International Transport Forum

The Investigation of Safety Management Systems and Safety Culture

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The Investigation of Safety Management Systems and Safety Culture

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Abstract

Since every Safety Management System (SMS) is intended to provide a framework by which an organisation manages risk, it is inevitable that accident investigators will take a close interest. The good investigator will always want to understand how the SMS was intended to control risk and how this control failed when put to the test.

This paper seeks to provide a practitioner's view on the investigation of SMS. In doing so it hopes to answer the following questions: What are the key elements of a typical safety management system that an investigator is likely to encounter? How should the role of these elements in the causation of an accident be investigated? How have SMSs been featured in real investigations? How should the investigator address safety culture? Can investigations influence the shape of safety management systems?

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Introduction

Since every Safety Management System (SMS) is intended to provide a framework by which an organisation manages its risk, it is inevitable that accident investigators will take a close interest. The good investigator will always want to understand how the SMS was intended to control the risk and how this control failed when put to the test.

This paper seeks to provide a practitioner's view on the investigation of SMS. In doing so it hopes to answer the following questions:

- What are the key elements of a typical safety management system that an investigator is likely to encounter?
- How should the role of these elements in the causation of an accident be investigated?
- How have safety management systems been featured in real investigations?
- How should the investigator address safety culture?
- Can investigations influence the shape of safety management systems?

What is a Safety Management System?

Much has already been written about safety management systems, and their application to complex industries such as transport. Fox (2009) argued that a safety management system is generally understood to be a "formalized framework for integrating safety into the daily operations of an organization including the necessary organizational structures, accountabilities, policies and procedures".

Any review of the academic literature on the subject, and regulatory guidance from around the world, will reveal a wide array of elements that might be included in a safety management system. In aviation the requirements of an SMS framework are encapsulated in Chapter 5 of the International Civil Aviation Organization (ICAO) Safety Management Manual (Doc 9859, AN/474). Current EU requirements for railway safety management systems are defined in Annex III of the Rail Safety Directive 2004/49/EC. Marine requirements are defined in the Annex to IMO Assembly Resolution A.741(18) – 1993 (The International Safety Management (ISM) Code).

The defined components of Safety Management Systems for all three modes are shown in Annex 1 to this paper.

The key components of a Safety Management System can be summarised as follows:

- setting of policy and allocation of management responsibilities
- goal setting and the monitoring of safety performance

- hazard identification and risk assessment
- comprehensive risk awareness (i.e. understanding of the hazards and risk)
- organisation, resource and workload
- competence and fitness management
- management of external factors (including interfaces with contractors and other organisations)
- information needed for safety management
- audit and review of safety management arrangements (assurance processes)
- management of technical change
- management of organisational change
- deriving safety learning from the reporting, investigation and analysis of accidents and incidents
- regulatory regime
- promotion of good safety culture.

Although no such list will ever encapsulate all views on the key elements of an SMS, the above provides a useful starting place for a consideration of the ways in which safety investigation can be used as a tool to improve the effectiveness of safety management systems.

The investigation of Safety Management Systems

Despite their often dreadful consequences, accidents provide an opportunity for organisations to examine the performance of their own SMS. Good investigation should seek to identify all of the factors that combined to cause an accident. It will therefore cause a searchlight to be shone into the darkest corners of an organisation’s management systems and challenge long held assumptions about the way they perform in practice.

The reasons why accident investigation is such a powerful tool for understanding the real-world performance of management systems include:

- Focus; careful analysis of a particular set of circumstances that led to an accident can provide a valuable insight into the ways that managers and teams perform their duties, and how their actions or inactions contributed to an accident.
- Objectivity; most audit processes are focused on the extent to which prescribed management systems are complied with. Such processes, which are vital to the quality assurance of organisation’s output, are designed to measure deviation from a norm which is considered to an indicator of good performance. On the other hand, good accident investigation will always look beyond questions of compliance and seek to understand the ways in which the management systems themselves contributed to the accident.

- Connectivity; investigation of accidents should always seek to identify the ways in which different, often quite disparate, parts of a systems combined to create the conditions for an accident.
- Empowerment; provided investigators are afforded the necessary status and guarantees of independence, they are often able to ask the questions that no-one felt entitled to ask in the past. Good investigation will pursue causal links from the factory floor to the board room whenever necessary to reveal important safety learning.
- Climate; following an accident there is often a willingness within an organisation to cooperate with investigators and a greater openness to the challenge presented by their recommendations.

Why investigate safety management systems?

Research suggests that a properly implemented SMS can help to reduce the risk of accidents and that there is a positive link between a developed safety management system and good safety performance (Gallagher, 1992). In 2011 the National Transportation Safety Board in the United States stated that many of its investigations had revealed that "SMS or system safety programmes could have prevented loss of life and injuries" ("most wanted list", 2011).

Reason argues that an SMS becomes part of an organisations' culture and the way people go about their work. The successful implementation of an SMS requires both a willingness to formalise the organisation's approach to safety, and a robust commitment to safety throughout the organisation.

Deficiencies in either the documentation or implementation of an SMS may well indicate issues with the wider organisational culture. Issues with the SMS that are revealed in an investigation may therefore act as a signpost to look further into the organisational factors that may have contributed towards an accident.

Failure to consider wider organisational factors and systemic causes can result in lost opportunities to implement corrective actions that will address the underlying problems. The UK's Health and Safety Executive state that: "the objective is to establish not only how the adverse event happened but more importantly what allowed it to happen."

Sources of evidence

Without evidence it is not possible to draw reliable conclusions about the influence of safety management systems on an accident. It is therefore important that this is considered when planning an investigation. Safety management is far too important a topic to be left to the end of an investigation and often needs to be addressed quickly before the evidence trail, and the willingness of witnesses to cooperate, fades.

The techniques that can be used to gather evidence relevant to safety management systems are summarised in Table 1.

Table 1. **Sources of evidence relating to safety management systems**

Type of evidence	Value to the investigator	Weakness
Formal documents describing the safety management system	Will allow an assessment of whether the formal process is compliant with requirements and/or addresses the risks. May reveal gaps in the documented system and point to issues that have not been taken into account.	Provides no substantive evidence of the extent to which the SMS has been implemented.
Procedures, standards and other technical documents	May reveal deficiencies in control measures and point to issues that have not been taken into account. Provide evidence of how the SMS is intended to be translated into action. Provide a point of reference when examining actual working practices.	Provides no substantive evidence of the extent of implementation unless the process output is also examined.
Audit reports and management assurance reports (from before the accident)	Provides a measure of how the organisation's safety arrangements were being applied before the accident. Gives evidence of the extent to which the organisation was aware of areas of risk and/or potential weaknesses in its management systems.	May not be comprehensive or may not give a reliable indication of performance. The audit or management assurance regime itself may be "part of the problem".
Formal evaluations of safety management performance against a published norm	<u>If carried our prior to the accident</u> Provides a measure of how the organisation's safety arrangements were being applied, and how successful they were thought to be, before the accident.	<u>If carried out after the accident</u> The accident may influence the way that SMS activities are performed. For this reason any formal evaluation carried out after an accident may not provide a reliable measure of its effectiveness.
Management papers, correspondence, minutes of meetings etc.	Provide a measure of how safety management arrangements were being managed, and the importance attached to safety. Gives evidence of the extent to which the organisation was aware of, and how it was addressing, areas of risk and/or potential weaknesses in its management systems.	Management papers form only a partial record of conversations taking place within the organisation. Information provided may not be complete.
Maintenance and operations records	May provide substantive evidence of the way that documented procedures and standards were applied in practice.	Are often found to be incomplete or inaccurate. A record of a completed activity does not provide proof that it was indeed undertaken, and to what quality.

Table 1. **Sources of evidence relating to safety management systems (cont.)**

Type of evidence	Value to the investigator	Weakness
Interviews, senior level	Provide a useful source of information about the implementation of the SMS and may enable the identification of organisational factors that should be taken into account – where possible corroboration should always be sought. Senior management interviews enable the investigator to assess the extent to which the risk was understood and whether it was being actively managed.	The answers provided will almost certainly be affected by the accident that has been investigated Senior managers have a duty to answer questions but will also represent the interests of their company when being questioned.
Interviews at working level	One of the best sources of information concerning the causes of an accident – interviews can point to issues with procedures, competence management, the interaction with supervisors and management. If an interview is skilfully conducted it may also be a useful way "to consider the historical dimension understanding the wider context within which an accident occurs" (so helping an evaluation of attitudes, behaviours and culture).	All witness evidence must be carefully evaluated if it is to be of value – corroboration should always be sought where possible Information provided during interviews is likely to be heavily influenced by the pre-accident relationship between an individual and his/her manager – this must always be factored in.
Group interviews at working level	If a group interview is skilfully conducted it may also be a useful may to evaluate attitudes, behaviours and culture.	Social pressure may affect what is said and the nature of the interaction with the interviewer Confidentiality may also be an issue
Safety culture surveys and questionnaires	A carefully conducted survey based on questionnaires, or interviews, can provide an indication of pre-accident practices, attitudes and behaviours	Safety culture questionnaires measure employee attitudes and beliefs and these are likely to be affected by the occurrence of an accident or simply by the fact that an investigation is taking place. This type of metric can be problematic in terms of reliability and validity and in terms of response rates. Antonsen (2009) distributed safety culture questionnaires to offshore workers before and after an operational accident and found that the pre-accident questionnaire failed to detect safety issues that were subsequently identified. Others (Hopkins, 2006) have argued that focusing on how people feel about safety is not effective as it shifts the blame towards the workforce because it is based on the assumption that people's attitudes may have changed an outcome.

