recordkeeping*, NPR9621.1B, 2006, pp.64,69.

81 DOE, *Implementation guide for use with DOE Order 225.1A, Accident investigations*, 1997, pp.IV-25-IV-26.

In addition to the ATSB, some organisations do not differentiate between causes and contributing factors in their reports. For example, the Canadian TSB's reports include 'findings as to causes and contributing factors', but the two terms are not differentiated.

5.3.2 Determining contribution or causation

The current definitions of cause used by ICAO and IMO (see Section 2.2.4) provide minimal indication as to how causation or contribution should be determined by a safety investigation. However, the but-for test (or counterfactual conditional) has gained widespread acceptance as a means of defining contributing and causal factors in the field of safety investigation.⁸²

Aside from the common use of a counterfactual definition, there is little discussion in the safety investigation field regarding exactly how contribution or causation should be determined. For example, there has been little discussion about criteria to use for conducting tests of existence or influence, or criteria to consider when developing or evaluating relevant arguments.

As noted in Section 5.1.1, concerns have been raised in the legal field with the use of the but-for test of causation. However, much of this concern appears to be associated with the difficulty that arises in using the but-for test for the purposes of assigning responsibility or liability. Stapleton (p.16) observed that although lawyers have difficulty with the but-for test, scientists do not have the same purposes and the same concerns.⁸³

5.3.3 Two approaches to making judgements about factors

When considering the standard of proof used in a safety investigation, it is important to be aware of the approach being used by the investigation to make judgements regarding contribution or causation. There are two main approaches, which can be termed the 'relative-to-occurrence' approach and the 'link-by-link' approach.

In the relative-to-occurrence approach, the judgement as to whether a safety factor is a contributing or causal factor is made in terms of its relationship to the ultimate occurrence event of interest (for example, the collision with terrain, breakdown of separation or engine fire). A common way of expressing the approach is to say that if the safety factor did not happen, then (at some level of probability) the occurrence (or the adverse consequences associated with the occurrence) would not have happened.

In the link-by-link approach, the judgement as to whether a safety factor was a contributing or causal factor is made in terms of its relationship to another

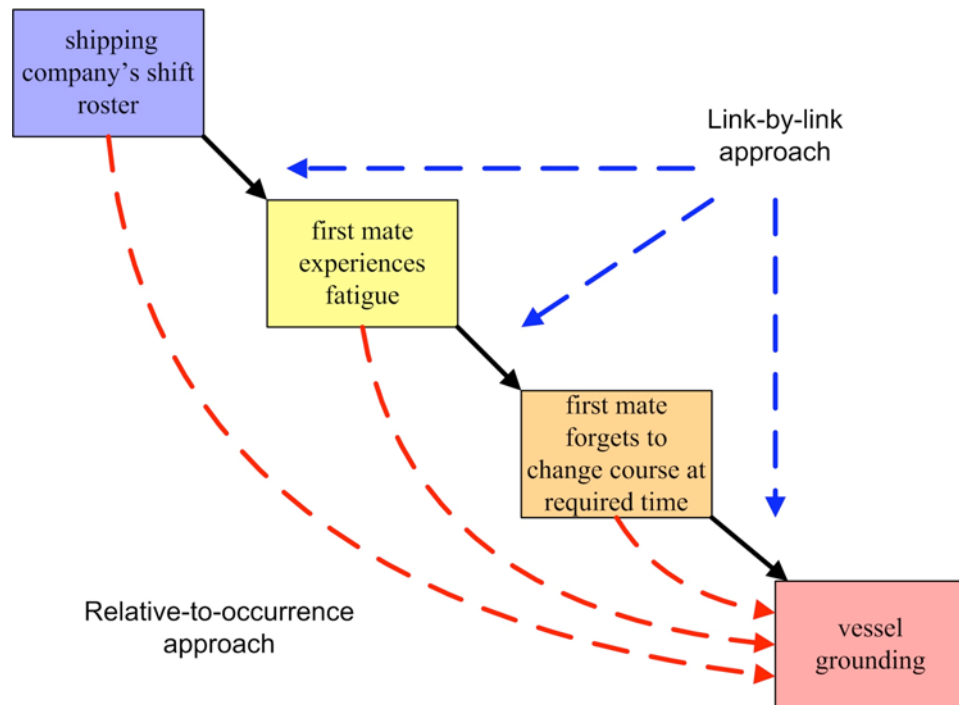
⁸² For example, see C. Johnson, *Failure in critical systems: A handbook of incident and accident reporting*, Glasgow, Glasgow University, 2003, pp.185-186. See also A. Hopkins, *Lessons from Longford: The Esso gas plant explosion*, Sydney, CCH Australia, 2000, p.124. In addition, the definitions used by NASA and DOE include counterfactual elements (see Section 5.3.1), as does the definition of contributing factor incorporated into AS4292.7-2006 (see Section 2.2.4).

⁸³ J. Stapleton, 'Scientific and legal approaches to causation', in I. Freckelton & D. Mendelson (Eds), *Causation in law and medicine*, Aldershot UK, Ashgate, 2002, pp.14-37.

contributing or causal factor. In other words, judgements about contribution are made about the strength of each link, rather than made in terms of the overall relationship between each potential factor and the occurrence itself.

Figure 16 summarises the differences between the two approaches. Further discussion of the approaches and their suitability for safety investigations are presented in the following sections.

Figure 16: Comparison of relative-to-occurrence and link-by-link strategies



5.3.4 Relative-to-occurrence approach

The relative-to-occurrence approach is the traditional approach used to determining contributing and causal factors in safety investigation (for example, see the definitions used by NASA and DOE in Section 5.3.1). In addition, the approach appears to be routinely used in coronial inquests in determining the cause(s) of death, and it is also the approach that is used in legal proceedings for determining responsibility, liability and/or compensation following an occurrence.

Although the relative-to-occurrence approach has merit for the purpose of determining responsibility, it has some limitations and is less suited for the purpose of enhancing safety. Firstly, relative-to-occurrence judgements can become very difficult if there are multiple links between the potential factor and the occurrence. For example, consider the situation outlined in Figure 16. The judgement as to whether the shift roster was a contributing or causal factor to the occurrence (that is, the ship grounding) involves considering or combining the uncertainties associated with each link in some way prior to making the overall determination. The difficulty of relative-to-occurrence judgements also increases if there are multiple ways in which a particular factor could be linked to the occurrence itself, which is often the case in complex occurrences (for example, see Figure 10).

Secondly, there is a significant dilemma associated with using a relative-to-occurrence approach which fundamentally constrains the potential for the approach to enhance safety. The dilemma is that the most effective findings for safety enhancement are often the most difficult to justify. This dilemma can be outlined in more detail as follows:

- To enhance safety through facilitating safety action, a safety investigation needs to identify those safety factors that are safety issues (see Section 2.3). The broader the scope of the safety issue, then generally the greater the potential for safety improvement.⁸⁴
- To identify safety issues, an investigation needs to look into the safety system and at factors more remote from the actual occurrence itself.
- The more remote an investigation proceeds away from the occurrence, the more difficult it becomes to demonstrate a relationship between a safety factor and the occurrence using a relative-to-occurrence approach. In other words, the more likely it is that the factor of interest will be assessed to have not been a contributing or causal factor. Depending on the standard of proof being used, this generally means that most contributing and causal factors will refer to individual actions and technical problems in relatively close proximity to the actual occurrence, and few safety issues are identified as contributing or causal factors.⁸⁵
- The sooner a safety investigation stops identifying contributing or causal factors, then the sooner it generally stops searching for other potential safety factors to help explain the occurrence and the factors already identified. As noted in Section 2.4, to be efficient and timely safety investigations should not stray too far from the paths of contribution when searching for potential safety factors.

Thirdly, as noted in Section 2.4, the importance of a safety issue should be determined by its level of risk for future operations, not the degree to which it was involved in the development of a particular occurrence. Unfortunately however, the ATSB often encounters attitudes such as ‘why is the ATSB looking at that, it had nothing to do with the accident’ or ‘there’s no need to make changes because the factor did not directly contribute to the occurrence’. In terms of safety issues, there can be an increased tendency to not perceive the importance of the issue for future safety enhancement unless it has been shown to be a contributing or causal factor.⁸⁶

84 For example, if there are problems with an operator’s approach procedures for a specific aircraft type, addressing this problem should enhance safety. However, a safety investigation should also consider why there were problems with the operator’s procedure. If the investigation finds there are problems related to the way the operator develops or reviews its procedures, or the regulatory requirements relating to the procedure of interest, then addressing these problems has the potential for more significant safety enhancement than simply addressing one procedure in one operator.

85 For example, the US NTSB uses a relative-to-occurrence approach based on the concept of ‘probable cause’. A recent analysis of US commercial aviation accidents found that only a small proportion of factors contained in investigation reports referred to risk controls or organisational influences. See S. Shappell et al., ‘Human error and commercial aviation accidents: An analysis using the human factors analysis and classification system’, *Human Factors*, vol. 49, 2007, pp.227-242.

86 For example, see the comments made regarding standard of proof in the investigation into the F-111 Deseal/Reseal program discussed in Section 5.3.6. It is also worth noting that most manuals on safety investigation only discuss the importance of finding contributing and/or causal factors;

The existence of such views suggests that there is more potential for safety enhancement when safety issues are identified as contributing factors relative to when they are not. By making it more difficult to conclude that a safety issue contributed to the development of an occurrence, the relative-to-occurrence approach is therefore unduly limited in its ability to enhance safety.

