Accident
Investigation Board
Norway








THE AIBN METHOD

Framework and Analysis Process for Systematic Safety Investigations

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1. INTRODUCTION

This document describes the Accident Investigation Board Norway's (AIBN) framework and analysis process for systematic investigations.

The individual departments in the AIBN work on the basis of different international and national commitments, guidelines and practices.[1] These differences shall be taken into account in the AIBN's management system in the form of procedures and work instructions that are adapted to each individual department.

There are also important, general similarities that apply to all the AIBN's investigations. Especially at a principal, overriding level, as regards to process, methodology and a systematic approach in investigations. This concerns how we collect, organise, analyse and interpret information and data from accidents in a systematic, verifiable manner, as well as how we understand accidents, why they occur and how safety can be improved to prevent new accidents occurring.

This framework applies independently of which department publishes a report, who is in charge of the investigation or who participates in the investigation team. The framework describes best practice for systematic investigations and forms the basis for a shared understanding and frame of reference for the AIBN's employees. It can help the departments to achieve their goal of being among the best in Europe in their respective transport sectors.

The safety-related and analytical framework shall form the basis for ensuring that the AIBN, also as a whole, can live up to society's expectations of it as a reliable, competent investigation authority.

This document contains several references to professional literature on safety and various methods and theories related to accident investigation. The framework of the Australian Transport Safety Bureau (ATSB, 2007 and ATSB, 2015) has been one of the main references for the AIBN in the preparation of this document.

2. OVERRIDING ANALYSIS PROCESS

The AIBN's framework and analysis process for systematic safety investigations is based on the regulations that apply to the AIBN's investigations and the AIBN's investigation management system. The factual information that is collected about an accident/incident[2] must form the basis for and drive the analysis process in all investigations. The quality and reliability of the information that is collected is decisive for the validity of the analysis and the conclusions.

An investigation of an accident can be divided into three overlapping main phases, as shown in Figure 1. The figure does not illustrate a purely linear investigation process, but three main phases that it is possible to move between, based on new experiences or findings (iterative process).

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[1] Regulations or international guidelines will take precedence over this framework in the event of disagreement.
[2] Hereinafter only 'accident'.

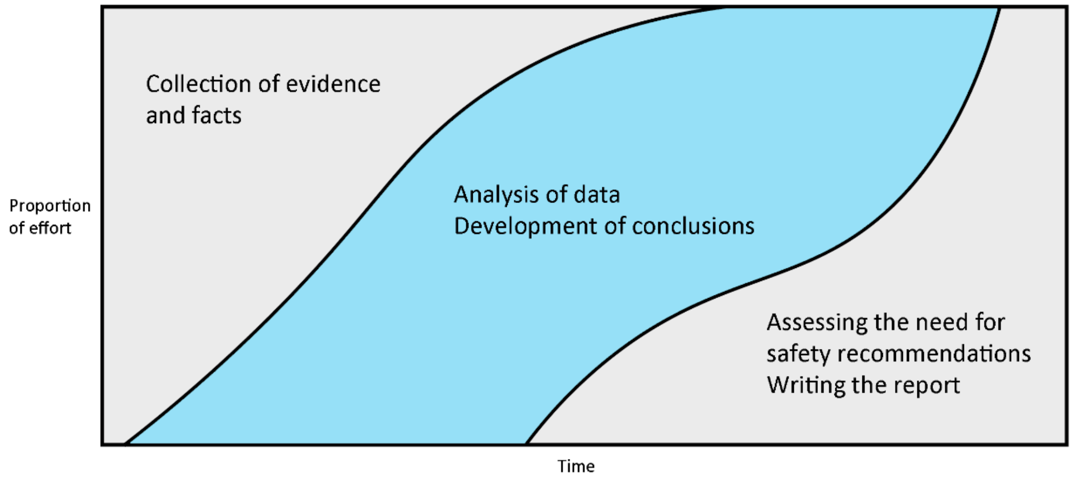

Figure 1: The three phases of an accident investigation (adapted from DOE, 1999). The AIBN's analysis process for systematic investigations details the middle phase (in blue).

Figure 2 on the next page illustrates the AIBN's analysis process for systematic investigations. This analysis process details the phase illustrated in blue in the centre of Figure 1. The AIBN's analysis process is divided into seven stages. It is important to note that the analysis process is also iterative. This means that experience or findings can be made at one stage of the analysis process that make it necessary to go back and reconsider and, if relevant, make changes to an earlier stage of the analysis.

In principle, the analysis process shall apply to all safety investigations that the AIBN carries out. The process shall be adapted to the *depth* of the investigation, i.e. the extent to which you have to investigate an aspect to reach your required level of understanding (indicated by the vertical dotted arrow in Figure 2), and the *scope*, i.e. the variety of relevant aspects you have to investigate (indicated by the horizontal dotted arrow in Figure 2). The process is used from the investigation is started until the investigation is completed and possible areas for improvement have been identified.

The investigation should be carried out systematically, and emphasis is the intention of each stage in the analysis process. The development of diagrams as illustrated in figure 2 is only an aid to the process.