Analytical techniques

Accident investigation should consider the SMS as part of the wider organisational factors that may be relevant to an accident. Good accident investigators will collect varied information from numerous sources which will then be analysed to determine what had happened, why it had happened and which defences had failed. Thoroughly examining the relevant SMS documentation, and the way it was implemented at every level of the organisation, will provide important evidence of the organisational factors that led to an accident.

It should be noted that an awareness of investigator biases and an acknowledgement of “the implicit and explicit assumptions that every method makes” (Hollnagel) is important when considering factors in an organisational context. Hollnagel has suggested that accident investigation is not a fully objective exercise and that an investigators’ background, training and preconceptions will inevitably influence findings. Dekker suggests that the selection of causes or contributory factors in an investigation is always a construction and that it may be more useful to think in terms of explanations rather than causes.

The investigation process adopted by the UK’s Rail Accident Investigation Branch (RAIB) involves the use of a formal causal analysis technique. This can be very effective in identifying organisational factors in an accident provided some of the less visible or obvious factors further down the causal chain are examined. The RAIB’s overall approach was developed with reference to the accident causation model shown at Figure 1. This model is designed to illustrate the factors that can contribute to the latent condition of a system that is able to fail catastrophically. Examples given include:

- corporate or organisation influences (such as senior management decisions or strategies, or organisational culture)
- technical and managerial pre-conditions (pre-existing conditions that introduce an inherent weakness in the safety arrangements)
- defective safety barriers (e.g. weaknesses in systems designed to deal with undesirable but foreseeable hazards)
- a local latent condition (e.g. past actions that had no immediate impact but may lead to a later failure).

The model at Figure 1 has been translated into a practical approach to causal analysis based on the following two stages:

- Identification of the sequence of events leading to the accident.
- The sequence of events analysis is based on a Sequentially Timed and Events Plotting (STEP) analysis approach; this is similar to a traditional timeline, but it is expanded vertically to differentiate the main actors (i.e. by providing parallel timelines for each main actor). Events are then plotted in order of their occurrence against the appropriate actor and causal linkages between the events are identified. Those events in the sequence that warrant further investigation as to cause are described as “fault events” and are then the subject of more detailed analysis.
- Failure analysis – identification of the factors (singular or in combination) that resulted in each of the fault events (failure conditions, unsafe actions or inactions, or unsafe conditions) in the sequence of events.
- The object of detailed failure analysis is to identify the factors (singular or in combination) that resulted in each of the fault events identified in the sequence of events. Figure 2 shows how active and latent events may have contributed to a fault event.

The failure analysis adopted by RAIB makes use of a fault tree style approach in which the immediate precursors of each fault event are investigated in a logical, structured manner. A simple example is given at Figure 3.