Finally, the relative-to-occurrence approach is used in legal proceedings, and the findings of safety investigations conducted using a relative-to-occurrence approach can therefore be readily interpreted in terms of a legal perspective. This association with legal proceedings has the potential for some parties to respond to safety investigation findings with future liability and compensation consequences in mind. For example, the US National Transportation Safety Board's 'probable cause' findings are based on a relative-to-occurrence approach, and are viewed as strongly connected to subsequent legal proceedings regarding liability⁸⁷:

The NTSB's Investigator's Manual defines "probable cause" as the condition(s) and/or event(s) or the collective sequence of conditions and/or events that "most probably caused the accident to occur." The Manual goes on to explain that had the condition or event been prevented, the accident would not have occurred...

...a finding of probable cause has repercussions that are felt well beyond the NTSB. Any person or entity found to have "caused" an accident will be considered by the public and the media to be at fault or responsible for the wrongdoing. In terms of the assignment of fault and blame for a major aviation accident, the NTSB's probable cause finding is "the whole ballgame."...

Beyond the regulatory impact, a finding of probable cause by the NTSB is very significant for the civil litigation associated with a major commercial aviation accident. Stakeholders on all sides describe the importance of the NTSB Blue Book and the probable cause determination in the same terms: These findings provide the "roadmap to liability." Claimants and defendants wait many months, and sometimes several years, for the NTSB to articulate the probable cause of the accident. After the NTSB investigation is completed, the restraints that have been placed on court proceedings are removed and the claimants and their lawyers move quickly to pursue the theories of liability that are outlined in the NTSB report.

Concern with blame and responsibility aspects has also been described as a barrier to effective organisational learning following an occurrence.⁸⁸

they do not discuss the importance of also addressing other safety factors that may be identified during an investigation.

87 L. P. Sarsfield et al., *Safety in the skies: Personnel and parties in NTSB accident investigations* (Master volume), Institute of Civil Justice / RAND, Report MR-1122/1-ICJ, 2000, pp.115-123. See also K. Bills presentation to Chiefs of Air Accident Investigation, 'Access to and Protection of Confidential Data – Annex 13, Legislation, Liability and Litigiousness', Singapore, 23 August 2007 (http://www.atsb.gov.au/newsroom/2007/speech/2007_28.aspx).

88 N. Pidgeon & M. O'Leary, 'Man-made disasters: Why technology and organizations (sometimes) fail', *Safety Science*, vol. 34, 2000, pp.15-30.

5.3.5 Link-by-link approach

The link-by-link approach has been previously advocated for safety investigations.⁸⁹ Although not explicitly stated, it has also been used by many investigations using a Reason model or systemic approach (for example, it is consistent with the approach that the ATSB and BASI have been using in their more significant investigations for many years).

For the purpose of enhancing safety, the link-by-link approach has several advantages compared with the relative-to-occurrence approach. For example, the link-by-link approach can simplify the judgements that need to be made in determining whether a particular factor was a contributing or causal factor. Instead of needing to combine probabilities across many links, only the influence of one factor on the next factor needs to be considered.

The link-by-link approach can also better enable an investigation to be more open and intellectually rigorous, by more clearly showing how the factors identified were (or were not) involved in the development of an occurrence. Although a link-by-link process to identifying potential factors can be used with a relative-to-occurrence approach, the links are often not made clear in investigation reports or findings which are based on that approach.

More importantly, the link-by-link approach can also facilitate a safety investigation's potential for enhancing safety. By making judgements about each link separately, there is more scope to proceed more remotely from the occurrence and identify higher-level safety factors (or safety issues) as being involved in the development of the occurrence. These higher-level factors, if addressed by relevant organisations, will enhance safety. In addition, the inclusion of the higher-level factors provides a richer picture of how an occurrence developed, which in turn provides learning opportunities for organisations that both were or were not involved.

The extent to which an investigation team which uses a link-by-link approach will identify higher-level factors depends on the standard of proof used for each link. Hopkins has advocated using a 'more likely than not' standard, and has successfully used the approach to identify high level problems as contributing to accidents in various industries.⁹⁰ In contrast, Ladkin has used a very high standard of proof, and the identification of higher-level safety factors beyond risk controls has been limited.⁹¹

There are potential problems with a link-by-link approach. Firstly, there may be a greater tendency to proceed too remotely from the occurrence and identify factors that cannot be practicably addressed. However, this problem can be minimised with a clear definition of a 'stop rule' and consideration of the concept of practicability when identifying potential factors (see Section 3.5).

89 For example: (a) A. Hopkins, 2000, Chapter 10; (b) P. Ladkin, *Causal system analysis: Formal reasoning about safety and failure*, Draft Version 2.0, Document RVS-Bk-01-01, August 2001, Chapter 12.

90 See A. Hopkins, 2000, 2003, 2005.

91 Discussions between P. Ladkin and ATSB investigators during a course on 'Why-Because Analysis' in October 2005, Canberra.

A second problem is that findings about safety issues produced using a link-by-link approach can be misinterpreted by some parties as being based on a relative-to-occurrence approach.⁹² As a result, some of the findings about contributing and causal factors may be perceived by these parties to be weak or poorly supported. Such misinterpretation can interfere with an understanding of the importance of addressing the issues in order to reduce the risk of future accidents.

The potential for misinterpretation of the link-by-link approach can be minimised by considering the standard of proof that is used for the links (see Section 5.4.1). It can also be minimised by clearly defining the types of findings and the approach being used by the investigation, and emphasising that findings produced with the link-by-link approach should not be directly compared with findings produced by a relative-to-occurrence approach (see also Section 7).

5.3.6 Standards of proof used in safety investigations

As far as the ATSB is aware, most organisations that conduct safety investigations do not clearly specify the standard of proof (or standard of evidence) they use when making findings regarding contributing and/or causal factors. However, as indicated in Section 5.3.1, a lower standard of proof is evidently used by some organisations when discussing contributing factors as opposed to causal factors.

ICAO has provided only basic guidance regarding the standard of proof or standard of evidence to be used in aircraft accident and incident investigations. However, with regard to writing findings, it has stated⁹³:

The determination of causes should be based on a thorough, impartial and objective analysis of all of the available evidence. Any condition, act or circumstance that was a causal factor in the accident should be clearly identified... The causes should be formulated with preventive action in mind and linked to appropriate safety recommendations...

When certain of a cause, a definitive statement should be used: if reasonably sure of a cause, a qualifying word such as “probable” or “likely” should be used....

The causes should be formulated in such a way which, as much as practicable, minimizes the implication of blame or liability. Nevertheless, the accident investigation authority should not refrain from reporting a cause merely because blame or liability might be inferred from the statement of cause.

92 For example, with regards to the Lockhart River Metro 23 accident, the CASA chief executive officer made a media statement on 4 April 2007 that he did not accept that CASA ‘caused the errors on the flight deck that resulted in the accident’, and that although there was ‘room for improvement’ in CASA’s oversight processes, these problems could not be linked ‘directly’ to the failures that occurred on the flightdeck. However, the ATSB report did not state that CASA directly contributed to the crew’s actions or the occurrence itself. The ATSB report concluded that limitations with the design of CASA’s regulatory oversight processes contributed to it not being able to detect fundamental problems with the operator’s safety management processes. Using a link-by-link approach, these safety management problems were in turn linked through various risk controls and local conditions with the crew actions involved in the occurrence.

93 ICAO, *Manual of Aircraft Accident and Incident Investigation: Part IV- Reporting*, Doc 9786 (1st edition), 2003 (p.IV-1-14). ICAO’s definition of cause is discussed in Section 2.2.4.

As noted in Section 5.3.5, Hopkins has advocated a ‘more likely than not’ standard using a link-by-link approach, whereas Ladkin has adopted a near certain standard with the same approach.

The concept of standard of proof was discussed in the inquiry into the reported adverse health effects of maintenance workers on F111 aircraft⁹⁴, particularly in relation to whether workers’ exposure to chemicals during the fuel tank deseal/reseal activities led to adverse health effects. The report noted that science needs to be conservative when it comes to drawing conclusions. For example, relationships are generally said to be ‘statistically significant’ only if the probability that they might occur by chance is less than .05 (or 5 per cent). In addition, the report observed that the criminal law requirement of beyond reasonable doubt was also conservative, as the risk of convicting an innocent person needs to be minimised. If such standards are not met that does not mean that a relationship did not exist, just that it could not be proven to the high standard that had been set. The report noted that these conservative standards, which are strongly biased to finding relationships unproven, were not appropriate to the board of inquiry. It was stated that if the use of such standards resulted in finding relationships unproven, this would have an adverse impact on safety by lessening the influence of any recommendations that were made. The report advocated that the civil standard of balance of probabilities was appropriate, and this standard was interpreted as meaning ‘whether something is more likely than not to have occurred’.

As far as the ATSB is aware, no safety investigation organisations have a clearly stated policy for the standard of proof or standard of evidence to vary according to aspects such as those associated with the Briginshaw scale. However, a review of the processes of the US NTSB noted that the standard of proof for its probable cause findings could vary depending on the profile of the occurrence.⁹⁵ More specifically:

Within the legal system, various measures of proof are employed to denote the level of certainty required for the imposition of criminal or civil liability. Evidence “beyond a reasonable doubt,” the highest standard, is required for criminal conviction. Many jurisdictions have adopted the somewhat lower measure of “clear and convincing” evidence to support the award of punitive damages in civil cases. A “preponderance of the evidence,” loosely figured at 51 percent of certainty, is all that is generally required to support a finding of negligence or other civil liability and the award of compensatory damages.