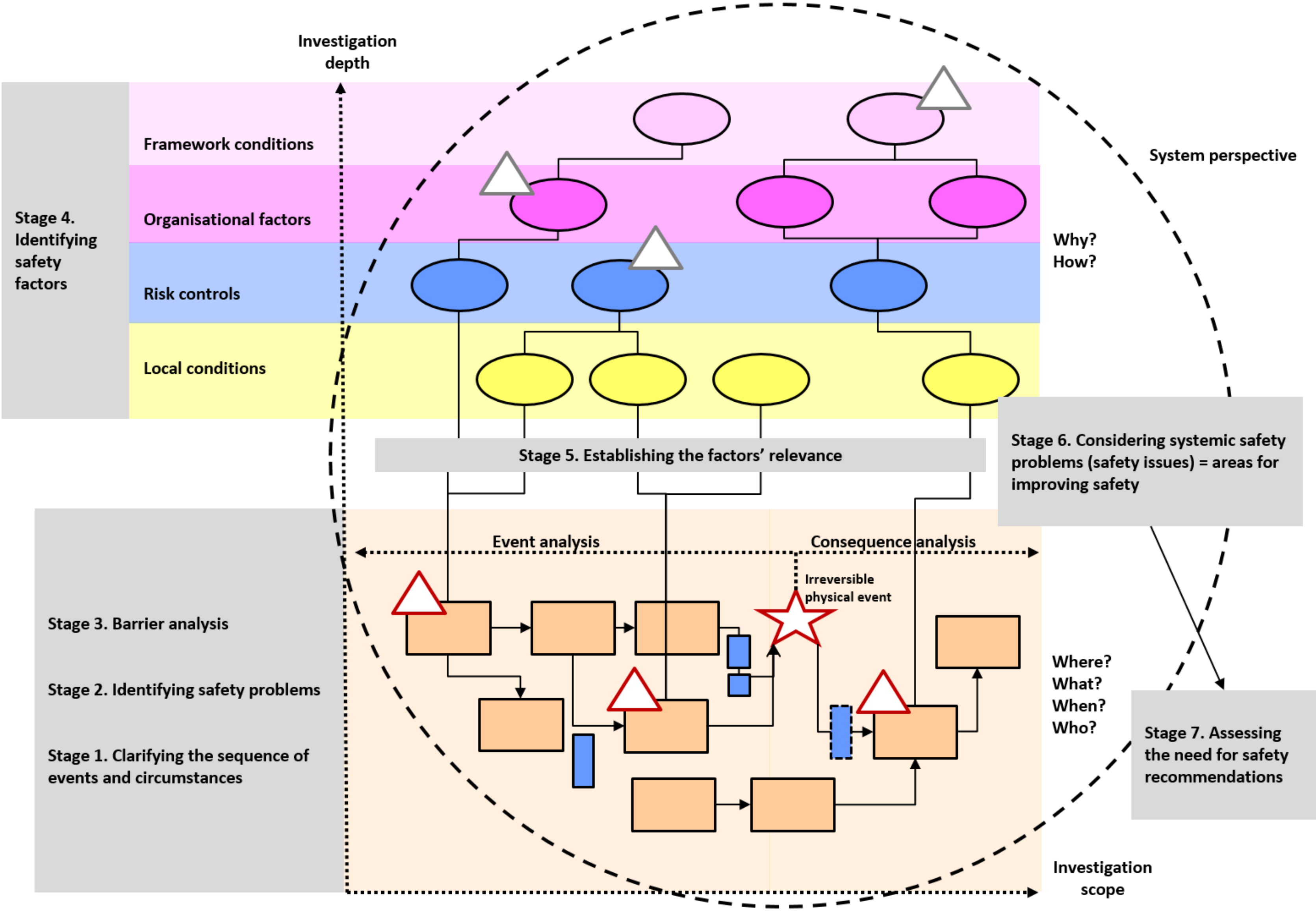

Figure 2: The AIBN's analysis process for systematic investigations (the AIBN method).

3. DESCRIPTION OF THE STAGES IN THE PROCESS

3.1 Stage 1. Clarifying the sequence of events and circumstances

An accident can take place quickly or over time. The time of the accident can be defined as the time an irreversible, physical event takes place. A sequence of events consists of events both before and after the time of an accident. The time of the accident is marked with a star in Figure 3.

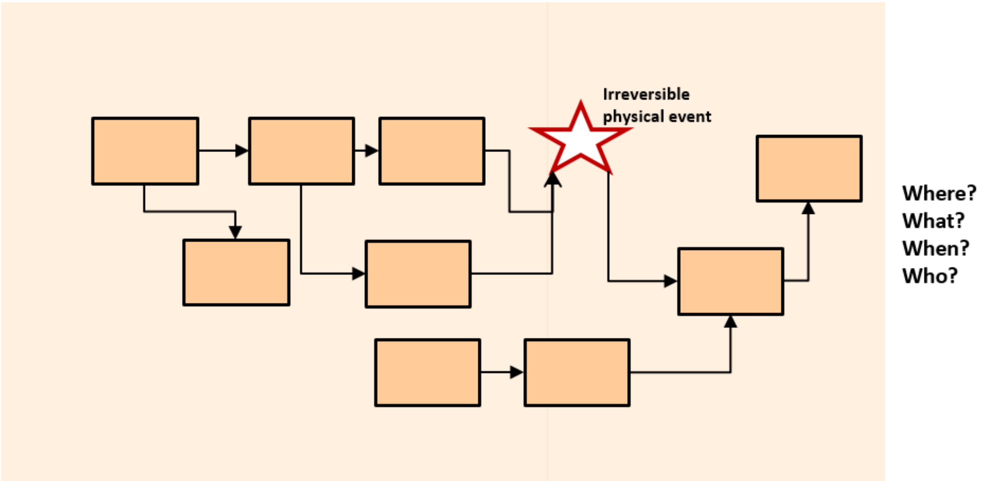

Figure 3: Stage 1. Clarifying the sequence of events and circumstances.