Figure 1. **Accident causation model**

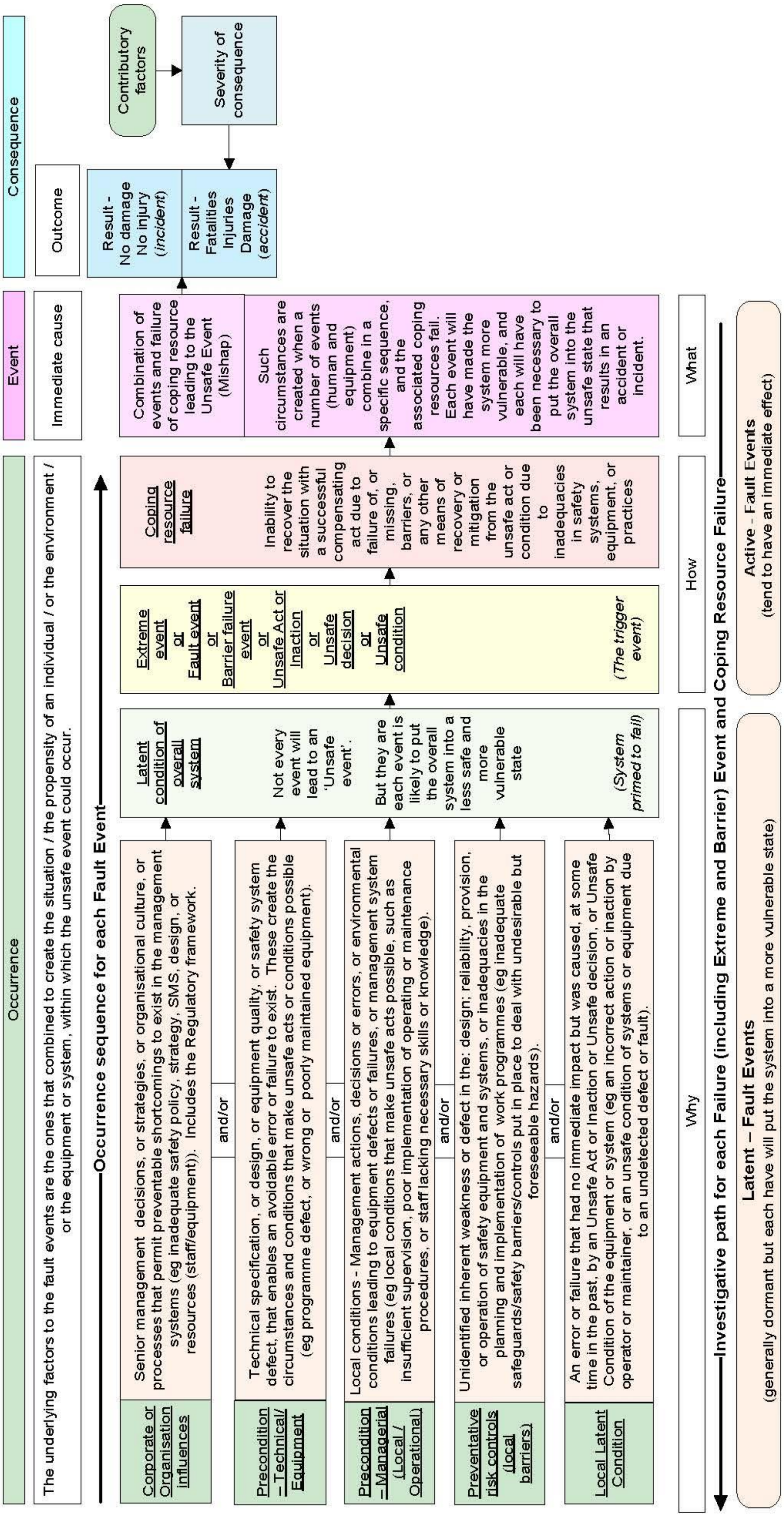


Figure 2. **Detailed analysis of individual fault events**

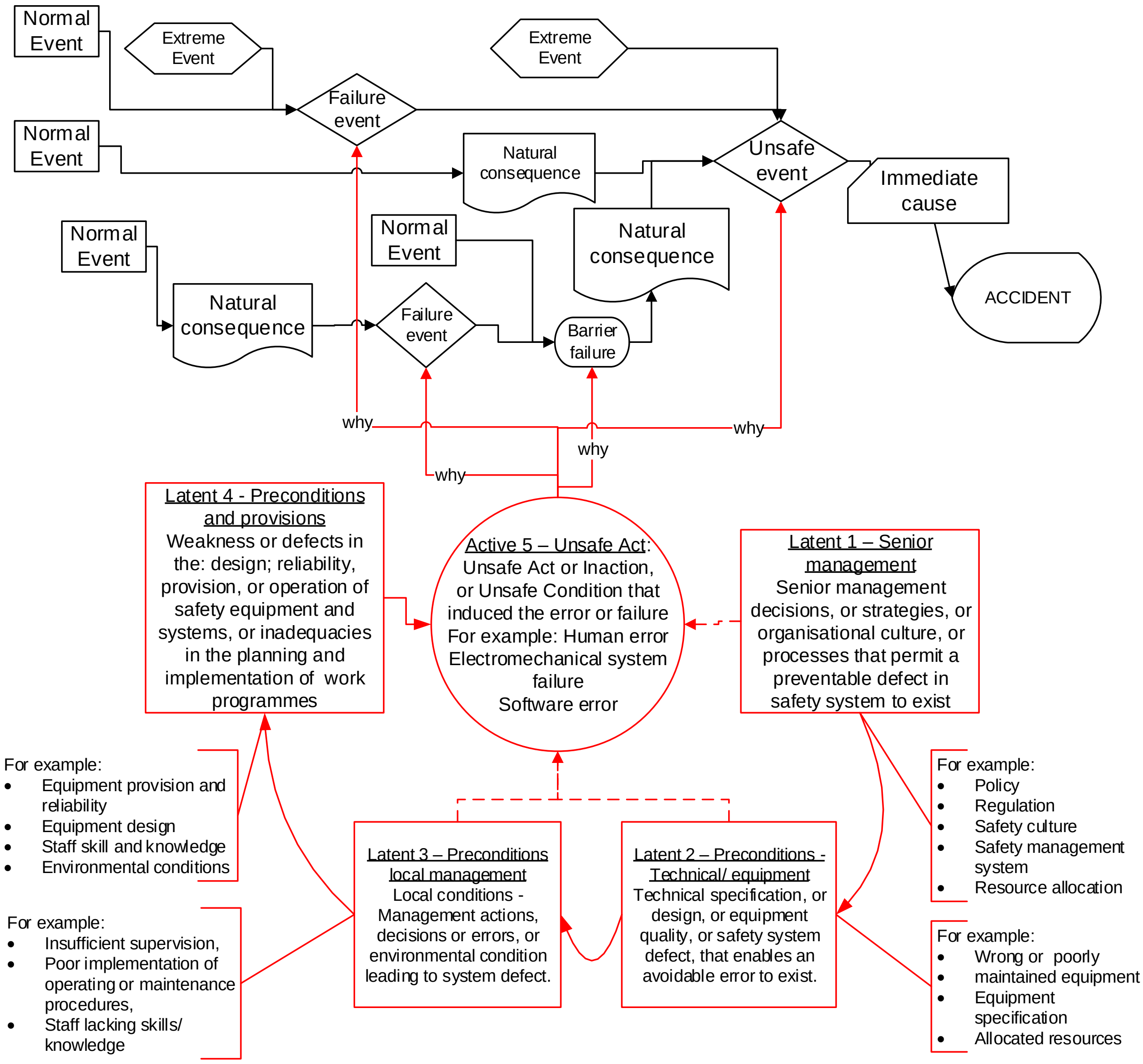
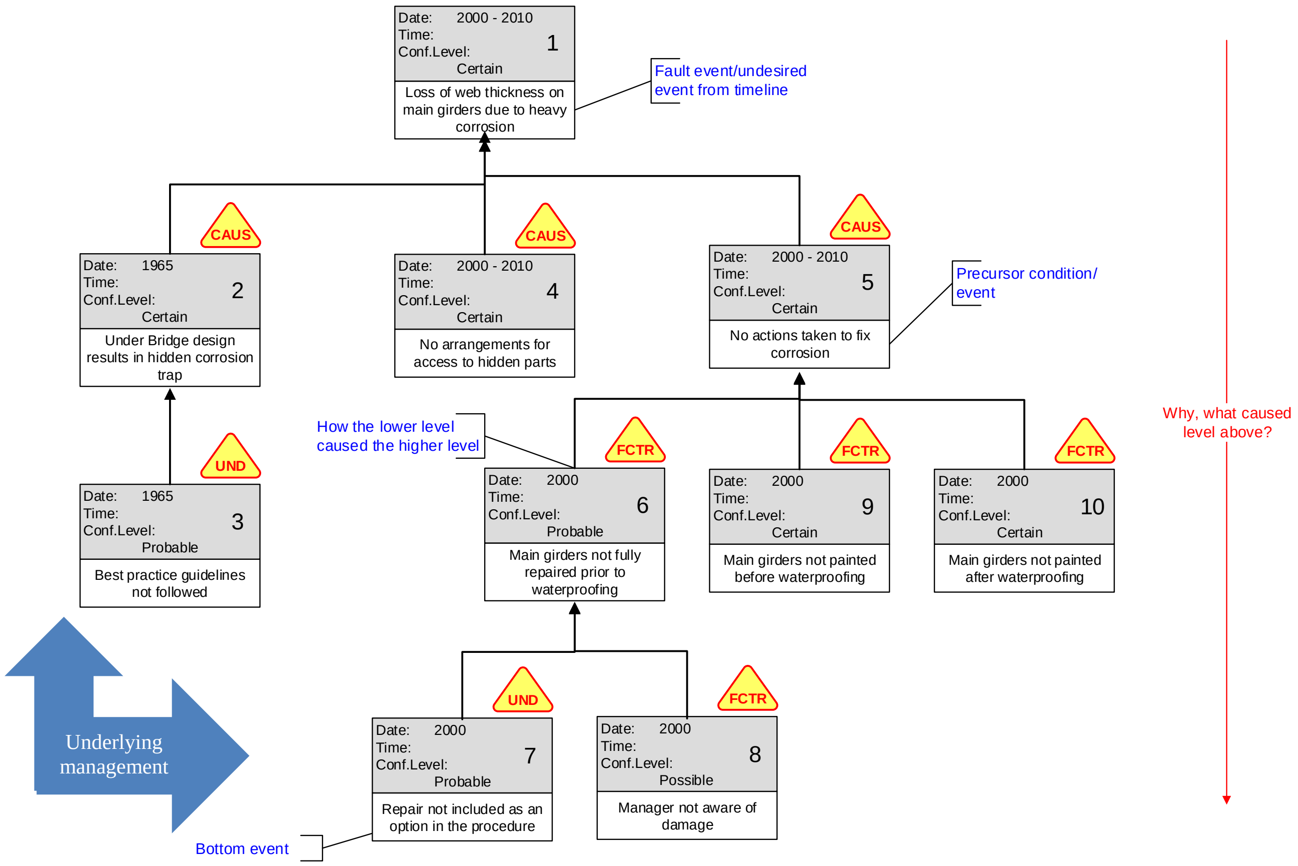


Figure 3. **Example of failure analysis (illustrating identification of underlying management factors by means of "classic" failure analysis)**



Safety management systems as a factor in UK rail accident investigations

The RAIB has carried out a survey of the 124 full investigations it conducted between January 2012 and December 2016. The survey data was analysed in order to count the number of times each SMS topic has been highlighted as a factor in an RAIB investigation.

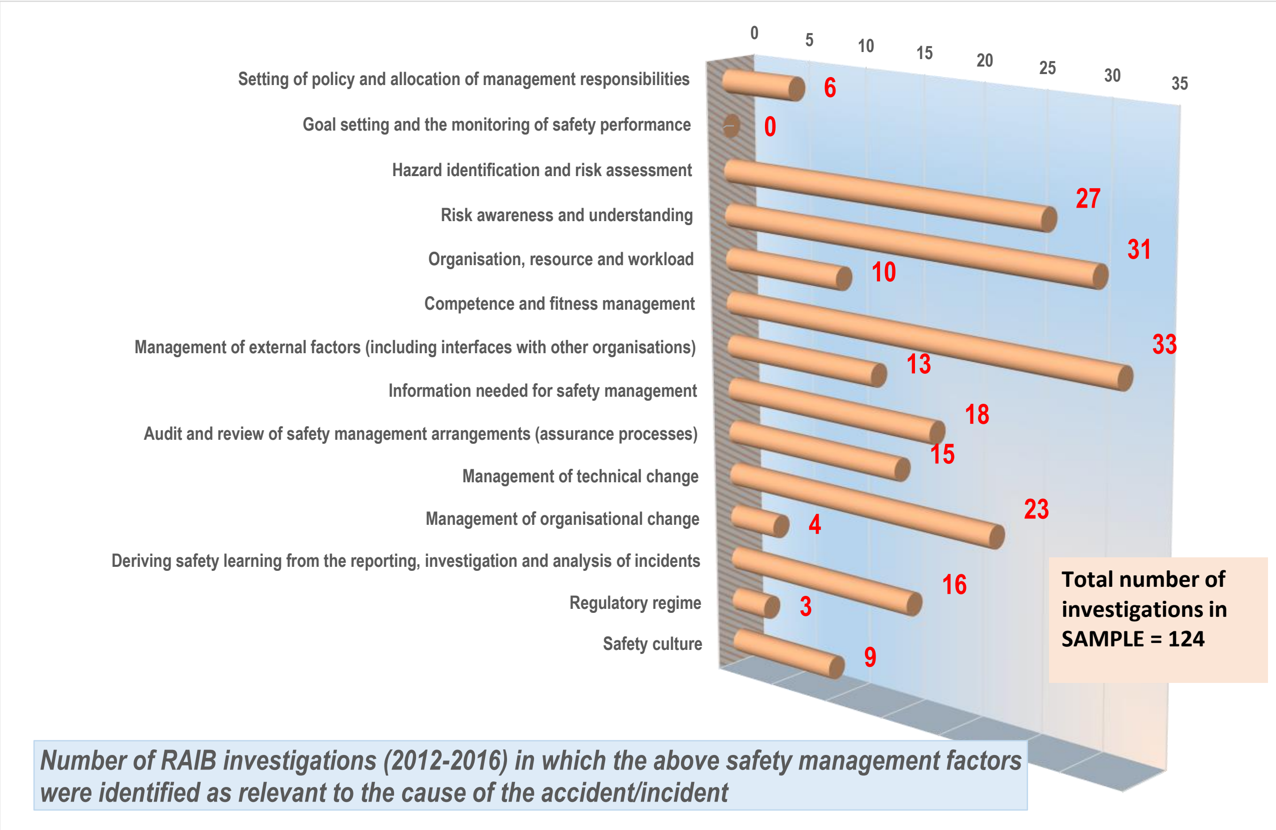
The following paragraphs present the results of this analysis for each of the SMS topics listed at the start of this paper. The overall statistics for each of the SMS topics are plotted at Figure 4.

a. Setting of policy and allocation of management responsibilities (identified as a significant factor in 5% of RAIB investigation reports between 2012 and 2016).