Instead of employing a similar determination standard for the NTSB’s findings, the term “probable” seems to take on different meanings depending on the severity of the accident and the public visibility of the agency’s proceedings. The “hotter” the investigation, the more certainty is demanded within the NTSB and by the parties and other stakeholders. At times, “probable cause” is equated with the legal standards of “clear and convincing” evidence or proof “beyond a reasonable doubt.”

⁹⁴ Royal Australian Air Force, *Report of the Board of Inquiry into F-111 (Fuel Tank) Deseal/Reseal and Spray Seal Programs*, Volume 1, Appendix 5, 2001.

⁹⁵ L. P. Sarsfield et al., pp.116-117.

Attempting to chase a moving standard impacts the NTSB's ability to complete its investigations in a timely fashion. Truth and certainty are always elusive goals, but in the discipline of accident investigation, the search depends on the analysis of highly complex systems, the testing of damaged components, the replication of unusual flight conditions, and recovery or even reconstruction of wreckage. In the face of such daunting tasks, NTSB investigators can lose sight of the fact that their central function is to demonstrate that certain events or conditions "probably" caused the accident...

As with coronial inquests, safety investigations generally do not have any formal rules of evidence constraining what types of evidence are allowed to be considered. The assessment of the quality of each item of evidence is therefore wholly at the discretion of the investigation team. There has been minimal guidance provided in the safety investigation field for how to make such judgements.

As with coronial inquests, safety investigations are generally not bound by formal rules of evidence constraining what types of evidence are allowed to be considered. The assessment of the quality of each item of evidence is therefore wholly at the discretion of the investigation team. Safety investigations are obligated to ensure the veracity of evidence but to date there has been minimal guidance provided in the safety investigation field for making such judgements.

5.4 Revisiting the ATSB analysis framework

5.4.1 Standard of proof

When comparing the standard of proof used for determining contribution in the ATSB analysis framework with other approaches, there are several aspects to consider. These include:

- the use of the term 'probably' to clearly indicate a standard of proof
- the link-by-link approach
- the use of the term 'contributing' rather than 'causal'.

In selecting an appropriate standard, the ATSB was aware that the use of a high or conservative standard (such as 'beyond reasonable doubt', 'almost certain' or similar) would produce few contributing safety factors in most investigations, particularly in terms of safety issues (or risk controls and organisational influences). This outcome would provide a relatively shallow or limited explanation of how most investigated occurrences developed. This would limit the learning potential that investigations could provide to the transport industry and its future safety.

The ATSB was also aware that the use of a relatively low standard (such as 'balance of probabilities'), combined with a link-by-link approach, could produce more contributing safety factors that would be perceived by many parties as having a relatively weak role in the overall development of an occurrence.

To achieve an appropriate compromise, the ATSB definition of contributing safety factor was aligned with a standard of 'probable' or 'likely'. Initially this was defined as meaning a likelihood of 75 per cent or more, based on a conservative interpretation of research into what different parties considered different verbal probability expressions to mean. However, this was changed to a likelihood of more

than 66 per cent (or two-in-three chance) following the high profile usage of that definition by the Intergovernmental Panel on Climate Change in early 2007 (see Section 2.6.3). In practical terms, given the difficulties in reliably estimating the likelihood that a given factor influences another factor, the ATSB considered that the difference between '75 per cent or more' and 'more than 66 per cent' was minimal when applying professional judgement to complex sets of evidence.

Coronial inquests use a relative-to-occurrence approach and a 'balance of probabilities' standard of proof. In comparison, the ATSB approach will use a higher standard of proof for factors relatively close in proximity to the occurrence (that is, more than 66 per cent versus more than 50 per cent). But as an ATSB safety investigation proceeds to identify contributing safety factors more remote from the occurrence, the degree of relationship of the factors to the occurrence itself will generally decrease using the ATSB approach.

For example, consider the situation outlined in Figure 16. If the link between the shift roster and the fatigue was assessed as being at least 67 per cent likelihood, and the link between the fatigue and the first mate's action was assessed as being at least 67 per cent likelihood, then the resulting likelihood of a relationship between the shift roster and the first mate's action could be as low as 45 per cent. The more links in the chain, then the lower the likelihood could be between the first (highest-level) factor and the occurrence.

The reduction in the likelihood between a higher-level factor and the occurrence itself over multiple links may not be substantial in practice. In many situations, the likelihood level for each link will be higher than the minimum required level of more than 66 per cent.⁹⁶ Nevertheless, for contributing safety factors at the higher levels of the ATSB investigation analysis model, the balance of probabilities standard for a direct relationship to the occurrence itself may not be met. As a result, all that can be said in such situations is that, if the contributing safety factor had not existed, then the occurrence 'may' not have occurred.

Hopkins has acknowledged that the use of a series of necessary (or counterfactual) conditionals to identify organisational factors related to an accident means that such factors can only be considered to be 'causes only in a relatively weak sense'.⁹⁷ The identification of such factors does not mean that a particular accident can be reliably predicted. However, the presence of such a condition increases the risk of an accident, which could take many different forms, including that which eventuated.

As noted in Section 5.3.1, the term 'contributing' is generally regarded as implying a lower level of relationship to an occurrence than the term 'causal'. The ATSB term 'contributing safety factor' is therefore consistent with the notion of including factors that may have a lower degree of direct relationship to the occurrence itself than is often associated with the term 'cause'. As already noted, the definition of 'cause' is a matter of significant debate in the fields of law and philosophy as well as safety, and the term is also strongly associated with concepts of responsibility, blame and liability. The ATSB term 'contributing safety factor' was also selected to avoid such debates and problems.

⁹⁶ For example, if the two links discussed above each had an assessed likelihood of 90 per cent, the resulting likelihood would be over 80 per cent.

⁹⁷ A. Hopkins, 2005, p.130.

5.4.2 Standard of evidence

The ATSB believes that to be satisfied that a particular event or condition was a contributing safety factor requires a reasonably high standard of evidence. Precisely defining what is ‘a reasonably high’ standard is obviously difficult, as it is for legal proceedings. Nevertheless, the ATSB believes that determinations of contributing safety factors should not be ‘made lightly’, and they should not be based only on opinions or estimates of the general likelihood that a type of factor is involved in such occurrences.

For example, in relation to the Lockhart River accident (see Figure 10), many experts may believe that it was likely that limitations in the crew resource management practices of one or both of the crew members probably contributed to the development of the occurrence. However, given the lack of a cockpit voice recording, the ATSB believed that there was insufficient evidence to be satisfied with a probability of more than 66 per cent that CRM problems influenced the crew’s performance on the accident flight.

As noted in Section 4.4.1, it is an ATSB policy that all of the key findings in an ATSB safety investigation report will be supported or verified by an evidence table. Each evidence table will include all relevant items of information, and appropriate qualifications regarding each item of information.

In other words, to be satisfied that a specific event or condition was a ‘contributing safety factor’ (or even an ‘other safety factor’), the ATSB analysis framework requires a structured and detailed examination of the quantity and quality of the available evidence using tests for existence, influence and /or importance. Unless the pattern of evidence is sufficient to support the proposed factor, no such finding will be made. That a reasonably high standard of evidence is used by ATSB investigators is evidenced by the fact that many ATSB reports contain statements that some aspects of an occurrence could not be determined.

As noted in Section 5.1.3, there is general agreement in the Australian legal system that the strength of the evidence required to be satisfied that a finding has been proven to the civil standard of proof should vary depending on the Briginshaw scale. The Briginshaw scale involves considering the seriousness of the finding, the inherent unlikelihood of the finding, and the gravity of consequences that flow from the finding for the party or parties involved.

The ATSB has not expressly incorporated the Briginshaw scale into its analysis framework. However, a like process is used to some extent in its analysis activities. For example, the ‘inherent unlikelihood’ aspect is specifically included as one of the criteria to consider in the ATSB guidelines for determining existence and influence. More specifically, if there has been no evidence of previous existence or influence, then a more cautious approach should be taken when evaluating existence and influence for the proposed safety factor (see ‘known history of existence’ in Appendix A and ‘known history of influence’ in Appendix B).

The ‘seriousness of an allegation’ and the ‘gravity of the consequences’ aspects of the Briginshaw scale are also considered in ATSB investigations in relatively extreme (or ‘grave’) situations. Examples would include factors associated with suicide, sabotage, other serious criminal conduct or perhaps what may be perceived by some parties as gross negligence. A parallel investigation by other agencies such as regulators or police is the appropriate means for examining and evaluating these types of factors. Information regarding such matters is only included in ATSB

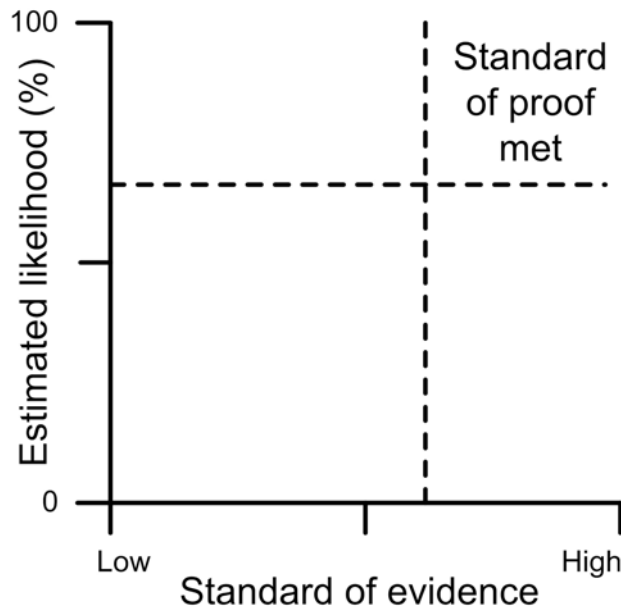
investigation reports where it is needed to understand the circumstances of an occurrence, and the ATSB proceeds more cautiously when evaluating evidence and (where necessary) developing findings about such matters.