The purpose of clarifying sequence of events and circumstances is to be able to understand and describe what happened, and describe what and who were involved in such a way that this affected the events that led to the accident and the pertaining damage and loss.

A sequential approach, i.e. describing the development of events along a timeline, is recommended. It can often be sufficient to establish a simple timeline along which the most important actions and events (rapid change of conditions) are identified and put together in chronological order.

The description of the sequence of events starts from the time when the transport process in question was functioning normally. The description ends when the accidental events has come to a halt, an eventual rescue operation has concluded and any injured persons have been evacuated. It may be necessary to carry out an uncertainty assessment of the sequence of events and to describe possible alternative scenarios.

In an early phase it will also be necessary to map and describe the circumstances or setting in which the accident took place. This includes information about operating personnel, the condition of material assets and equipment, infrastructure and weather conditions etc. It should also be clarified how an ideal transport process or work operation was meant to take place.

One of several methods for systemising a timeline of events is the STEP[3] method (Hendrick and Benner, 1987). The method has proved to be especially useful in cases

[3] Sequential Timed Events Plotting

where several actors are involved and where many events and actions take place over time. STEP will be useful in order to structure actions, events and the relationship between them, and to uncover deficiencies, uncertainty and the need for further information.

Stage 1. The sequence of events and the circumstances surrounding the accident must be sufficiently clarified to understand and describe what happened, where and when the events occurred and who was involved. This stage should also have clarified how an ideal transport process or work operation was meant to proceed. Any uncertainty and alternative interpretations of the sequence of events should have been assessed at this stage.

3.2 Stage 2. Identifying safety problems in the sequence of events

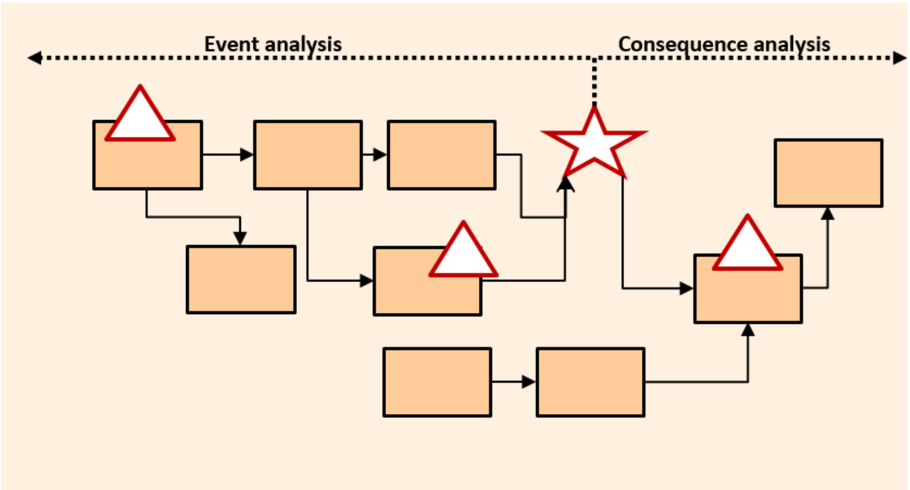

Figure 4: Stage 2. Identifying safety problems in the sequence of events.

The purpose of this part of the analysis is to identify possible safety problems that existed or arose during the sequence of events in connection with the accident in question, that is consider 'what went wrong' in the sequence of events.

Safety problems in the sequence of events can be identified through various event and consequence analyses. The event analysis is the AIBN's assessment of the events and actions that led to an irreversible, physical event. The consequence analysis is an assessment of the events and actions that had an impact on the damage/injury and survival aspects of the accident.

Safety problems in the sequence of events can be found in a condition or event or in the connection between events along a timeline. In order to identify safety problems, we can look for the following:

- Where the sequence of events could have been changed or interrupted (barrier approach; see also Stage 3).

- Where the sequence of events involved loss of control/poor control (risk control approach).

- Where the sequence of events deviated from safe or expected functions (nonconformity approach).

Safety problems can be illustrated as red triangles in a sequence of events and actions along a timeline. This is illustrated in Figure 4.

At this stage, it is important not to jump directly to a description of what could or should have been present, or specific solutions. A safety problem should be formulated so that it allows for the possibility that the problem arose or existed as a result of different contributory factors and so that the problem can be solved in different ways.

The safety problems that have been identified in the sequence of events can be considered as possible symptoms of underlying, systemic safety problems (see Stage 6) .Topics for further investigation can be formulated and described on the basis of identified safety problems in the sequence of events. For each safety problem, several questions can be formulated that will be relevant to answer through more detailed study.