The setting of policy has rarely featured in RAIB investigations since it started investigation. One exception was an investigation carried out in 2012 concerning a minor tourist railway which appeared to have no documented safety management system (Kirklees, report 04/2012). The low level of such references in RAIB report may well reflect the fact that policy statements tend to be written at such a high level that it very difficult to link them to a specific occurrence.

There have been a small numbers of cases where management responsibilities were found to be inadequately defined. A notable example of this, identified following a series of investigations into accidents at level crossings, was the poor coordination of associated risk management activities at level crossings (a subsequent RAIB recommendation led directly to the appointment of full-time level crossing managers to take charge of risk assessment and inspection at level crossings).

Figure 4. **SMS topics identified as factors in RAIB investigations (Jan 2012 to Dec 2016)**



b. Goal setting and the monitoring of safety performance (addressed by a recommendation in 0% of RAIB investigation reports between 2012 and 2016).

Goal setting does not feature as a major theme in RAIB investigations. This is probably a reflection of the fact that the RAIB sees goal setting as a matter for the companies and the regulator, and is unlikely to challenge a goal or safety target unless it was clear that the goal was inconsistent with the overall aim of continuous improvement. However, a number of the recommendations that the RAIB has made may well lead to railway companies establishing new targets for risk reduction (for example, in areas such as risk to a passengers at the interface between trains and platforms).

c. Hazard identification, and risk assessment (identified as a significant factor in 22**%** of RAIB investigation reports between 2012 and 2016).

The non-identification of hazards and poor risk assessment are regular findings of RAIB investigations. The types of hazards/risks that are not identified fall into two broad categories:

- newly appreciated hazards that have emerged from a number of recent investigations
- known hazards that were overlooked, or subject to poor risk assessment

With regard to the first category, instances have included:

- collision between train and pedestrian on footpath level crossing; effect of skew angle on the safety of users, particularly the elderly (Grimston, report 23/2016)
- passenger trapped and dragged in the doors of departing train; the hazard presented by door control system had not been understood by the operator (West Wickham, report 03/2016)
- freight train derailed due to combination of track twist, bogie twist and a residual asymmetric load; the hazard posed by stone binding to the inside of hopper wagons had not been recognised (Angerstein 1, report 11/2015)

With regard to the second category, instances have included:

- wrong side failure of an electrically operated wagon mounted stone discharge boom that caused it to slew into the path of an approaching train; inadequate risk assessment of poorly maintained electrical control equipment (Mount Sorrel, report 21/2016)
- collision of a tram following poor braking due to low rail head adhesion; inadequate risk management of poor rail head conditions (Shalesmoor, report 17/2016)
- collision of a tram with a pedestrian; limited risk assessment of tram operations in a city centre area (Market St, report 06/2016)
- derailment of a container train carrying an asymmetrically loaded container over twisted track; absence of a cross-industry strategy for the management of freight train risk (Camden Road, report 21/2014)
- collision of a train with buffers; non-identification of the increased risk due to the use of one-shot sanding devices rather than auto-sanders (Chester, report 26/2014)
- failure of overhead line causing it to fall onto a metro platform when still energised; inadequate understanding of the risk of contact wire failure following arcing in train mounted contact breakers (Walkergate, report 09/2015)

d. Comprehensive risk awareness (i.e. understanding of the hazards and risk) (identified as a significant factor in 25% of RAIB investigation reports between 2012 and 2016).

A total of 31 RAIB investigations between 2012 and 2016 have found evidence that the corporate entity had not recognised a significant gap, or deficiency, in their existing risk control measures. Examples include

- derailment of a freight train at Reading West due to a combination of track geometry and uneven weight distribution within a container that was being conveyed on the train; RAIB recommended that additional mitigations were needed to control the risk of asymmetrical loading in containers (Reading West, report 02/2013)
- fatal collision at Beech Hill level crossing due to sunlight obscuring the road traffic signals; RAIB recommended the implementation of a new process for assessing and managing the risk associated with sunlight at level crossings (Beech Hill, report 17/2013)
- derailment of a freight train on track with cyclic top defect (a series of regularly spaced dips in the track), near Gloucester; RAIB recommended a new process to assess the resistance of new wagons to cyclic top (Gloucester, report 20/2014)
- steam-hauled charter train passed signal at danger, at Wootton Bassett; RAIB recommended that the railway industry carry out an assessment of the risk of operating

heritage rolling stock and locomotives on the national infrastructure (Wootton Bassett, report 08/2016)

e. Organisation, resource and workload (identified as a significant factor in 8% of RAIB investigation reports between 2012 and 2016).

A shortage of trained staff was a factor in a number accidents investigated by the RAIB. This has either resulted in the remaining staff becoming overloaded or safety critical activities not being covered as envisaged by the safety management system. In several cases this has been associated with organisational change that had resulted in a number of posts remaining vacant (e.g. Heworth, report 16/2015).

f. Competence and fitness management (identified as a significant factor in 27% of RAIB investigation reports between 2012 and 2016).

The railway industry is heavily reliant on the competence of its staff for delivering the requirements of its SMS. It is therefore hardly surprising that competence features in a significant number of RAIB investigations. Recent notable examples include:

- derailment of a passenger train when the signaller authorised the driver to pass a signal at danger; competence management of signallers (and managers) who only work boxes on an irregular basis (Knaresborough, report 16/2016)
- two signals passed at danger; inadequate driver management arrangements leading to poor management of fatigue risk (Ruscombe and Reading West, report 18/2016)
- passenger train collides with buffers; inadequate supervision of trainee driver (Kings Cross, report 15/2016)

g. Management of external factors (including interfaces with contractors and other organisations) (identified as a significant factor in 10% of RAIB investigation reports between 2012 and 2016).

The railway industry is remarkable for the number of external interfaces that it has. Organisations the railway must engage with on matters of safety importance include highway authorities, utility companies, land developers, the owners of neighbouring land, the emergency service and customers.

Recent examples of investigations involving parties external to the railway have included:

- train derails after hitting a herd of cows; inadequate fence maintenance (Godmersham, report 05/2016)
- train hits brick parapet knocked from bridge onto the line by a reversing road truck; inadequate signage to warn truck drivers that the route is unsuitable for their vehicles and late notification by the emergency services (Froxfield, report 02/2016)
- tunnel being constructed for utility company collapsed causing a dip in the track and subsequent derailment of a freight train; inadequate procedures for protecting the line from the activities of third parties (Stoke Lane, report 02/2015)

h. Information needed for safety management (identified as a significant factor in 15% of RAIB investigation reports between 2012 and 2016).

A total of 18 RAIB investigations between 2012 and 2016 RAIB have found evidence of significant gaps in the information needed for the management of safety. Examples have included:

- the RAIB investigation into a collision between a train and car at Stowmarket identified an absence of information on sites where road vehicles have left the road and fouled the railway line (Stowmarket, 25/2012)
- the RAIB investigation into two large augers being drilled into a railway tunnel that was open for traffic identified that there were gaps in the information available to developers concerning the location of underground railway tunnels (Old Street, 03/2014)

i. Audit and review of safety management arrangements (assurance processes) (identified as a significant factor in 12% of RAIB investigation reports between 2012 and 2016).

A question that is often asked in RAIB investigations is why a particular deficiency had not been addressed before by the responsible manager detected as part of the company's audit system.

Shown below are two examples of investigations when the company has been recommended to consider why their management assurance regime failed to detect a deficiency that was later revealed by the investigation.

- A freight train derails on a section of track with a longstanding defect. Although the defect was known about no effective action had been taken to address this issue. The investigation showed that the local depot had been unable to keep up with the required track maintenance issues for some time. There was a major backlog of work and insufficient resource to cope (Heworth, report 16/2015).
- A passenger train derails at Paddington. Although there were also issues with the set-up of the suspension on the train, there was a longstanding track fault. As at Heworth, the defect was known about but no effective action had been taken to address this issue (Paddington, report 03/2015).

j. Management of technical change (identified as a significant factor in 19% of RAIB investigation reports between 2012 and 2016).