In some cases, the ATSB can anticipate that directly involved parties may express dissatisfaction with a contributing safety factor or other finding contained in an ATSB report. When this occurs, it is inevitable that the ATSB will more closely examine the available evidence during its investigation and review processes prior to releasing a draft report. In addition, if a party does express dissatisfaction with a draft report's finding, its views will be considered along with a review of the available evidence. In these situations, the ATSB will more closely examine the evidence available. Although it will not be intentionally applying a different standard of evidence, in some of these situations a closer examination may occasionally identify areas where findings may not have been adequately supported or could have been better defined.

In summary, something akin to the Briginshaw scale is applied in a small proportion of cases where it is deemed necessary and as part of natural justice in ATSB investigation analysis activities. However, there are several reasons for not incorporating a broader application of the scale into the ATSB investigation analysis framework, and these are discussed in Section 6.4.

Figure 17 provides a simplified representation of the relationship between probability, standard of evidence and standard of proof in the ATSB analysis framework. Relative to the civil balance of probabilities standard (see Figure 15), the main differences are the higher likelihood level and the relatively fixed nature of the standard of evidence. The important distinction between the link-by-link approach and the relative-to-occurrence approach also needs to be considered when making any comparisons between the two standards.

Figure 17: Simplified representation of the ATSB standard of proof



5.5 Summary comparison between the ATSB framework and other approaches

Table 3 summarises some of the basic features of the analysis approaches of different types of occurrence investigations: legal proceedings generally (in relation to accidents), coronial inquests, non-ATSB safety investigations, and the ATSB investigation analysis framework. The table focuses on how the different approach define contribution or causation, and the standard of proof and standard of evidence used when making such determinations.

Most types of legal proceedings are interested in the concept of causation for the purposes of determining responsibility and apportioning liability. Although the approach to causation used by legal proceedings may be appropriate for this purpose, this section of the report has outlined how it has limitations when used for the different purpose of enhancing safety.

In contrast, coronial inquests and safety investigations are concerned with the purposes of enhancing safety or preventing future occurrences. Accordingly, when determining contributing or causal factors, both safety investigations and coronial inquests aim to go beyond the factors that immediately preceded the occurrence. However, coronial inquests and many safety investigations generally use a similar approach to causation as used in legal proceedings.

The ATSB analysis framework has some significant differences relative to other approaches. The differences may be a matter of nuance at times, and similar findings may result regardless of which approach is used. However, on other occasions, the differences could result in different sets of findings for the same accident. No set of findings is necessarily more or less valid; they would just arise from the use of different approaches. Nevertheless, given the nature of the approaches, the ATSB approach will generally find it easier than the legal approach to identify safety issues more remote from the occurrence itself, and therefore provide a more detailed or richer picture of the factors involved in the development of an occurrence.

There is also a slight difference in emphasis between different types of investigations. ATSB safety investigations have a primary focus on identifying safety issues, regardless of whether they can be proven to be contributory, but this view is not as explicitly stated in most other types of safety investigations or coronial inquests. In addition, although coronial inquests have different purposes from other types of legal proceedings, they also have similarities to such proceedings in areas such as standard of proof and consideration of causation. Coronial inquests can also involve apportioning responsibility for the occurrence and their findings can also be associated with subsequent legal proceedings.

The last row of Table 3 states that the ATSB approach uses a structured examination of available evidence in making its determinations regarding proposed factors. This does not mean to imply that other investigation approaches do not conduct a detailed, thorough, or high quality examination of the available evidence when determining contributing or causal factors. However, a key part of the ATSB framework is that a structured process is formally defined and integrated into the analysis framework in order to improve the consistency and rigour of analysis activities. In most other approaches, as far as can be determined, the means of examining the evidence and making determinations is not formally defined and relies extensively on the expertise of the decision maker.

Regardless of which approach to determining factors is used, from a safety enhancement perspective it is best for all relevant organisations to take note of any safety issues identified during a safety investigation, and assess the safety risk of these issues for future operations rather than focus on the extent to which the issues were related to any particular occurrence in the past.

Table 3: Comparison of approaches to determining contributing and/or causal factors

	Legal proceedings	Coronial inquests	Safety investigations (general)	ATSB investigations
Purpose of inquiry	Determine responsibility	Determine cause(s) of death; Enhance safety (accident prevention); Not for purpose of blame or liability	Enhance safety (accident prevention); Not for purpose of blame or liability	Enhance safety (accident prevention); Not for purpose of blame or liability
Term for causation / contribution	Cause(s) (and some references to contributing factors)	Cause(s) (and some references to contributing factors)	Various (cause, contributing factor, proximate cause, root cause, significant factor, ...)	Contributing safety factors
Definition	Common sense and but-for test	Common sense and but-for test	No standard, though but-for test is common (some organisations have vague definitions, some no definitions)	Based on but-for test
Linking approach	Relative-to-occurrence	Relative-to-occurrence	Usually relative-to-occurrence	Link-by-link
Standard of proof	Balance of probabilities (>50% likelihood)	Balance of probabilities (>50% likelihood)	Various (often unstated)	Probable / likely (with indicative likelihood of more than 66% likelihood for each link)
Standard of evidence	Varies with Briginshaw scale	Varies with Briginshaw scale	Generally unstated; no reference to Briginshaw scale	Fixed (Briginshaw scale only in extreme situations); Structured examination of available evidence for all factors

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6

CONCERNS WITH THE ATSB AND SIMILAR ANALYSIS APPROACHES

Section 6 outlines concerns that have been expressed regarding the ATSB framework and similar approaches, and the ATSB consideration of these concerns. These concerns primarily relate to the standard of proof and standard of evidence used in ATSB investigations, and the model of accident development used as a part of the ATSB investigation analysis framework.

6.1 Should the ATSB use the same approach as Coronial inquests for determining findings?

It could be argued that it would be useful to have safety investigation agencies such as the ATSB develop their findings in the same way as do coroners. This situation could more easily lead to comparisons between the findings where one entity investigates and the other does not investigate.

At present, caution should be used when comparing a coroner's findings with the ATSB's findings on the same accident, regardless of what approach is used for analysing evidence. Both investigations will have differences in the set of evidence that has been collected. For example, it is not unusual for the ATSB to have conducted interviews with a different range of people from that used by the coronial investigation. It is also not unusual for there to be differences in what some individuals report to the ATSB relative to what is reported by the same individuals in a public inquest. ATSB interviews are conducted confidentially and also require a response even if it may tend to incriminate.⁹⁸ ATSB interviews also generally occur closer in time to the occurrence, whereas appearance at a public inquest often occurs many months or even years later.

The use of a similar analysis approach to that used by coronial inquests would more likely create a situation where ATSB findings would be associated with subsequent legal proceedings for determining blame or liability. Various parties may become more focussed on interpreting and responding to an ATSB investigation report in the context of such legal proceedings about the occurrence rather than interpreting it as a basis for enhancing safety and providing learning opportunities for the future. Such responses could distract attention and resources away from the important task of addressing identified safety issues. It would also be expected that there could be significantly more pressure placed on the ATSB by some external parties in relation to the findings it produces.

Overall, the ATSB believes its analysis framework is more suited to a safety investigation function. This consideration outweighs the potential benefits some parties may see in using an approach that is closer to that currently used by coronial jurisdictions.

⁹⁸ In most jurisdictions, immunity against self incrimination can be provided by coroners, although there are generally limits as to the situations in which it can be provided.

6.2 Is the ATSB standard of proof too precise?

In his findings related to the Lockhart River accident, the Queensland State Coroner stated in relation to the ATSB methodology (p.7):

...to suggest that the accuracy of deductive reasoning or even speculative assessments to which the approach will be applied can be gauged with such precision is, in my view, misconceived. A calibration that may be ideally suited to measuring tangible items or the outcomes of chemical or physical processes may have no application to the vagaries of human behaviour.

The ATSB well understands the nature of human behaviour and the limitations on the available evidence that can be obtained during an investigation to determine exactly how or why individuals and organisations (as well as technical components) performed the way they did. The use of ‘more than 66 per cent’ was never intended to be interpreted as meaning that judgements of the likelihood that a finding was true could be made with a high level of precision. Rather, the level was chosen to provide an indicative guide as to the meaning of the term ‘probable’, relative to other key anchor points such as ‘more likely than not’ (50 per cent) or ‘certain’ (100 per cent); something akin to the US ‘clear and convincing’ standard.

In relation to the decision as to whether a particular safety factor contributed to another safety factor (or the occurrence itself), the term ‘probable’ was used in the ATSB definition of contributing safety factor to convey that a standard of proof greater than ‘more likely than not’ and less than ‘beyond reasonable doubt’ was appropriate. The term ‘probable’, and its associated description of more than 66 per cent likelihood (or two-in-three chance), appears to best meet that need.

Regardless of what standard of proof is used, judgements as to the likelihood that a proposed finding is true need to be made with reference to some level of probability. In that regard, the same difficulties arise for a ‘more than 66 per cent’ standard as would a ‘more likely than not’ or any other standard.