Stage 2. The safety problems shall have been identified in the sequence of events, so that we have a clear idea and description of 'what went wrong'. The identification of safety problems shall then form the basis for a decision and delimitation of the topics to be investigated in more detail. This includes what data are to be collected, which investigation methods will be used and what resources are required in the further investigation.

If relevant, this stage can also form the basis for preparing a preliminary report or status report on the investigation or a notification of safety-critical issue.

3.3 Stage 3. Barrier analysis

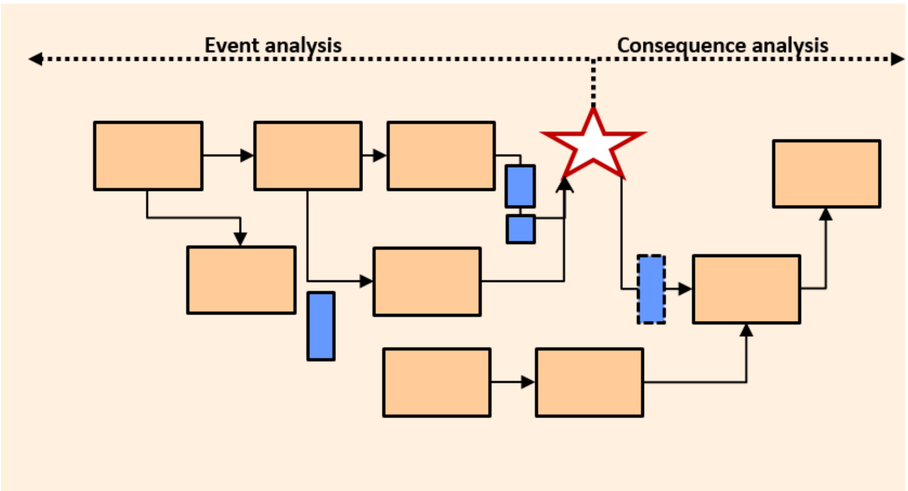

Figure 5: Stage 3. Barrier analysis.

In larger systems or if the sequences of events extend over time, it can be useful to carry out a specific analysis of barriers. In other investigations, the barriers are so clearly defined through the mapping of the sequence of events and the identification of safety problems that a barrier analysis is not necessary.

The following definition[4] of barrier is used here:

[4] Similar definitions are used in Petroleum Safety Authority Norway (2013), The Norwegian Railway Authority (2013) and Rosness et al. (2004).

Technical, operational or organisational measures that separately or together could have prevented or stopped the sequence of events in question, or limited the consequences of the accident.

This means that barriers shall a) prevent nonconformities from occurring, b) prevent accidents: detect and/or notify of nonconformities, c) prevent damage/injury: limit consequences (Alteren et al., 2005, p. 12).

It is useful to distinguish barriers, which have a limited meaning and unique purpose directed at a specific sequence of events or hazards, from more general safety measures, which are not directed at a predefined scenario (such as reporting systems, mentor schemes for new employees and safety culture). Barriers will in principle not be necessary or in function during normal operation.

The barriers can be illustrated as blue rectangles in a sequence of events on a timeline in the following way (see Figure 5):

Barriers that were in place and that worked.

Weaknesses and failings in existing barriers.

Barriers that had not been established at the time of the accident (both barriers that should have been and that could have been established).

Sometimes, it can also be useful to categorise the barriers by function or area; see for example Alteren et al. (2005).

The additional use of a barrier analysis form, based on for example the handbook from DOE (2012), can ensure a well-structured and verifiable barrier analysis.

Stage 3. The barrier analysis shall ensure that the investigated systems' established defences are identified, and that the barriers that potentially could have been in place to prevent or limit the damages in the sequence of events in question have been identified. The barrier analysis can also form the basis for considering and prioritising areas for improvement at Stage 6.