The unintended consequences of technical change are a regular feature in RAIB findings. These fall into two main categories:

- safety validation of new products
- safety validation of modified products

With regard to the first category, instances have included:

- collision of train with tractor on level crossing; issues with design of automatic gates and incorrect installation (Oakwood Farm, report 07/2016)
- collision of train with open door of signalling cabinet; inadequate product approval process (Watford tunnel, report 12/2015)
- derailment of freight train on track with regularly spaced dips in track; a newly commissioned wagon was found to be unusually sensitive to track irregularities when partially loaded – this had not been detected during the approval process (Gloucester, report 20/2014)

With regard to the second category, instances have included:

- electrical arcing on train leads to evacuation of passengers; issues with design of a modified train and poor installation (Windsor and Eton, report 11/2010)

- arcing between overhead line and a road freight vehicle carried on railway wagon caused a major fire in Channel Tunnel; light weight roof structure was removed from railway wagon without adequate assessment of the safety implications (Channel tunnel, report ET/2016)
- a work train ran away and collided with two road-rail vehicles; the safety validation of modifications to the parts of the train had not identified the risk of a foreseeable single human error leading to a total loss of braking without the possibility of recovery (Bryn, report 09/2016)

k. Management of organisational change (identified as a significant factor in 3% of RAIB investigation reports between 2012 and 2016).

Unintended consequences of organisational change are an occasional feature of RAIB investigations. Instances have included:

- failure of a viaduct on line that was still open to express trains; loss of safety critical corporate knowledge due, in part, to organisational change (Lamington, report 22/2016)
- a derailment of a freight train due, in part, to poorly maintained track; reluctance to recruit new workers pending future organisational change that is likely to be driven by the introduction of new technology (Heworth, report 16/2015)

l. Deriving safety learning from the reporting, investigation and analysis of accidents and incidents (identified as a significant factor in 13% of RAIB investigation reports between 2012 and 2016).

Examples of investigations in which the RAIB has identified the need for enhanced processes to derive safety learning from previous incidents have included:

- following the identification of gaps in the understanding of fatigue risk in the UK rail freight industry, the RAIB recommended more detailed analysis on incident patterns in order to inform future fatigue management (Reading and Ruscombe, report 18/2016)
- a passenger became trapped in the doors of a metro train, and was subsequent dragged; the RAIB recommended the introduction of a system to monitor the frequency of door obstructions in order to check the efficacy of new measures designed to reduce the risk to passengers during boarding and alighting (Jarrow, report 26/2016)

The RAIB also monitors the quality of investigations undertaken by the railway industry. The quality of such investigations is very variable with some limited in scope to the immediate causes and an assessment of compliance with documented procedures. Very few examine the underlying management issues.

m. Regulatory regime (identified as a significant factor in 2% of RAIB investigation reports between 2012 and 2016).

It is only rarely in RAIB investigations that a regulator is found to have taken an action that led directly to an accident. However, on occasions the RAIB has identified the scope for improvement in the way that the regulator performs its certification or supervisory duties.

An example of an investigation in which the RAIB identified the actions of regulator as a factor followed a signal passed at danger at Stafford (Stafford, report 16/2013). In this case it was found that the UK's railway safety regulator, the Office of Rail Regulation (ORR) had not examined the implementation of Devon and Cornwall Railways' safety management system despite the operator being new to the operation of trains in the UK (this led the RAIB to recommend that ORR undertake a periodic management review of its assessment of safety certificate applications and the resolution of outstanding issues through supervision).

n. The promotion of good safety culture (identified as a significant factor in 7% of RAIB investigation reports between 2012 and 2016).

Following accidents in which workers were struck by trains at Stoats Nest Junction in 2011 and Newark in 2014, the RAIB made recommendations for a review of cultural issues that influence behaviour of persons working on the track. In both cases a breakdown of site discipline and vigilance were considered to have allowed the conditions for the accident to have occurred (Stoats Nest, report 16/2012; Newark, report 01/2015).

In a recent investigation into a signal passed at danger at Wootton Bassett (Wootton Bassett, report 08/2016), the RAIB identified numerous areas in which the organisation that operated the train was either non-compliant with its documented SMS, or had failed to implement measures that are generally considered to be good practice. It was therefore concluded that "the number of occasions when the requirements of relevant rules, standards and the safety management system were not observed and the gravity of some of the non-compliances found strongly suggest that (the operator) had a weak safety culture when the incident at Wootton Bassett Junction occurred".

A wider perspective

Other investigators are constantly encountering elements of safety management systems when seeking to understand the causes of accidents. Fox (2009) has carried out a detailed analysis of the implementation of safety management systems drawing heavily on the findings of the Transportation Safety Board in Canada between 01 January 2001 and 31 December 31 2008. Based on this analysis she observed the following organisational risk management practices as factors in the causation of accidents:

- no formal risk analysis conducted
- risk analysis conducted but hazard not identified
- hazard identified but residual risk underestimated
- risk control procedures not in place, or in place but not followed
- issues related to equipment design and/or maintenance practices
- inadequate tracking or follow-up of safety deficiencies
- insufficient personnel for the task at hand, heavy workload, inadequate supervision
- insufficient training or lack of qualifications for the task to be performed
- conditions conducive to physical or mental fatigue
- ineffective sharing of information before, during or after the event including verbal
- communications, record-keeping or other documentation
- gaps created by organisational transitions affecting roles, responsibilities, workload and procedures.

These can be grouped under a number of broad headings which describe the underlying cause in organisational terms:

- adaptations/drift; adaptations of, or drift from, prescribed processes to "get the job done" – often linked to lack of resource or time
- goal conflicts; deviation from process stemming from a conflict between production and safety
- non-reporting of incidents
- identifying hazards and mitigating risks; issues associated with the non-identification of hazards and poor risk assessment include:
    - lack of "Requisite Imagination" or "Mindfulness"; the inability, or lack of willingness, to imagine what might happen as an input to the identification of hazards and subsequent risk assessment
    - weak Signals; an inadequate response by the organisation to initial indications of potential problems
    - incorrect assumptions….about the hazard or extent of risk (e.g. non-recognition of the impact of a proposed change)
    - underestimating risks; an inability to properly understand and assess risk (Fox points out that risk assessments featured in investigations were often too informal or the participants were not sufficiently knowledgeable to identify potential hazards).
- resilience; the extent to which organisations are able to contain an unexpected hazard and recover
- multiple accidents; an organisation's inadequate response to previous accidents.

Shown below are brief summaries of some high profile incidents in safety critical industries where SMS was an important factor in the investigation.

Air Ontario flight 1363 Dryden air crash, ice on wings (1989)

The public enquiry into this accident looked at a number of organisational factors surrounding the competitive pressures at the time due to deregulation in Canadian aviation in the late 1980s which had led to deficiencies in safety standards. The report looked at safety management and Transport Canada and highlighted issues with allowing Air Ontario to expand its fleet without taking action to address existing deficiencies. The report states: "because of resource constraints, an inadequate regulatory framework and organisational deficiencies, the present Transport Canada organisation is ill equipped to provide in an efficient manner a uniform level of safety."

Buncefield explosions and subsequent fire at Hertfordshire oil storage terminal (2005)

The investigation found that the safety management system focused too closely on personal safety and lacked any real depth about the control of major hazards. The report produced by COMAH (Control of Major Accident Hazards) found that auditing and monitoring had only focused on whether systems were in place but did not look deeper to consider the quality of the system, whether it was being used or whether it was effective.

BP Texas city Oil Refinery explosion and fire (2005)

The report by the Chemical Safety Board noted a number of technical and organisational failings. It suggested that: "the overall safety culture and process safety management programme had serious deficiencies." They noted that performance contracts, incentive programmes, behavioural safety initiatives and industry benchmarking all reflected a lack of focus on process safety management and major accident prevention. The subsequent Baker report was produced in response to the incident; it was an independent panel led by the Secretary of State at the time, James Baker. This report made a number of recommendations about SMS including:

- the need for process safety leadership
- integrated and comprehensive safety management
- process safety knowledge and expertise
- process safety culture
- clearly defined expectations and accountabilities for process safety
- support for line management
- leading and lagging performance indicators
- process safety monitoring
- board monitoring.

The report concluded that: "If other refining and chemical companies understand the panel's recommendations and related commentary and apply them to their own safety cultures, process safety management systems and corporate oversight mechanisms, the panel sincerely believes that the safety of the world's refineries, chemical plants and other process facilities will be improved and lives will be saved."

Nimrod, Royal Air Force inflight fire resulting in crash in Kandahar, Afghanistan (2006)

The report (by Charles Haddon Cave QC) focused on how financial targets had become more important than safety. It also noted that a safety case should be based on an explicitly defined safety management system specifically for aircraft. The report stated that: "the Nimrod safety case was a lamentable job from start to finish, it was riddled with errors and it missed key dangers. It was essentially a paperwork exercise."

Deepwater Horizon, Explosion and oil spill (2010)

The Chemical Safety Board concluded that a more robust process safety management regulatory regime would enhance existing US offshore regulations. They stated that there was a need for a more goal setting risk reduction regulatory model and the need to focus on continuous improvement as there had been a failure to monitor the "real time health" and effectiveness of the SMS and the use of lagging rather than leading indicators.

SMS and Uberlingen mid-air collision (2002)

This mid-air collision occurred over Uberlingen in Germany and involved a Russian Bashkirian Airlines Tupolev-Tu passenger jet and a DHL 747 cargo jet. The total number of fatalities was 71. Swiss air traffic control (ATC) was in charge of the sector involved. The ATCO (air traffic control officer) on duty at the time became aware of the fact that the aircraft were flying level on a collision course less than one minute before it occurred. He instructed the Bashkirian jet to descend which it did. Their TCAS (traffic collision avoidance system) RA (resolution advisory) had correctly instructed them to climb. The DHL jet followed the TCAS RA to descend.