6.3 Is the ATSB standard of proof too low?

In its final submissions to the Queensland State Coroner during the Lockhart River accident inquest, CASA proposed that the use of a more than 66 per cent standard by the ATSB ‘may be too low in terms of providing a reliable indicator of causes of the accident’.

Some key points to note regarding such claims are (see also Section 5.4):

- The ATSB analysis approach does not determine legally-defined ‘causes’, and its definition of contributing safety factors is not consistent with, and should not be interpreted as being consistent with, a legal approach to determining causes.⁹⁹
- The ATSB use of the term ‘contributing’ is consistent with the use of the term in safety investigations to include factors that have a lower level of direct relationship to an occurrence than may generally be associated with terms such as ‘causes’ or ‘causal factors’.

⁹⁹ As noted in Section 2.2.4, the ATSB definition is consistent with relevant ICAO, IMO and Australian Standards’ requirements.

- From a safety enhancement perspective, the extent to which a particular safety factor was involved in the development of a particular occurrence should be of lesser importance. It is more important for organisations to examine the safety issues (contributing or not), assess the safety risk level of those issues, and initiate appropriate safety action.
- There are no agreed standards of proof for contributing (or causal) factors in the safety investigation field. In deciding on a standard, the ATSB selected a compromise between a high standard (which would produce few contributing safety factors) and a low standard (which could produce factors that may be perceived as having a relatively weak role in the development of an occurrence).

Although different parties will have different views as to what an appropriate standard of proof should be for a safety investigation, most would probably support the view that an independent investigation body such as the ATSB should be ‘safety-focussed’ or even ‘safety-biased’ rather than taking a highly conservative approach.¹⁰⁰

The ultimate purpose of a safety investigation is to enhance safety. If a highly conservative approach to determining contributing safety factors is taken, then there is a limited potential for an investigation to identify safety issues that can be used as a basis for facilitating safety action. There is also a limited potential for an investigation’s findings to provide a sufficiently detailed explanation of how an occurrence developed to facilitate learning opportunities, both for parties involved and not involved in the occurrence. With a mid-range standard, clearly defined terms, and appropriately qualified findings, the ATSB believes its current approach produces a reasonable, useful and appropriately qualified picture of how an occurrence developed.

6.4 Should the ATSB use the Briginshaw scale?

In his findings related to the Lockhart River accident, the Queensland State Coroner stated (p.7):

...there seems no good basis for requiring the same level of certainty in relation to all possible contributing causes in all cases and seeking it solely from within the evidence gathered during an investigation. Lawyers apply what is referred to as the Briginshaw principle whereby the level of persuasion or conviction required and the evidence necessary to establish it may vary, having regard to the seriousness of the issue under consideration; the gravity of its consequences and inherent likelihood of it occurring.

As discussed in Section 5.4.2, the ATSB does apply the ‘inherent likelihood’ aspect of the Briginshaw scale in its determinations of contributing safety factors. The

¹⁰⁰ For example, in its response to the public Discussion Paper version of the present report, CASA noted that ‘given that prevention is the sole aim of accident investigations, a link-by-link approach is then clearly to be preferred’ and ‘...while it is possible to have more stringent standards of proof between links, this may adversely affect the ability to identify remote factors which have preventative value for future accidents, even if they played no obvious or demonstrable role in a particular event’. However, CASA expressed some concern regarding how findings based on a link-by-link approach could be effectively communicated (see Section 7).

other aspects are also considered with regards to relatively extreme (or ‘grave’) matters.

The ATSB recognises the important rationale behind the Briginshaw scale and its relevance for various types of legal and disciplinary proceedings. However, there are several reasons to consider that it is not required or beneficial for the ATSB to apply the scale more broadly in safety investigations:

- The ultimate purpose of a safety investigation is to enhance safety. As discussed in Section 6.3, the use of a highly conservative approach to the development of some findings could have a negative impact on safety, by reducing the potential for an investigation to identify safety issues and provide learning opportunities.
- The application of the seriousness and gravity of consequence aspects of the scale only in relatively extreme situations appears to be consistent with how the scale is used in some legal contexts (see De Plevitz’s comments at the end of Section 5.1.3).
- The consequences that may arise from ATSB report findings are generally not as significant for the parties involved as may be the case from other types of investigations or inquiries. The provisions of the *Transport Safety Investigation Act 2003* require that an ATSB report cannot be used for civil or criminal proceedings (Section 27), and that the names of individuals are not included in reports (Section 25). The information obtained during ATSB investigations cannot be obtained from the ATSB, without ATSB permission, by other parties and therefore be used in legal proceedings. The result of these provisions is to help minimise the possibility of any adverse consequences that may arise from the conduct of an ATSB investigation or the publishing of the ATSB’s findings.
- A broader application of the Briginshaw scale would increase the complexity of the analysis process. The scale requires value judgements to be made regarding the ‘seriousness’ of a finding and the potential consequences that may arise from a finding. These judgements are often not easy to make, and there does not appear to be detailed guidance information available to assist in making the judgements.
- A broader use of a Briginshaw scale would also lead to a more stringent approach being taken to some types of findings versus other types of findings. The end result is that it would become more difficult to do meaningful trend analysis of the factors involved in a series of occurrences. Some factors would be over-represented and others would be under-represented. For example:
 - A more stringent approach could be applied to identifying individual actions or safety factors associated with an organisation compared with including environmental factors or technical problems.
 - Two occurrences may be very similar in nature. Both may involve an almost identical individual action. One of the occurrences may result in fatalities, whereas the other one, due to circumstances unrelated to the factor of interest, may not result in fatalities. Applying the Briginshaw scale would suggest that a more stringent approach would be required to state that the factor contributed to the fatal accident as opposed to the non-fatal accident. A similar situation would apply to organisational factors.
 - In determining whether an individual’s action was a contributing safety factor, the investigation would need to consider the nature of the action. More specifically, if the action involved a deliberate deviation from

procedures or the individual had the potential to be perceived as more 'culpable', then a more stringent approach may be needed to state that the action contributed to the occurrence than in the case where the action was an inadvertent error. A similar situation would apply to organisational factors.

The ATSB recognises that, in some instances, adverse consequences for some parties may arise from findings in an ATSB safety investigation report that are reported publicly. However, a safety investigation has an obligation to determine and communicate the safety factors related to an occurrence, and an investigation report must include factual material of sufficient weight to support the analysis and findings. It is not the object of a safety investigation to determine blame or liability, and at all times the ATSB endeavours to balance the use of material that could imply adverse comment with the need to properly explain what happened, and why, in a fair and unbiased manner.

6.5 Is the ATSB analysis model biased towards finding that organisational factors contributed to accidents?

In its final submissions to the Queensland State Coroner during the Lockhart River accident inquest, CASA stated the ATSB investigation analysis model (see Section 3.4) 'assumes that there will always be organizational influences which could have, if in place, prevented the problems at lower levels of the model'. It further stated that the model 'builds in a systematic bias, creating an unwitting focus on organizations such as CASA, and encourages speculative attempts to link it to the cause of the accident so that the requirement of the model will have been satisfied'.

As discussed in Section 4.2, the ATSB uses its model during investigations as one approach to identifying potential safety factors. The model provides a series of questions that can be used to help identify potential safety factors. Other sets of questions, not based on the model, are also used. The outcome of these activities is a list of potential safety factors that may have been involved in the development of the occurrence. Before any findings are made regarding whether these potential factors were involved in the development of the occurrence, or were otherwise important, they need to be tested or verified. This involves carefully examining the available evidence and conducting tests for existence, influence and importance (see Section 4.3), as well as considering the concept of practicability when dealing with safety issues (see Section 3.5).

The ATSB investigation analysis model encourages investigators to look for problems with risk controls and organisational influences as, if there are problems in these areas, this is where safety enhancements can be made. There is no requirement in the ATSB investigation analysis model, or analysis guidelines, that investigators must find problems at all levels in the model for any type of occurrence. In fact, most ATSB investigations do not find problems at the higher levels of the model for a variety of reasons, such as there being insufficient evidence available, or that it was not practicable for the relevant organisation(s) to have addressed the safety factors¹⁰¹. This point has been included in ATSB

¹⁰¹ In addition, where there is a straightforward technical explanation of an occurrence, organisational influences may have little relevance. Further, because of budget constraints, many ATSB investigations are not resourced to undertake detailed examinations of broader systemic factors.

guidance material on the investigation analysis model since at least 2002, and has also been emphasised in the ATSB's analysis guidelines since they were first developed in 2005.

In relation to regulatory agencies, some ATSB investigations do identify safety issues associated with regulatory requirements, although relatively rarely are problems identified with regulatory oversight processes. The regulator's role in preventing accidents in high reliability industries such as commercial transportation is undoubtedly difficult.¹⁰² However, if a safety investigation identifies limitations with regulatory oversight activities, and it appears that such limitations can practicably be addressed, then the investigation has a responsibility to make appropriate findings. If these limitations have a 'probable' connection to other contributing safety factors, then it is also reasonable that they also be listed as contributing safety factors. Including such factors helps explain why these other contributing safety factors occurred; it may also provide learning opportunities for other regulatory agencies.

6.6 Has the pendulum swung too far towards searching for organisational factors?

In his 1997 book, Reason stated that there had been 'ever-widening search for the origins of major accidents' in recent times.¹⁰³ He noted that investigators and analysts had backtracked from accidents to organisational conditions, regulatory and system issues, and in some cases to economic and societal issues. He suspected that the pendulum 'may have swung too far in our present attempts to track down possible error and accident contributions that are widely separated in both time and place from the events themselves'. This view was more recently endorsed by Young et al. (see also Section 6.7).¹⁰⁴ Both Reason and Young et al. argued that there should be more focus in some investigations on looking at the reasons for individual actions.