3.4 Stage 4. Identifying safety factors

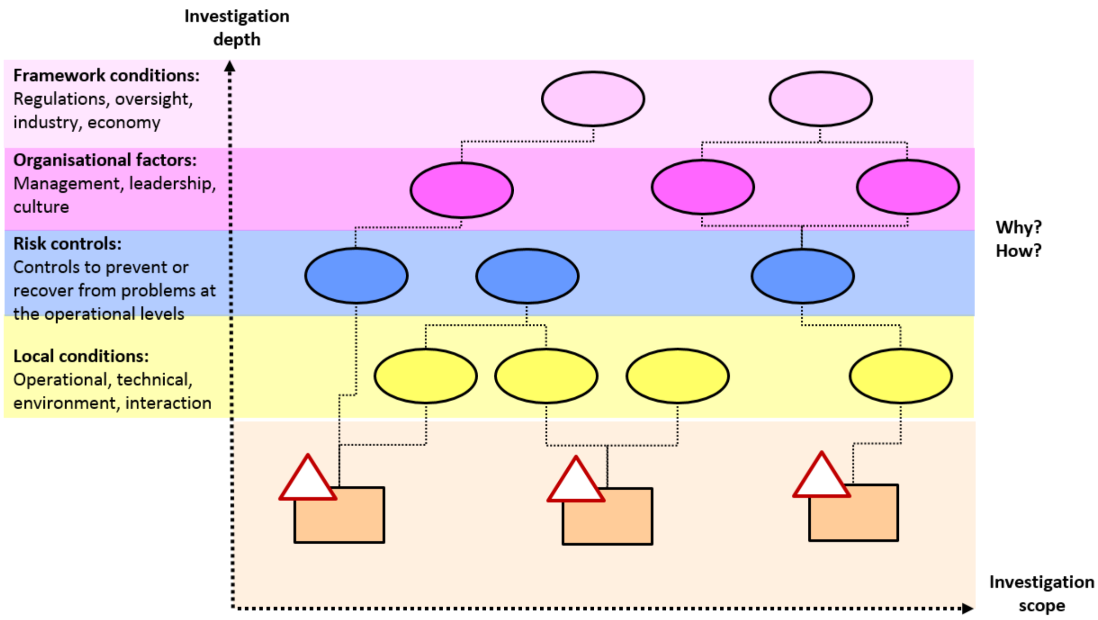

Figure 6: Stage 4. Identifying safety factors.

3.4.1 Purpose and scope

The purpose of mapping and studying safety factors is to be able to:

- Explain and understand how and why the identified safety problems were present during the sequence of events.
- Explain and understand how and why safety systems and barriers that could have prevented the accident were lacking or did not work as intended.

This part of the analysis process is based on an epidemiological approach, meaning that the purpose is to identify connections between the sequence of events and contributing safety factors at different levels. These are factors that have not necessarily had a clear cause-and-effect relationship, but that are considered to increase the risk of an accident (for example fatigue/exhaustion, pressure to get the job done, unclear work descriptions etc.). This stage corresponds to the 'levels-based approach' in the ATSB method (ATSB, 2015).

The results of the sequential part of the investigation (Stages 1–3) direct our attention to the triggering mechanisms, nonconformities, faults/errors and control problems, or to obvious consequential errors that have been identified. The challenge at Stage 4 lies, among other things, in asking how the system (organisations and authorities) could 'accept', or had not identified, that this accident risk existed without having sufficient built-in tolerance for potential faults/errors and nonconformities. At the same time, it also entails endeavouring to understand why a decision or action appeared reasonable at a given time (Dekker, 2006, p. 26).

It is important to be aware that at each subsequent level of the analysis of safety factors (expanding the depth of the investigation) requires more information to be collected and more investigation resources. The increased complexity will also lead to more challenges in the analysis and reporting. It is therefore important to consider whether the benefits in terms of safety justify the increased use of resources that an expansion of the investigation entails. This entails an obligation to make a reasoned decision, whether it is decided to expand the investigation or not.

A method that can be useful in this part of the investigation is a Why-because analysis (WBA), which starts at the operational and technical level, and moves on to the more underlying level. The idea behind the method is to repeatedly ask ‘why’ and then to look for explanations (‘because’).

Another relevant approach is a gap analysis. In a gap analysis, the actions and circumstances of the accident are mapped and assessed in relation to normal practice (informal), expected practice (formal: procedures and regulations) and safe practice (ideal). This means that gaps or deficiencies can be identified in relation to three different reference points.

During the investigation of safety factors, it can be expedient to draw up an influence diagram or causal diagram showing all the factors that have influenced the accident. A diagram can help to systematise and gain an overview of findings and factors, and to clarify the relationship between them. There are several types of charts that can be used, for example: the ATSB method (ATSB, 2015), AcciMap (Rasmussen, 1997), MTO diagram (see Sklet, 2002).

3.4.2 Dimensions in the investigation of safety factors

3.4.2.1 *Investigation of human factors*

The purpose is to identify and explain factors that could have affected the people involved in the sequence of events, and how and why they have acted/not acted. This includes situational awareness, fatigue, know-how/experience, health condition, ergonomics, workplace factors etc.

The investigation should also say something about how others in the same situation could have acted, i.e. compare actions in the sequence of events with normal, expected and ideal practice.

3.4.2.2 *Investigation of technical factors*

If a technical fault or deficiency has been identified in the sequence of events, it will be necessary to investigate it in more detail to understand how or why it could arise. Further investigations can consist of testing equipment, simulations, analysis of data logs, reconstructions and metallurgical examinations.

A technical fault may be the result of maintenance, and thus it is necessary to obtain data about maintenance that has been carried out, maintenance management and quality assurance. In order to pursue the failure mechanisms that caused a specific technical fault to occur, it may be useful to carry out a fault tree analysis (FTA).[5]

[5] A FTA was carried out in connection with the Report on aircraft accident on 10 October 2006 at Stord Airport, Sørstokken (ENSO) involving a BAE 146-200, OY-CRG, operated by Atlantic Airways.

3.4.2.3 *Investigation of factors in the surroundings/local conditions*

It will often be necessary to investigate other circumstances surrounding the accident in more detail, for example: weather conditions, sea and wind conditions, light conditions and visibility, blind zones, the traffic situation, possible distractions and noise.

3.4.2.4 *Investigation of damage/injury and survival aspects*

An accident investigation usually have to identify and explain which factors have affected the injuries to people and the damage to material assets and the environment. It may be necessary to review post-mortem reports and patient records, as well as a technical review of material in order to identify damage mechanisms and energy paths. It may be expedient to request the assistance of medical and/or technical experts. It will be necessary to review the use of personal protective equipment and what requirements apply to it.