At the time of the accident the ATCO was working alone which was common practice although contrary to existing Swiss ATC procedures for working a night shift without a supervisor. The system he was using was degraded as maintenance work was being carried out on the radar system and a fall back system was being used. This system provided no optical STCA (short term conflict alert) although it did provide an aural alert which the ATCO reported he had not heard.

The original report into the accident which was carried out by the BFU (German Federal Bureau of Aircraft Accident Investigation) identified a number of contributory factors. It examined the TCAS system and it covered the task management of the ATCO, team management, resourcing, situational awareness, workload, communications and warning systems. It also looked at organisational factors and safety culture in the company.

This report was later reviewed by Johnson (2004) with the aim of identifying safety improvements that might not have emerged from the initial investigation and to extract additional lessons that may be learned. An extended time line was used in order to take into account the management and planning of the work and maintenance. The review suggests that under-manning alone was not the root cause of the accident it was under-manning and a failure to recognise the risks associated with the maintenance work. It suggests that additional emphasis should have been placed on concrete SMS techniques (mainly a maintenance risk assessment) that might have identified hazards before the accident took place and that there needed to be adequate preparation for what they identify as an "error inducing environment". The review highlights that two recommendations in the report were not supported by causal analysis (although evidence in the report supports them). Seventeen additional recommendations were made. Taken together they suggest that the original BFU report had been insufficiently focused on the SMS in general, and the risk assessment process in particular.

The BFU report had also stated that there was inadequate training of staff and a lack of advanced emergency situation training and a lack of a reporting culture. The Johnson review suggests that more focus should have been made on risk assessment as even if the staff had been better trained there is little evidence that they would have coped any better with the operating environment at the time.

The review recognised that safety policy and principles surrounding the SMS were in compliance with the requirements and even included some which were not mandatory. Johnson points out that the important factor in the incident was the implementation and monitoring of the policy rather than its existence. In conclusion, he states: "our analysis has extended that of the BFU by showing in a concrete way how those different problems interacted and created the context in which the Uberlingen accident was likely to occur….It is important that ATM officers and Safety Managers see these connections if they are to realise the true importance of safety management systems in the prevention of future accidents or near-miss incidents."(p.44)

The review points out that the original report failed to take into consideration the lack of a comprehensive risk assessment of the maintenance work (especially a systematic risk assessment of the radar in fall back mode). It highlights the importance of looking extensively at organisational factors and their contribution to an accident and how easily these can be missed.

The investigation of safety culture

What is safety culture?

Although the term "safety culture" is often used there exists no single universally accepted definition and attempts to create one have proved to be problematic. James Reason has stated that: "few phrases are so widely used but so hard to define".

The term was first used by the International Atomic Agency (International Nuclear Safety Advisory Group) (INSAG) in the report into the accident at Chernobyl where it was concluded that the need to create and maintain a safety culture was a precondition for ensuring nuclear power plant safety. The report stated: “that there is a need for a nuclear safety culture in all operational nuclear power plants” (1986, p.76).

In other safety critical industries safety culture began to be recognised in the late 1980s - early 1990s. In aviation the NTSB report into the Continental Express Flight 2574 (an accident where the horizontal stabiliser became separated from the airframe due to missing screws) stated that: “a probable cause was the failure of senior management to establish a corporate culture that encouraged and enforced adherence to approved maintenance and quality assurance procedures” (1992, p.54). Safety culture became recognised as a contributory factor in a number of incidents and accidents in subsequent years. In the rail industry the Cullen report (2001) emphasised the significance of developing an effective safety culture in response to Ladbroke Grove. Numerous reports have highlighted safety culture as an important factor in incidents and accidents and it is now a routinely used term. Dien (2012) notes that the importance of the emergence of the concept of safety culture was that it acknowledged for the first time that management activities were part of the safety process.

Safety culture has been informally described as: “the way we typically do things around here”, or as: “doing the right thing even when no one is watching” (Sumwalt, 2007, p.37). Many researchers and organisations have developed their own definition of safety culture. A frequently used definition given by the HSE states that: “the safety culture of an organisation is the product of individual and group values, attitudes, perceptions, competencies and patterns of behaviour that determine the commitment to the style and proficiency of, an organisation’s health and safety management” (HSE, 1999, p.45).

Different organisations have focused on different areas in their definition, for example some have included the role of the individual employee and that of personal responsibility. Eurocontrol, for example, have stressed the importance of commitment to safety throughout an organisation stating that safety culture is: “the way that safety is perceived, valued or prioritised in an organisation. It reflects the real commitment to safety at all levels of the organisation.” Others have focused on the importance of the perception of management systems and the organisation as a whole (Minerals Council of Australia, 1999) and some more theoretical definitions have focused on the assumptions and practices underlying the construction of beliefs about safety and danger (Pidgeon, 2001). It starts to become clear that safety culture is a multi-dimensional concept with little consensus over definition but widespread use (Guldenmund, 2000). Differences in definition will also arise in different industries as it cannot be assumed that safety culture looks the same in every safety critical industry (Von Thadden and Gibbons, 2008).

Safety culture is also a sub-set of the overall organisational culture and most importantly is not static. Like the overall organisational culture it will change and evolve over time. Safety culture like organisational culture requires relatively long periods of time to be established and is unlikely to be changed or turned around quickly (Sumwalt, p.7)

Safety culture vs safety climate

A distinction has been made between safety culture and safety climate. Safety culture has been seen as being a more stable concept. It is more about the safety behaviours within an organisation and what an organisation does. Safety climate is a more superficial reflection of the immediate circumstances within a company and can be influenced by recent events. Safety climate has been described as a snapshot of the current state of safety (Mearns and Flinn, 1999). It has also been described as: “an indicator of an organisation’s safety culture as perceived by the employees at any one given time” (Cox and Flinn, 1988). Although safety culture and safety climate are two distinct concepts they are often used interchangeably.

What does a "good" safety culture look like?

Much research has been carried out to identify indicators of a positive safety culture. James Reason (1997) has identified five main components of a strong safety culture on a generic basis and many of the guidelines in industry have been adapted from this model. For Reason, a strong safety culture is an informed, reporting, learning, flexible and just culture.

An informed culture is one in which; "those who manage and operate the system have current knowledge about the human, technical, organisational and environmental factors that determine the safety of the system" (Reason, 1997, p.294). He has noted that if an organisation has an informed culture; "they will know where the edge is without having to fall over it" (Reason, 1997, p.302).

A reporting culture is one that allows and encourages people to report their errors and near misses. This can often be difficult to achieve but can be helped by using a confidential reporting system, keeping a separation between those who collect information and those who would implement sanctions, providing fast and useful feedback and making the reporting system easy to use (O'Leary and Chappell). Within aviation there has been a move to introduce laws to encourage a reporting culture by attempting to establish a common process across the EU for submitting reports (EU, 2015).

A learning culture is evident when an organisation has the willingness and competence to learn from its safety information and will include this when implementing safety reforms.

A flexible culture is a culture that can re-configure itself and respond to change and may change from a conventional hierarchical structure to one which is flatter (Hudson). A flexible culture also encourages people to adapt and allows people regardless of their position to have an active role in the overall organisational safety.

The final indicator of a positive culture for Reason is a "just" culture which "lies at the heart" of any safety culture (p.302). A just culture avoids apportioning blame on an individual which in turn facilitates a focus on systemic deficiencies rather than on individual failings. In a just culture there will be an atmosphere of trust and a clear understanding of the difference between an error and a violation for all involved. Each of these factors is important for the overall safety culture and is inter-dependent – an informed culture can only be built on a reporting culture which in turn relies on a just culture.

Different industries will have different ideas as to what a good safety culture looks like and even within an organisation there may be variance in which factors are considered as positive indications of a safety culture between different departments or groups.

Measuring and grading safety culture

Different industries have created distinct safety culture frameworks and guidelines which aim to identify the characteristics of an effective safety culture for their specific industry. For example, the ORR safety culture toolkit was established to enable inspectors to investigate a safety culture. Five main safety indicators are considered: leadership, two way communication, employee involvement, learning culture and an attitude towards blame. EASA has identified six main components: commitment, behaviour, awareness, adaptability, information and justness. It is therefore possible that indicators of a positive safety culture may be in part domain specific. For the regulators the aim will be not to prescribe a culture but to encourage organisations to develop a strong safety culture. The ORR's Rail Management Maturity model (2011) considered an organisation's ability to achieve excellence in risk control. Many of the factors that are identified in the model as positive indicators of maturity would also be factors that indicate an effective safety culture. However this tool is designed to be used proactively and does not specifically concentrate on safety culture.