The focus of Reason's concern appeared to be on investigations that identified problems that were 'beyond the reach of system managers'. The ATSB's view is that many safety investigations could probably be criticised more for not looking hard enough for potential safety issues during investigations, rather than falsely identifying unreasonable or misguided safety issues.

Young et al.'s concerns appeared to go beyond those of Reason, and include a perception that misapplication of the Reason model can 'shift the "blame" ever backward from front-line operators to designers and managers' (p.13). In response to these types of concerns, Reason et al. (2006, p.13) noted:

The risk of shifting the blame towards the managers has been clearly acknowledged by J. Reason and newer versions of the model do not refer to 'unsafe decisions' or managerial failures but rather to organisational features. The fact that front line operators' slips sometimes fully accounts for the

¹⁰² J. Reason, 1997, Chapter 8.

¹⁰³ J. Reason, 1997, p.234.

¹⁰⁴ M. S. Young, S. T. Shorrock, J. P. E. Faulkner, & G. R. Braithwaite, 2005, 'The (R)Evolution of human factors in transport safety investigation', *ISASI Forum*, July-September 2005, pp.10-13.

accident scenario does not mean that it explains the accident from a safety management perspective, and that ‘fixing’ the operator therefore is the right safety management strategy. The fact that deterministic causal connection between latent conditions and accidents cannot easily be identified (particularly before the event), does not rule out that efficient prevention policy can be based on addressing latent conditions. Although such connections may be long and difficult to control, they may also offer a real opportunity for effective accident prevention. Hindsight is a problem if it is used as a basis for holding individuals responsibilities (which seems to remain a subliminal preoccupation for Shorrock & al). From a safety management perspective, the key point is to identify, as well as possible, the potential contributors to a multi-factorial process. Here hindsight can be of benefit, although it should be used with care.

In order to minimise the potential to look ‘too far’, the ATSB investigation analysis framework emphasises the concept of practicability and has specified a stop rule (Section 3.5). A finding about a safety issue generally should not be made if it is not reasonable or practicable for the relevant organisation(s) to address the issue. However, if during the analysis of an occurrence an investigation is still identifying potential safety issues that are practicable to address, then it is important for safety enhancement purposes to further analyse those factors and the reasons why they occurred.

6.7 Should safety investigations identify the ‘most important’ contributing factors?

There is a common tendency for parties associated with (or affected by) an occurrence to want a safety investigation to determine the ‘most important’ contributing or causal factors. Terms such as ‘real’, ‘direct’ or ‘critical’ are often used to refer to such factors.

One problem with this approach is that the judgement as to which is the most important factor(s) is a subjective value judgement, depending on the purpose that the relevant party perceives the investigation should (or should not) be addressing. As a result, the judgement can be influenced by factors other than an interest in explaining the occurrence and determining the best means of learning from the occurrence and enhancing safety. For example, Hopkins noted that there are ‘principles of selection’ which different parties use to select the factors they think are the most important.¹⁰⁵ If such parties have financial or reputational interests at stake, then they make seek to avoid adverse comment by focussing on factors unrelated to their organisation. Similarly, Dekker stated that there are problems associated with focussing on a subset of the factors involved in an occurrence and that the selection of factors can be ‘driven more by socio-political and organizational pressures than by the evidence found in the rubble’.¹⁰⁶

There would be significant difficulty in obtaining agreement as to what are the ‘most important’ factors. Some would argue for the factors that are closest in time or proximity to the occurrence, or the factors that had the highest degree of certain connection to the occurrence. However, this view would generally result in

¹⁰⁵ A. Hopkins, 2000, pp.134-138.

¹⁰⁶ S. Dekker, 2006, p.76.

individual actions of operational personnel being listed as the most important factors, detracting attention from the role of other factors. It could also be argued that the most important factors are those at the highest level of an accident development model, such as the investigation analysis model used by the ATSB. This approach would also result in a disproportionate focus on one set of factors. The development of an occurrence involves a series of different factors at different levels in a system, and all should be recognised as having a role to play in increasing the safety risk.

If the 'most important' contributing factors are highlighted in an investigation report, it can be expected that these factors will be perceived or used by many parties for the purposes of assigning responsibility (or blame) for the occurrence. As different parties will have different views as to what the most important contributing factor(s) should be, this could result in significant pressure on an independent safety investigation organisation, as evidenced by the NTSB's experience in using the 'probable cause' as the basis of its findings (see Section 5.3.6).

A desire to emphasise the relative importance of particular factors may also arise from an intention to better explain the nature of an occurrence. For example, Young et al. proposed (pp.11-12) that the ATSB investigation of the B747-400 runway overrun at Bangkok did not sufficiently acknowledge the contribution of one individual action (the experienced captain's cancellation of the go-around decision), and as a consequence 'the rest of the findings were distorted'. They stated that this action was the most critical event in the accident sequence, and the nature and reasons for this action were not adequately discussed in the report.¹⁰⁷ They also noted that the organisational influences that were identified in the investigation report as being contributing factors did not have any influence on this critical error.

Young et al.'s comments illustrate the limitations in prioritising one or more contributing safety factors as being more important than any other. The captain's go-around cancellation was one of five crew actions determined by the investigation to have played a contributing role. The go-around cancellation may have been the most unusual of the actions, but reasonable arguments could be raised for saying that some of the other crew actions were 'more important'. A point of more significance is that, if any of the actions had not occurred, then the accident (or other contributing safety factors directly related to the accident) would probably not have occurred. The other four crew actions were able to be traced back to a series of local conditions, risk controls and ultimately organisational influences that had a realistic potential to be involved in future accidents. As a consequence, a large part of the ATSB report discussed these conditions, and a substantial amount of safety enhancement resulted.

In summary, prioritising contributing safety factors in terms of their perceived importance or degree of contribution relies on subjective judgements and can limit the effective search for safety factors that can be addressed to enhance safety. In order to avoid these problems, the ATSB investigation analysis framework does not

¹⁰⁷ The ATSB's perspective is that the captain's action of cancelling the go-around was examined in detail by the investigation. However, based on the available evidence, it was not possible to determine any safety factors that contributed to this action. Further investigation into the reasons for the action was not possible, and discussing this action any further in the report would have served no safety or explanatory benefit.

rank contributing safety factors in terms of their degree of contribution to the occurrence. The concept of the ‘most important’ factors is best reserved for describing the safety issues which are associated with the highest safety risk levels for future operations. Such issues may or may not have been determined to have contributed to the occurrence being investigated.

As a final point, it is worth noting that considering practicability and assessing safety issues in terms of their risk level for future operations serve an important role in prioritising the potential recommendations that may arise from a safety investigation. Without these principles, safety investigations can sometimes produce a very large number of recommendations which are difficult (if not impossible) for relevant organisations to address.

6.8 Should safety investigations identify who is (most) responsible?

There is a common tendency for parties associated with (or affected by) an occurrence to want a safety investigation to determine who is responsible (or most responsible) for the development of the occurrence. Consequently, there is also a belief that an investigation of the occurrence and subsequent discussions should then focus on or emphasise the contributing safety factors related to the person or organisation most responsible.

Statements regarding responsibility are able to be very closely linked to the concepts of blame and liability. The role of safety investigations, as stated in relevant legislation and international protocols (see Section 1.3), is not to assign blame or liability. Assigning blame or liability will have significant implications on the ability of future safety investigations to effectively gather relevant information.

As with the notion of the ‘most important’ factors, determining responsibility will be a subjective value judgement. It would be difficult to achieve judgements that are commonly agreed, and different parties’ views will often be influenced by factors other than an interest in explaining the occurrence, enhancing safety and identifying learning opportunities.

The concept of responsibility is also related to the concept of ‘culpability’, which has been frequently discussed in recent years in discussions relating to safety management. For example, Reason has argued that a ‘no-blame’ culture is generally not feasible or desirable for organisations conducting internal investigations, and that a small proportion of individual actions may deserve sanctions or disciplinary action of some form.¹⁰⁸ Accordingly, the determination of which actions should result in sanctions should be based on considering the intentions of the individual and a range of situational factors.

It could be argued that if an individual action which could be associated with a high degree of culpability was found to contribute to an occurrence, then an investigation should focus on that factor and not need to deal with any risk controls or organisational influences that may be related to that factor. It is true that, if an individual action appears to be associated with a high degree of culpability, then generally it can be expected that there will be fewer contributing safety factors

¹⁰⁸ J. Reason, 1997, pp.205-213.

found for that action in terms of the relevant organisation's risk controls. However, further analysis could identify potential factors that may have influenced the action or could have helped prevent the action or minimise its impact, regardless of the level of culpability involved. To ignore these factors would mean ignoring a useful opportunity for safety enhancement.¹⁰⁹

In summary, there is an undoubted need for some legal proceedings and other types of investigations to determine responsibility or culpability for an occurrence. However, there are significant problems associated with a safety investigation performing this role.

6.9 Are Reason model analysis methods too prescriptive?

Hopkins has noted that there are limitations with using an analysis framework that is heavily based on the Reason model.¹¹⁰ He has argued that the prescriptive use of the model 'leads to inconsistencies and to constraints that makes it difficult to draw up coherent causal diagrams'. Young et al. (p. 13) have also cautioned against the prescriptive use of the model as an investigation method.