3.4.2.5 *Investigation of risk control*

Investigation of risk control entails to identify and explain what measures the organisation had initiated to control risk. This includes a broader perspective than the barrier analysis (Stage 3). The purpose is to identify the measures the organisation had implemented to prevent, reduce, identify or recover from operational and technical problems (e.g. work plans, maintenance, training, procedures, monitoring and alarm systems). See also ATSB, 2015, p. 41.

3.4.2.6 *Investigation of organisational factors*

The purpose of investigating organisational factors is to gain an understanding of in what way and why the organisation's risk control might have been insufficient. This involves describing processes, conditions and characteristics of an organisation which influence the ability and effectiveness of its risk control (for example risk analyses, audits and reporting systems). Three different terms are used about organisational factors and safety: safety management systems (SMS), safety management and safety culture (see the list of definitions).

See the Transportation Safety Board of Canada's (2014) 'Guide to Investigation for organizational and management factors'.

3.4.2.7 *Investigation of safety-related framework conditions*

An investigation of safety-related framework conditions can help us to explain and understand how and why failures or deficiencies occurred at lower levels. Safety-related framework conditions include regulations, inspections and oversight activities aimed at facilitating sufficient safety level, and priorities and decisions made at the overall level. Other external circumstances and framework conditions, such as policies, finances and market, may also have affected the organisations and other parties involved. Normally the AIBN's investigations will be delimited at this level. See Rasmussen (1997) and the socio-technical system involved in risk management.

In the case of legal issues that require an examination of the regulations and any weaknesses or holes in such regulations, it is important to be aware of the existence of a legal method. The legal method is used to identify what the legislator intended to be applicable law in the area. This is not always easy to read from the wording of an act or regulations. The legal method is about how to identify the content of the legal rules through relevance, interpretation and weighting. Legal experts should be involved in this process. Where there is doubt, it is also important to engage in dialogue with the developer of the regulations, including the directorate and the supervisory authority, to clarify how they interpret the regulations in the area in question.

3.4.2.8 *Systemic approach*

The circle in Figure 2 represents the system perspective, i.e. that safety is dependent on adaptation and interaction between several different items at several different levels in a socio-technical system. Therefore, it usually will be challenging to model/explain how and why various factors and interactions between then may have contributed to an accident. This is an important perspective for all accidents the AIBN investigates.

For accidents in complex systems, the interactions in the sequence of events and between the different safety factors can be particularly complex and difficult to describe. This complexity may appear in Stage 1 in that the sequence of events is difficult to clarify and in Stage 2-3-4 in that safety problems, barriers and safety factors are difficult to identify. Based on Hollnagel and Speziali (2008), a systemic approach will be an appropriate perspective to investigate accidents in complex systems[6]. The purpose of a systemic approach is to understand how adverse events may be a result of unexpected combinations of variations in normal behaviour (Hollnagel and Speziali, 2008), as well as to find ways to monitor and control the variability (Hollnagel, 2002). This approach is a complement to, and not in place of, the stages in the AIBN's analysis process.

Stage 4. Safety factors have been identified, so that we have gained knowledge about and insight into how factors at different levels may have contributed to and affected the sequence of events and safety problems. The width and depth of the investigation are evaluated against learning effect, safety value and resource/time spent. All sub-investigations are concluded and connected so that we have a sufficient basis for establishing an overall picture of the accident and preparing an eventual influence diagram/AcciMap.

3.5 Stage 5: Establishing the factors' relevance

The purpose of this stage is to explain and understand the extent to which and in what way the identified safety factors have affected the sequence of events. This means that some form of assessment of cause and effect (causality assessment) is necessary. This must be done throughout the analysis process, i.e. every time new factors are identified.

For example, if the influence of alcohol is a finding – to what extent has it affected the person in question and his/her actions in the sequence of events? Or, if part of a procedure has not been followed – to what extent has it affected the sequence of events?

ATSB's (2015) description of the analysis process has an illustrative flow chart, as shown in Figure 7.

[6] Such complexity may be seen in some cases in commercial aviation. New framework conditions such as globalization of the economy, rapid technological development, changes in legislation and new organizational structures can contribute to increased complexity also within the other transportation modes.