In order to measure the safety culture of an organisation different metrics have been used. Measurements are often the starting point for developing effective safety culture improvements. In terms of subjective measures, self-completed questionnaires are often used to measure the attitudes and perceptions of the safety culture by employees. One problem with this type of metric is that perceptions can change and can be affected by events or information and there is recognition that such questionnaires are unlikely to measure culture but will measure safety climate. Antonsen (2009) has argued that a questionnaire will not reveal enough and a more interactive assessment is necessary. Other measures used have included workshops, card sorting exercises, focus groups and qualitative assessments (Eurocontrol). Objective measures of safety culture can also include audits, reports and investigations and training (Parker, Lawrie and Hudson, 2006).

A number of safety culture maturity models have been developed (Reason, 1993; Westrum 1984; Fleming, 2000). These models allow organisations to determine their current level of maturity and to identify the strengths and weaknesses of their safety culture. Westrum's original model was linear where a culture could move from pathological (where safety is not a priority and is driven by fear of not getting caught) to bureaucratic (where safety is achieved by following rules and procedures) to generative (where trust and accountability are key factors) (see Table 2).

Table 2. **Westrum (2004) "A typology of organisational cultures"**

Pathological (power orientated)	**Bureaucratic (rule orientated)**	**Generative (performance orientated)**
Low co-operation	Modest co-operation	High co-operation
Messengers shot	Messengers tolerated	Messengers trained
Responsibilities shirked	Narrow responsibilities	Risks are shared
Bridging discouraged	Bridging tolerated	Bridging rewarded
Failure leads to scapegoating	Failure leads to justice	Failure leads to enquiry
Novelty crushed	Novelty leads to problems	Novelty implemented

Westrum suggests that the model is not a direct measure of safety culture but it does relate strongly to safety. The way that information is processed in an organisation can contribute to the creation of a safety climate. A climate with good information flow: "is likely to support and encourage other kinds of cooperative and mission enhancing behaviour such as problem solving, innovation and inter-departmental bridging." (p.33). Fleming (2001) has suggested that although lower accident rates are associated with higher levels of safety culture maturity there is no evidence to support this and such models are useful as a framework rather than a diagnostic tool.

Westrum's model was later developed (Reason, Parker et al. 2006) and included proactive and reactive cultures so that the levels were defined as pathological, reactive, bureaucratic, proactive and generative. In a reactive culture action will happen after an incident or accident and can be characterised by the statement: "safety is important to us. We do a lot every time we have an accident" and a proactive culture by the statement: "we try to anticipate safety problems before they arrive." Other frameworks have been developed, for example the Keil Centre five level safety culture maturity model and the HSE culture ladder.

Organisations and regulators have developed different safety culture measures and indicators of positive safety culture. In the UK rail industry the RSSB has developed a safety culture toolkit which allows an organisation to assess its own safety culture through a questionnaire and other measures. This provides an industry benchmarking report and will provide an overall level of safety culture development. Measuring safety culture is often seen as the starting point for developing an effective safety culture improvement initiative.

The RSSB has also produced guidance on safety culture and behavioural development. This looks at the behavioural aspects of safety culture as behaviour is a subset of culture and by changing behaviour, a change in attitudes may follow which could result in a change in culture. Behaviour modification is at the basis of behaviour based safety. By using reinforcement or feedback behaviour can be increased or decreased. This may work well with certain behaviours (simple/discrete) but it may not always address root causes.

It is evident that a number of measures and safety culture indicators exist but there may be issues surrounding these. It is clear that there is a difficulty in creating a comprehensive safety culture indicator. The IAEA have stated that: “No composite measure of safety culture exists. The multi-faceted nature of culture makes it unlikely that such a measure will ever be found.” Pronovost and Sexton suggest that there is still no consensus about which domains are important in a safety culture and that there are issues surrounding validity and reliability of questionnaire responses. They also suggest that there may be some unforeseen effects of developing certain areas of a positive culture and for example suggest that in a clinical setting where units evolve with greater trust and collaboration they may also develop a sense of invulnerability. Others have argued that certain factors such as power and conflict have been ignored in safety culture research (Antonsen, 2009) in that culture and power are intertwined and conflicting views on safety in an organisation may be a safety resource that facilitates learning.

Safety Management Systems and safety culture

Safety culture has often sat within guidance and legislation surrounding safety management systems. CAA guidance suggests that the success of an SMS hinges on having a positive safety culture and that an SMS can provide an organisational framework to serve as a structure to generate a positive safety culture. It is seen as necessary for an organisation to have both an SMS and a good safety culture. Hudson has argued that an SMS will not always allow organisations to identify gaps and that for this to happen it needs to develop an organisational culture: “that supports processes beyond prescription.”

How to approach the investigation of safety culture within an organisation

Having considered the difficulties surrounding defining and measuring safety culture the task of investigating it can appear impossible. For a regulator the aim of an investigation into an organisation is to be able to identify strengths and weaknesses of a culture and to provide feedback. For an organisation itself it will aim to measure its safety culture in order to benchmark and to make safety improvements whereas for accident investigation safety culture will be considered retrospectively if it is seen to be in the causal chain contributing to an accident.

Having examined the different tools available to measure safety culture it is clear that some of these would not be practical for accident investigators. Safety culture questionnaires measure employee attitudes and beliefs and these are likely to be affected by the occurrence of an accident or simply by the fact that an investigation is taking place. This type of metric can therefore be problematic in terms of reliability and validity, and in terms of response rates. Antonsen (2009) distributed safety culture questionnaires to offshore workers before and after an operational accident and found that the pre-accident questionnaire failed to detect safety issues that were subsequently identified. Others have argued that focusing on how people feel about safety is not effective as it shifts the blame towards the workforce because it is based on the assumption that people’s attitudes may have changed an outcome (Hopkins, 2006).

Due to practical constraints it is unlikely that some of the other subjective measures recommended for measuring safety culture would be suitable for accident investigators. Time constraints and level of involvement in an organisation may rule out using workshops and focus groups and other more interactive measures.

If safety culture is examined as part of an investigation it is possible that an organisation may display positive indicators for safety culture but this may not necessarily mean that no problems exist. The dynamic nature of safety culture and the issues surrounding its measurement can be problematic. There is also little research to support that a good safety culture will translate into fewer accidents and vice versa. Strauch points to a NTSB report in 2013 where a cargo vessel struck a bridge. The company involved had indicators of a good safety culture but the investigation into the accident found some of the practices to be poor stating that: “the company became complacent regarding the safety of the vessels operation” (p.viii).

Czech, Groff and Strauch (2014) have argued that elements of an SMS can be used as a guide for accident investigators to examining organisational factors that may have contributed to an accident. They argue that by looking at objective evidence such as work practice, procedures and policies and training records and by interviewing people involved this will allow an examination of how an operator manages its safety. They argue that: “in this way an investigation can collect objective evidence of otherwise subjective issues like social pressure or just culture concerns” (p.7). They recognise that this is not a new approach to accident investigation but suggest that: “the approach to investigating safety culture issues must be structured, repeatable and focused on the objective indications of what are otherwise subjective issues.”

Stauch has stated that an attempt to assess safety culture in an investigation could be either ineffective or misleading. He argues that simply because we are limited in our understanding of safety culture and its measurement means that any direct assessment of safety culture will fail. He has argued that the way forward is to examine organisational factors that are identifiable and assessable and to consider how these factors relate to an accident; these factors in turn will provide insights into organisational culture.

The root causes of accidents have often been attributed to organisational factors and for Reason organisational accidents arise from; “the concentration of several contributory factors originating at many levels of the system.”

It would appear that a good starting place for investigating the safety culture of an organisation is to examine and explore in depth any organisational factors relating to the accident. How this is done effectively is the subject of debate. Dien, Dechy and Guillame (2012) suggest that it is not possible to carry out organisational analysis by examining documentation alone, they argue that it is necessary to interact with people involved in an organisation and to consider background knowledge. They state that it is important: “to consider the historical dimension understanding the wider context within which an accident occurs” they suggest that it is necessary to look back further in the accident sequence. They also propose that it is important to provide a “thick” description of the event which is as detailed as possible and includes a dense description of the situation leading up to it.

Sagan (1994) suggested a check-and-balance approach for investigations where results will be derived from several different organisational analyses suggesting that the results could be compared and discussed: “in order to define one set of shared results gaining a ‘global vision’ of the event.”

Standard methods to analyse organisational factors in accidents have often focused on causal methods which can help consider factors in a logical sequence. Problems with such methods have been highlighted. Dien et al. (2004) have argued that these methods do not take into account the origin of the occurrence of an accident. They suggest that causal analysis should be complemented by other analysis such as a historical reconstitution of the event which would catch the first signs of deterioration and an in-depth analysis of the organisational network looking at “relations, dependencies and interactions” (p.153). Falbruch (2002) has also highlighted some of the problems with event analysis and suggests that there are certain characteristics of human information processing and general attribution processes that might jeopardise the quality of such analysis. These include the formation of premature hypothesis where the first plausible cause is taken as an explanation and the general human tendency to reduce complexity which may lead to mono-causal thinking. He also highlights the difficulty arising from identifying contributory factors that are remote in time and space from the actual event which may result in indirect contributory factors (such as organisational factors) being overlooked.