The ATSB and its predecessor BASI experienced significant problems in attempting to apply the Reason model in a rigid manner during some investigations. There were difficulties in determining how to categorise certain types of factors, and how to deal with factors that did not appear to fit into any of the boxes of the model. There were also problems in determining the order that factors should be identified during the investigation or presented in investigation reports. Some methods based on the Reason model advocate that the 'failed defences' should be identified first, then the unsafe acts. However, it is generally difficult to identify problems with defences or risk controls without first having clearly specified the nature of the individual actions and other events associated with the occurrence, and the local context in which they occurred.

Another significant problem with an analysis method heavily based on an accident development model is that the model can become the focus of the analysis process. As a result, insufficient attention may be given to ensuring that any hypotheses that arise from using the model are adequately tested prior to being listed as findings.

Based on its past experience, the ATSB analysis framework has recognised the limitations and benefits of using a model of accident development during an investigation. The Reason model has been modified to make it more applicable to a wider range of occurrences, and the role of the model has been clearly limited to one of helping identify potential factors and, in some situations, helping communicate the results of the analysis of complex occurrences.

109 For example, even though the Queensland State Coroner concluded that the primary responsibility for the Lockhart River accident 'must rest with the captain of the aircraft', he also concluded that it was still necessary to 'consider the context in which the actions occurred and the external influences that may have impacted on his behaviour' (p.54).

110 A. Hopkins, 2003, p.17.

6.10 The Reason model does not appropriately reflect the nature or complexity of modern accidents

Some writers on safety have characterised the Reason model as an ‘epidemiological’ model rather than ‘systemic’ model.¹¹¹ They have stated that although epidemiological models have many advantages over traditional ‘sequence of event’ type accident models, they also have many limitations.

For example, it is argued that the models such as the Reason model oversimplify the complex nature of how systems function. The model is said to focus on specific cause-effect relationships, and seeks to decompose a system and identify ‘failures’ of the different components. In particular, it focuses on identifying problems with defences and aims to make these defences stronger. In contrast, it is argued that systemic models realise that accidents (as well as normal performance) are phenomena that emerge from the interactions between the different components in a system.

The descriptions of systemic models and their differences with the Reason model appear to be somewhat obscure and hampered by few examples highlighting the differences in how each model is supposedly applied. The stated limitations of the Reason model would also appear to be based on a fairly strict interpretation of early versions of the model, and differences between later versions of the model and the descriptions of ‘systemic’ models would appear to be fairly subtle (see for example Reason et al., 2006).

As far as can be determined, there is nothing in these authors’ descriptions of a ‘systemic’ approach which is inconsistent with the ATSB investigation analysis framework. The ATSB definition of safety factor recognises that the events and conditions which contribute to accidents should not be regarded as ‘failures’. The identification of potential safety factors also takes a broad and flexible approach, which can be tailored to suit the complexity of the circumstances of an occurrence. The adapted version of the Reason model is only one tool which is used in the identification process.

¹¹¹ S. Dekker, 2006, pp.87-92; E. Hollnagel, 2004, Chapter 2. See also discussion in J. Reason et al., 2006.

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Analysis activities ultimately rely on the judgement of investigators, but analysis has been a neglected area in terms of standards, guidance and training of investigators in most safety investigation organisations. The ATSB analysis framework has been designed to guide and support the difficult judgements required of its investigators. By providing standardised terminology, a generic accident development model, a defined process, tools, policies, guidelines and training, the ATSB believes that its framework will improve the rigour, consistency and defensibility of its investigation analysis activities, and improve the ability of its investigators to detect safety issues in the transportation system.

There are many different views and interests associated with how a safety investigation should be conducted and what types of findings it should produce, and no approach to analysis will be universally agreed. In developing its framework, the ATSB considered a range of approaches, views and concerns, and attempted to achieve a balanced approach which most effectively achieves its aims.

The ATSB analysis framework's approach to defining and determining contributing safety factors has differences to the coronial approach and many traditional approaches used by safety investigation organisations. All the approaches are aiming to identify how and why an occurrence developed, and identify factors that should be addressed to enhance future safety. Consequently, the differences between the approaches may be a matter of nuance in many situations, and similar findings may result regardless of the approach being used.

Nevertheless, there is also the potential for different sets of findings to be produced. These differences are due to the ATSB's approach being tailored to the objectives of safety investigation. It is widely agreed that the approach to determining contribution (or causation) is dependent on the purpose of the investigation. Based on this view, the ATSB approach has been designed specifically with the purpose of enhancing safety rather than allocating blame or liability. More specifically, the ATSB's link-by-link approach together with a 'probable' standard of proof has the following advantages over many other analysis investigation approaches for the purpose of safety investigation:

- It better enables the search for potential safety issues, particularly those more remote from an occurrence. The enhanced searching will result in more safety issues being identified and communicated to relevant organisations to enhance safety.
- It has greater potential for providing a richer or more detailed description of the factors involved in the development of an occurrence, which provides better learning opportunities for the transport industry.
- It is more distinct from the approach used in legal proceedings for determining blame or liability. Therefore, there is less potential for the existence of barriers to learning or safety action due to an investigation's findings being associated with such legal proceedings, or interpreted with such proceedings in mind.

Given such advantages, the ATSB believes that its approach is well suited to its role as an independent safety investigation body. However, for the ATSB analysis framework to be most effective in enhancing safety, it is important that relevant

parties understand the framework, and how it may differ from other approaches to investigating occurrences.

As noted in Section 5.3.5, one particular area of potential misunderstanding is for findings developed using ATSB's link-by-link approach to be incorrectly interpreted as being equivalent to findings developed using a relative-to-occurrence approach (such as during legal proceedings). In its response to the public Discussion Paper version of the present report, CASA expressed concern about the ATSB view that this potential for misinterpretation could be minimised with clearer communication about the ATSB analysis framework (see end of Section 5.3.5). More specifically, CASA stated:

...if investigation results are targeted at the general public, CASA does not believe that the avoidance of blame can be achieved by somehow stressing definitional differences. If the ATSB wants to be free to develop causal explanations as complex as that described by [Figure 10], it should acknowledge that this level of complexity can not easily be communicated by means of a one page media release, and that there is virtually no hope of accurate communication when the details are further compressed into a radio or television sound bite that may only last for several seconds.

Even though it can be difficult to eliminate perceptions of blame by some parties in relation to investigation reports, the ATSB believes that such perceptions can be minimised with enhanced communication of its analysis framework. The present report, together with industry and conference presentations, is one means of enhancing this communication. An additional enhancement will be to include in ATSB investigation reports (and summaries of findings of complex reports) clear statements to explain that ATSB investigations use a different methodology and will often produce different findings compared with legal proceedings or other types investigation, and that the use of the term 'contributing safety factor' should not be considered as being equivalent to 'causes' in a legal sense, or reflect what the findings of a legal proceedings would produce.

The enhanced ATSB investigation analysis framework is just a starting point. The intention is that, as investigators and external parties become more familiar with the framework, they will actively contribute to its ongoing improvement. In other words, the framework is a platform for documenting the ATSB's organisational learning about analysis methods.

The ATSB has received significant interest and support from the safety investigation field in earlier presentations on its analysis framework and comparisons with other types of investigation (see also Appendix D). It is also hoped and expected that ongoing development and provision of information about the ATSB framework can help the safety investigation field as a whole consider some important issues and help develop the best means of conducting safety investigations to enhance safety. Accordingly, any feedback or comment that any individual or organisation has regarding the ATSB analysis framework, ways to enhance the framework, ways for ATSB to better communicate its findings, or any other matters discussed in this report would be gratefully received.

APPENDIX A – ATSB CRITERIA FOR THE TEST FOR EXISTENCE

Direct evidence

Were there direct observations or measurements of the existence (or non-existence) of the proposed factor? For example, a lack of fuel in an aircraft's fuel tanks and fuel lines could be used as direct evidence of fuel exhaustion. More generally, on-board recorders and witnesses can be useful sources of direct evidence.

Symptoms or effects

Were there indications of symptoms, effects or consequences of the proposed factor? For example, evidence of a person yawning or napping may be useful indications of fatigue. Evidence of smoke could be a useful indication of fire. However, be wary of circular arguments—for example, we cannot say that a lack of knowledge was our only evidence of inappropriate training, and also say that inappropriate training was our only evidence for a lack of knowledge.

Sources or reasons

Were there indications of events or conditions which could lead to or exacerbate the proposed factor? For example, a lack of sleep, long work hours in recent days or working early in the morning can be useful indications for the existence of fatigue. However, be wary of circular arguments—for example, we cannot say that inappropriate training was our only evidence for a lack of knowledge, and also say a lack of knowledge was our only evidence for inappropriate training.

Other correlated events or conditions

In addition to symptoms and sources, were there indications of any other events or conditions known to be associated with the existence of the proposed factor? For example, it may be known that, in certain situations, when there is a higher than normal noise level there is a high level of vibration. Evidence of a higher than normal noise level could therefore be used as a potential indicator of vibration, even though the two conditions are not causally related.

Predictability

Could the existence of the proposed factor be deduced, calculated or inferred from available information? For example, estimates of an aircraft's fuel level at the beginning of a flight, and estimates of its consumption during a flight, could be used as evidence to indicate fuel exhaustion.

Comparison with a known standard

Does the available evidence match other situations where the proposed factor was known to have existed? For example, the pattern of the effects on the pilot's speech in the Beech Super King Air 200 accident on 4 September 2000 (VH-SKC, ATSB investigation 200003771) closely matched the pattern from a previous incident where the pilot was known to have been experiencing hypoxia (VH-OYA, ATSB

investigation report 199902928). When comparing with a known standard, we need to be aware that there may be variations in the pattern of the data due to individual differences in susceptibility to a factor or other differences between the two situations.