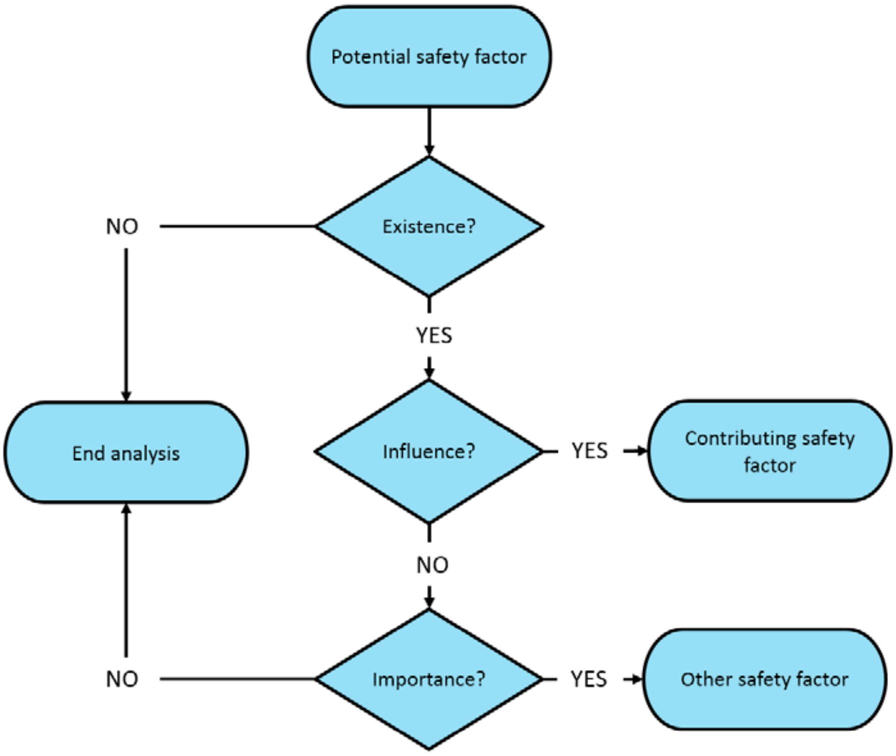

Figure 7: The process for testing potential safety factors with regard to existence, influence and importance (ATSB, 2015, p. 145).

An investigation can uncover safety factors that turn out not to have contributed to the accident in question. If they are regarded as important enough with regards to safety, the investigation can consider and discuss them, but it must be clearly stated in the report that they did not influence.

'The substitution test' (Reason, 1997, p. 208), in which it is considered what effect it would have had on the sequence of events if one person had been replaced by another, is useful at this stage of the analysis. The test can also be used to look at the effect of replacing a condition, object or action.

It is often necessary to obtain supplementary information such as statistics, published guidelines, literature and research reports, and to look for information, knowledge and support for safety factors in other investigations (nationally and internationally). It may also be necessary to obtain external assistance in the relevant discipline area.

Stage 5. Assessing the factors' relevance is intended to ensure transparency in how the investigation and identified safety factors, are rooted in the specific sequence of events, and contribute to make the investigation verifiable. All safety factors shall be assessed in such detail that we demonstrate that we have understood and explained the extent to which and in what way the identified factor has existed and affected the sequence of events. Factors that proves not to have contributed to the accident are examined in terms of importance with regards to safety.

3.6 Stage 6. Considering systemic safety problems

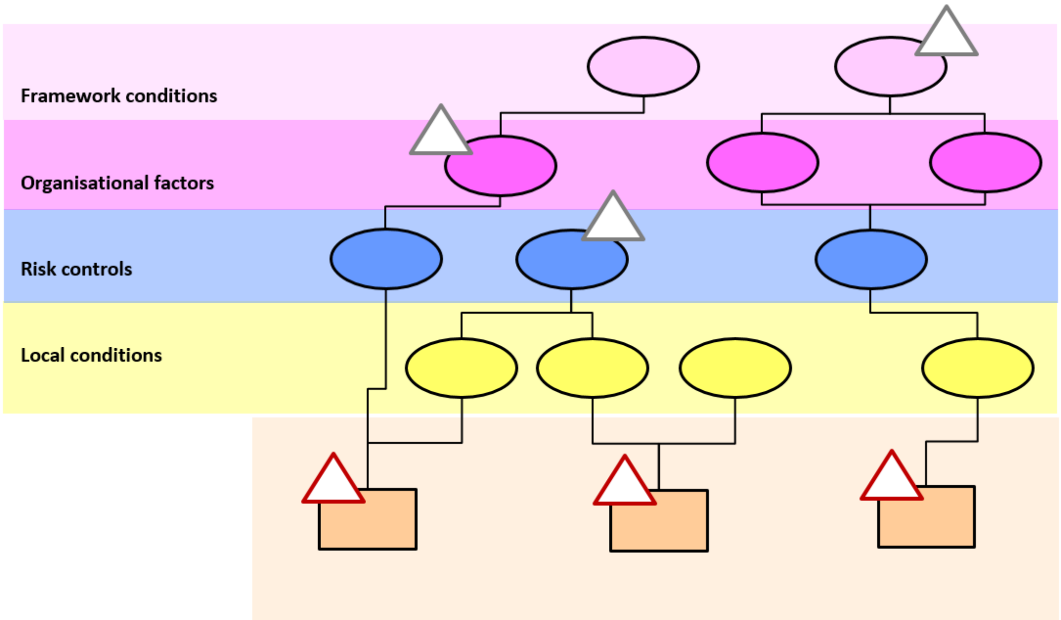

Figure 8: Stage 6. Considering systemic safety problems = areas for improving safety.

The preceding stages of the investigation should have established an overall picture of the accident, i.e. identified how it was possible for the sequence of events and the resulting loss or injury/damage to occur despite the defence system and barriers that were in place, and which factors at different levels contributed to this.

In this stage, areas for improving safety should be considered so that new accidents can be prevented. It is desirable that the AIBN's investigations will contribute to safety at a level that is fundamental and that can provide lasting improvements to the transportation system and work process, i.e. double loop learning[7] according to Argyris (Hovden et al, 2004, p. 175).

This stage is therefore about assessing systemic safety problems. A systemic safety problem is a safety factor that (see 'safety issues' p. 26 in ATSB, 2015):

- can reasonably be regarded as having the potential to adversely affect the safety of future operations

  and

- is a characteristic of an organization or a system, rather than a characteristic of a specific individual, or characteristic of an operational environment at a particular point in time.

Systemic safety problems can be described as the investigation's most significant findings for safety. Systemic safety problems will usually refer to problems with an organisation's risk controls, or a variety of organisational influences and framework conditions that impact on the effectiveness of its risk controls. 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 (ATSB, 2015, p. 26). A systematically repeating

[7] Single loop learning is of a corrective character, i.e. the transport system is only brought back to original condition.

safety factor at the operational or technical level will also in some cases be viewed as a systemic safety problem.

The safety concept, i.e. the conditions that needed to be in place in order for a transport process or work operation to function, should be evaluated when considering systemic safety problems. Here, questions can be asked about the extent to which the conditions for normal operation are too demanding or entails a risk in itself.

Stage 6. Assessment of how safety can be improved by considering systemic safety problems. A systemic safety problem is a safety factor (independent of whether it contributed to the specific accident), which an organisation or authority has some level of control and responsibility and, if not addressed, will increase the risk of future accidents.

3.7 Stage 7. Assessing the need for safety recommendations

The identified systemic safety problems points to areas for improving safety. The following aspects decide whether it is necessary for the AIBN to issue a safety recommendation to deal with a systemic safety problem:

a) The importance and impact of the systemic safety problem (risk assessment).

b) The eventual safety action already taken or planned. Therefore it is important to collect information about implemented and planned measures from the involved organisations during the investigation[8].

c) Necessary to consider practicality, i.e. what is believed possible or realistic to implement for the 'owner' of the systemic safety problem.

d) The effect on safety of an eventual improvement.

A system perspective (illustrated by the circle in Figure 2) means that removing one 'contributory factor' alone will not necessarily prevent an accident from recurring. Different measures that affect several areas or main components (people, technology, the environment and control/management) and the interaction between them may be necessary in order to prevent new accidents.

Finally, it is necessary to decide how the analysis and conclusions will be communicated in the final report from the investigation.

Stage 7. A reasoned decision has been made about the areas in which it is necessary to make safety recommendations. Assessing the need for safety recommendations is based on the seriousness of the identified systemic safety problems, safety action already taken, improvement effect and practicality.

[8] Sometimes it may be expedient that the AIBN issues a safety recommendation to help realize eventual plans (depending on the individual planning process).

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DEFINITIONS

Barrier	Technical, operational or organisational measure that separately or together could have prevented or stopped the sequence of events in question, or limited the consequences of the accident.
Contributing safety factor	Factor that have not necessarily had a clear causal effect, but that is deemed to have been capable of affecting or influencing the accident.
Epidemiological approach	This approach views events that lead to accidents like the spreading of a disease, i.e. as the result of a combination of factors, some manifest and some latent, some internal and some external, that coexist in time and space. The identification of barriers, energy carriers and latent conditions, as well as the strengthening of barriers and defences, are important elements in this approach.
Danger	An action or circumstance that can lead to an undesirable incident.
Gap analysis	Mapping and assessment of the actions and circumstances of the accident in relation to normal practice (informal), expected practice (formal) and safe practice (ideal).
Iterative process	Experience or findings can be made at one stage of the process that make it necessary to go back and reconsider and, if relevant, make changes to an earlier stage.
Risk	A combination of the probability and the consequences of an undesirable incident.
Safety concept	The conditions that must be in place in order for a transport process or work operation to function, and the technical and human limitations that exist in relation to the process or operation.
Safety culture	Concern how an organisation sees and assesses risk, as well as the norms that govern how people in the organisation act, cooperate and communicate.
Safety factor	An event or condition that increases the risk of an accident. If the factor arose in the future it would increase the likelihood and/or severity of the accident. NB! A safety factor does not need to have contributed

	to the accident, but it must have the potential for contributing to accidents in the future.
Safety management	Management functions intended to ensure safety. Includes factors such as training, ensuring that resources are allocated to safety work, procurements, motivation/incentives etc.
Safety management systems (SMS)	Describes methods and tools used in safety work. The basis for all safety management is the systematic assessment of safety performance in the past (investigations, reporting), present (audits, inspections) and future (risk analyses).
Safety problem in the sequence of events	'What went wrong' in the sequence of events, i.e. where the sequence of events could have been changed or interrupted, loss of/poor control and deviations from safe or expected functions.
Sequential approach	The development of actions and events in an accident sequence described along a timeline.
Systemic approach	The purpose is to understand how adverse events may be a result of unexpected combinations of variations in normal behaviour, as well as to find ways to monitor and control the variability.
Systemic safety problem	A safety factor for which an organisation has some level of control and responsibility and, if not addressed, will increase the risk of future accidents.
System perspective	Safety is dependent on adaptation and interaction between several different items at several different levels in a socio-technical system.
Uncertainty	Degree of certainty associated with a claim or conclusion. May vary from 0 per cent (can be ruled out) to 100 per cent (completely certain).