Unfulfilled expectations

Was there anything you would expect to see if the proposed factor existed which you have not seen? For example, if certain types of toxic fumes existed, you may expect to have evidence of coughing or respiratory irritation. The absence of such symptoms suggests that toxic fumes did not exist.

Unexpected evidence

Was there anything you would not have expected to see if the factor existed but did see? For example, if it is proposed that a pilot had a lack of skill to handle an abnormal situation, you would not expect to find evidence that the pilot had handled more complex situations of a similar type in the recent past.

Known history of existence

Is there a known history of this type of factor? If there is, then consider the situations under which it previously occurred. Compare the current situation with the previous situations. Examine the differences to see if they could meaningfully affect the likelihood that the proposed factor existed. If there is no previous history (or the known likelihood is very low), further justification may be required from other evidence.

Alternative explanations of the evidence

Are there alternative explanations that fit the available information? The available evidence for the proposed factor may also be compatible with the existence of other (independent) proposed factors. In such cases, we will need to carefully compare the pattern of available evidence to identify which factor is the most likely. For example, incapacitation of all on board an aircraft may be due to a lack of oxygen or the presence of a toxic substance - a comparison of the merits of each proposed factor could identify which is most likely.

APPENDIX B – ATSB CRITERIA FOR THE TEST FOR INFLUENCE

Relative timing

Did the proposed factor exist at the right time to have an influence on the problem? The factor would have to exist before or at the same time as the problem, but the time interval between the two may also be important. For example, if determining whether a fault indication led to a driver initiating braking action, you would need to consider the driver's response time. For example, a response time of 500 msec or less would be very unlikely unless the driver was expecting the indication.

Reversibility

If the factor was removed (or reduced in magnitude), was there a decrease in the magnitude of the problem? In situations where the presence of the factor was intermittent and its influence was not permanent, it may be possible to examine whether there was an improvement in performance when the factor was removed. For example, the problem may be erratic performance of navigational equipment and the proposed factor may be interference from a personal electronic device (PED). If the problem disappeared after the PED was stopped, then this could indicate that the PED influenced the problem.

Relative location

Did the proposed factor exist at the right place to have an influence on the problem? For example, even if smoke or fumes existed in the aircraft cabin, this does not mean that they existed in the cockpit and could therefore have influenced the performance of the flight crew.

Magnitude of factor

Was the magnitude or extent of the factor sufficient to have had an influence on the problem? For example, if glare is identified as a potential factor influencing a person's visual performance, it is important to examine whether the level of glare was above the level known to have an influence on human performance.

Plausibility

Is there a plausible explanation for how the factor influenced the problem? In other words, does it make sense? For example, to say that high temperature led to the fracture of a component, more justification may be needed to say exactly how the temperature changed or weakened the nature of the material.

Known history of influence

Is there a known history of such factors leading to such problems? If the answer is:

- yes, then consider the situations under which the relationship previously occurred. Compare the current situation with the previous known situations.

Examine the differences to see if they could meaningfully affect the likelihood that the proposed factor had an influence.

- no (or the known likelihood is very low), further justification may be required from other information.

When examining previous investigation reports, research reports or other information, it is important to consider the consistency of the results and the extent to which the results from different sources are independent. It is also important to consider the credibility of each piece of information. Relevant expertise may be required to interpret the credibility of research reports.

Presence of enhancers

Were there any events or conditions present which are known to increase or enhance the influence of the factor? For example, lack of recent nutrition, high temperature or mundane tasks may exacerbate the influence of fatigue. In some situations, it may be appropriate to examine these enhancing events or conditions as separate safety factors.

Presence of inhibitors

Were there any events or conditions present which are known to moderate or inhibit the influence of the factor? For example, a high arousal level may offset the influence of fatigue, at least for short periods of time.

Characteristics of the problem

Were the characteristics of the problem consistent with what you would expect if the factor had an influence? Relevant characteristics may include magnitude, trend, type or duration. For example, error type is particularly important for explaining individual actions. Slips and lapses are commonly associated with distractions, but more evidence would be required to demonstrate that a distraction led to a violation.

Another important characteristic to consider is the specificity of the problem. If it is vague in nature (for example, poor morale or inadequate risk management), then it is more difficult to demonstrate that any particular event or condition led to the problem.

Required assumptions

What assumptions do you need to make before you can accept that the factor had an influence on the problem? For example, if it is proposed that an ambiguously worded procedure led to a maintenance worker's actions, it needs to be assumed that the person was aware of the procedure and trying to follow the procedure. Explanations which have the fewest assumptions and the simplest assumptions are usually the best.

Alternative explanations for the problem

Are there alternative explanations for the problem? As the number and/or strength of the alternatives increases, then more justification may be required to state that a particular factor had an influence. If the alternative explanations are likely to be

mutually exclusive or contradictory (for example, technical malfunction versus individual action), then it is useful to compare the ability of each alternative to address the available evidence. Differences in the ability to explain items of evidence, and differences in the required assumptions, should be highlighted and systematically evaluated.

If the alternative explanations may be complementary (for example, fatigue and high temperature) then the same process can be used. However, the possibility that both alternatives may have had an influence needs to be considered.

Directionality of influence

Could the problem have led to the factor, or were both the result of some other event or condition? This question helps differentiate association from influence. It is also one specific form of alternative explanation that should always be considered. Relative timing will be a key aspect to consider for the first part of the question, and relative plausibility will be a key aspect to consider for the second part of the question.

Counterfactual conditional

If the factor did not exist, would the problem have (probably) happened or occurred anyway? If so, why? This is a restatement of the definition of a contributing safety factor. The use of this question may reveal additional aspects to consider when evaluating influence.

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APPENDIX C – ATSB CRITERIA FOR THE TEST FOR IMPORTANCE

Prior existence

To what extent has the factor occurred or existed before? If there are indications that the safety factor has occurred or existed numerous times before, then there would be a stronger case for arguing that it should be analysed further to identify the underlying reasons. This may be relevant even if safety action had been taken to address the factor in the past, as the ongoing existence of the factor may indicate that the safety action was not successful.

Scope of future existence

What is the number and range of operations to which the factor is potentially applicable? If the factor could realistically only relate to a small range of operations, then it may be of less concern. Similarly, if it could realistically only relate to private operations rather than commercial operations, then it may be of less concern.

Severity of factor

What is the severity, magnitude or extent of the factor on this occasion? As the severity of the factor increases, then the severity or magnitude of the higher-level factors influencing it may increase. For example, if a driver was experiencing a very high level of fatigue at the time of an occurrence, then this would be more cause for concern than if the level of fatigue was only moderate. Similarly, the absence of any procedures may be of more concern than if there were procedures but they were limited in scope or poorly worded.

Controls in place

To what extent are there controls or processes in place to detect and recover from the factor? If there appear to be no controls in place to detect or recover from the factor before it has an impact on operations, then there is a good case to continue the analysis to identify the potential for controls to be in place. If there were controls in place, but they did not appear to be as effective as they were believed to be, then there is also a case to suggest further analysis is required. Of particular concern is when the system is vulnerable (for example, only one other thing needed to go wrong to result in an accident). In addition to the number of controls in place (or defences in depth), the relative effectiveness of the controls and their independence should be considered.

Relationship to change

Is the safety factor associated with the operation of a new system or process? The introduction of new equipment, procedures or other system components can be a vulnerable time, and there is less known history of safe operations available. Therefore, with new systems or processes, a stronger case can be made to regard a given safety factor as important.

Presence of underlying safety issues

Does the available evidence suggest the existence of underlying problems or safety issues in the system which may have contributed to the safety factor? This judgement will probably need to be made prior to any such underlying issues being examined in detail. However, there may still be suggestions, in the evidence already considered, that there are underlying safety issues associated with the safety factor that should be explored further. For example, an investigation may identify that a crew was fatigued, but could not conclude that it influenced their performance. Nevertheless, the available information may indicate that crews were required to work excessive hours. Based on this information, there is a good case for conducting further analysis to determine the reasons for the fatigue and ascertain whether there are safety issues that should be addressed.

External interest

Is there a substantial level of interest or controversy associated with the safety factor? On some occasions, there may appear to be no safety-based reasons for continuing to analyse a particular factor. However, there may be a very high level of external interest or controversy associated with the factor. Even though it may be clear that it had no influence on the occurrence, it may be still worthwhile to continue to analyse the factor so we are in a position to explain why it occurred. In addition, if the factor is a safety issue, continuing with the analysis will mean that the issue gets subject to a full risk analysis. The risk analysis may be more effective in addressing any external concerns regarding the depth of the investigation. The 'external interest' criterion should only be the sole reason for continuing analysis in exceptional circumstances.

APPENDIX D – SUBMISSIONS

Submissions

An early draft of this report was provided to coroners in each of the states and territories in Australia and two internationally-recognised safety specialists. Feedback was provided by the two safety specialists, and minor modifications were made as a result of this feedback.

An amended version of the report was then issued publicly as an Aviation Research Discussion Paper on 11 March 2008, with submissions required by 16 April 2008. Copies were directly provided to coroners in each of the states and territories in Australia, the Civil Aviation Safety Authority (CASA), and a selection of legal and safety specialists. Responses were received from CASA, two legal specialists and several safety specialists.

Overall, the majority of the submissions received on the public Discussion Paper and the earlier version had minimal concerns or suggestions for change. All of the submissions were reviewed and, where considered appropriate, the text of the report was amended accordingly.