Numerous models and classifications for accident investigation exist. Shappell and Weigmann (2000) developed HFACS (Human Factors Analysis and Classification system) which is based on Reason's model of latent and active failures. The system was developed to help in the investigation process to identify underlying causal factors and to identify issues within the entire system. It describes human error at four levels; unsafe acts of operator, preconditions for unsafe act, unsafe supervision and organisational influences. The organisational influences consider resource management, organisational climate (including culture) and operational processes. This model recognises that organisational errors often go unnoticed and are overlooked. This model has been adapted by Reinach and Vale (2005) who attempted to increase its applicability to train accident/incident investigations. At the organisational level they added organisational contraventions; this subcategory looked at senior level and executive contraventions and shortcuts associated with either existing processes and procedures, or externally imposed ones. They suggest that contraventions are more about shortcutting and rule bending than violations.

In conclusion it would seem that there are a number of tools that exist in accident investigation to help identify any organisational factors. A good investigation will thoroughly analyse each organisational factor and through this process any safety culture issues could be revealed. It is also important that the consideration of organisational factors does not simply relocate the problem further up the causal chain (Woods et al., 1994) and place blame on management without understanding why certain decisions are made. It is necessary to recognise the influence of organisational factors in accidents; these are in all likelihood related to safety culture as safety culture is part of the wider organisational culture.

Can accident investigations influence the shape of safety management systems?

In her paper on the implementation of safety management systems Fox concludes that: "accident investigators should continually strive to uncover the contextual drivers that influence decision-making, goal conflicts, local adaptations and 'non-compliance' with formally documented rules, procedures and safe practices to facilitate organisational learning and effective follow-up after an occurrence"

If investigators play their role in uncovering the contextual drivers that lead to gaps organisational risk management it is also important that their recommendations are crafted so as to maximise the impact on future safety improvements.

Recommendations to address weaknesses in safety management systems can fall into the various categories shown in Table 3.

Given the range of options presented in the table above, it is concluded that the selection of the right type of recommendation is critical to investigators driving change in organisational risk management. Four examples of significant change prompted, at least in part, by accident investigations are provided below.

Table 3. **Types of recommendations to address safety management issues**

Type of recommendation	**When most appropriate**	**Risks**
A recommendation based on actions targeted at the specific area of weakness identified by the investigation	When the specific actions needed to address the risk are clearly seen by the investigator	Risk that the solution to the problem is now owned by the investigator rather than the organisation that is being investigated
A recommendation which identifies the problem and challenges the organisation to find a solution	When the solution to the problem is not immediately obvious and therefore warrants further examination	Can lead to a delay in the implementation of measures to address the risk (particularly if the organisation has an immature safety culture or is reluctant to participate in finding a solution)
A recommendation which urges that a risk be evaluated and suitable actions taken	When the investigator cannot, on the basis of the available evidence, be sure that further actions to address a particular risk are justified	Can provide a means for a reluctant recipient of a recommendation to avoid taking substantive actions
A recommendation to address the attitudes and behaviours of managers and/or staff	When the prevention of an accident is heavily dependent on the correct application of a process by the staff involved and/or the quality of their decision making When there is no obvious engineered safeguard to reduce reliance on human reliability	Specific and effective actions to address human behaviours and underlying safety culture can be more difficult to define
A recommendation to conduct a wide-ranging review of the entire safety management system and its implementation	When the evidence points to wide-spread inadequacy with the safety management system and/or its implementation	Can be difficult to justify unless the underpinning evidence is particularly strong
A recommendation to address issues with regulatory oversight, or to increase the extent of regulatory oversight	When investigator judges that either: • regulatory oversight was deficient or • that the influence of the regulator would have a major impact on the management of the risk	Can detract from the organisation’s responsibility to manage its own risks

Ladbroke Grove (rail, 1999, UK)

Accident: Head-one collision between two trains after a signal was passed at danger

Recommendations: The public inquiry, presided over by Lord Cullen, led directly to a major reform of the way that safety was managed by the UK rail industry. Measures recommended included improved strategic safety management within individual railway companies, the establishment of a pan-industry safety body, improved regulatory oversight and the creation of an independent investigation body for railway accidents.

Actions: Lord Cullen's recommendations led to fundamental changes to the UK railway's safety management systems. Much greater pan-industry cooperation in matters related to safety was facilitated by the establishment of Railway Safety, later to become the Railway Safety and Standards Board (RSSB is an independent body, owned by the UK railway industry, which manages standards, carries out high level risk assessment and conducts safety research). The role of the safety regulator was clarified following the accident and an independent rail accident investigation body was established, the Rail Accident Investigation Branch (RAIB).

Piper Alpha (oil production platform, 1988)

Accident: Explosion and subsequent oil and gas fire

Recommendations: There were 106 specific recommendations in the report but probably the most important was the recommendation that focused on the need for anyone operating an offshore installation to have a safety case accepted by the UK health and Safety Executive. This was designed to ensure that a safety management system was in place and that the risk was being actively managed.

Actions: Shell Exploration and Production led in developing one of the first formally documented safety management systems. The changes made to the safety management of high hazard industries of this type were to reinforce a move towards more self-regulation and goal-based safety management techniques.

Grayrigg (rail, UK, 2007)

Accident: High speed derailment of passenger train following catastrophic failure of a set of facing points (otherwise known as switch and crossings, S&C)

Recommendations: The report issued by the RAIB included 29 recommendations. Of these nearly half covered issues closely associated with organisational risk management. These included:

- improved processes for monitoring the performance of safety critical assets (S&C), including the recording of defects and failures
- the adoption of a structured risk based approach to assessing the reliability of safety critical components – as an input to improved design
- the provision of information required by maintainers to ensure the continued safe condition of safety critical assets
- a fundamental review of the competence management systems for maintenance and inspection staff
- an examination of human reliability risk in the context of S&C maintenance and inspection, including an exploration of the potential safety benefits of improved technology (such as automated inspection systems)
- improved regulatory oversight of the maintenance regime safety critical assets
- a review of the ways that the principles of engineering safety management should be applied to existing assets
- clearer definition of the roles and responsibilities of senior engineering managers, particularly in areas of interface between track and signalling

- improved management assurance processes, including the inclusion of end-product checks in audits and other forms of compliance checking
- understanding the impact of long hours on human performance.

Actions: The above recommendations led to a programme of improvement activities by the infrastructure manager. Actions arising from this included:

- new management processes for recording possible precursors to loss of integrity in S&C (such as loose bolts or cracked fastenings)
- the development and installation of an alternative design of stretcher bar across the network
- provision of information to maintainers and the establishment of a structured competence management regime
- improved risk assessment techniques for all safety critical components (based on application of the bow-tie methodology)
- creation of a new role, "Head of S&C", designed to ensure that a single senior engineer has overall technical responsibility for all interfaces within a set of S&C.

Challenger space shuttle (USA, 1986)

Accident: On 28 January 1986, the American shuttle orbiter Challenger broke up 73 seconds after lift-off. The disaster claimed the lives of all seven astronauts on-board. It was later determined that two rubber O-rings, which had been designed to separate the sections of the rocket booster, had failed due to cold temperatures on the morning of the launch

Recommendations: The report issued by the commission that investigated the accident included nine recommendations. These included:

- a review of the management structure to enable clearer accountability, the creation of a safety advisory panel and improved management communications (recommendations II and V)
- identification of all safety critical components, subsequent hazard analysis and identification of items for improvement to ensure safety and reliability (recommendation III)
- the establishment of an independent Office of Safety, Reliability and Quality Assurance, reporting directly to the NASA Administrator, with direct authority for safety, reliability, and quality assurance throughout the agency (recommendation IV)

Actions: Actions arising from these recommendations included:

- a major review of the NASA management structure that led to a strengthening of the responsibility of the centralised headquarters for all programmes and improved lines of communication
- the establishment of an independent Space Flight Safety Panel
- improved processes for reviewing flight readiness
- a detailed failure modes and effects analysis (FMEA) was performed on each component of the Shuttle system to identify hardware items that were critical to the performance and safety of the vehicle

- a comprehensive hazard (risk) analysis was performed
- NASA established an Office of Safety, Reliability, Maintainability, and Quality Assurance (SRM&QA). This office was established to deliver the following functions:
    - to act as a check and balance for the overall NASA operation
    - to provide an independent assessor of safety critical activities
    - to develop and ensure implementation of clearly defined policies and procedures for SRM&QA.
- an improved integrity assurance programme to ensure that the performance of all systems met the design requirements for each flight. This included the inspection, maintenance, operations and analysis activities that were required to ensure safe and reliable operation.

Discussion and conclusions

A safety management system can be described as a formal framework for the management of risk. This paper has identified the need for accident investigators to look carefully at the way that the organisation sought to understand its risk, the adequacy of its control measures and the underlying reasons for any failure in their application.

No special investigative techniques are required to gain a full understanding of the role of the SMS in the causation of an accident. Rigorous application of most current techniques used by accident investigation practitioners should always lead the investigator to ask the following five key questions of an organisation (see also Figure 5):

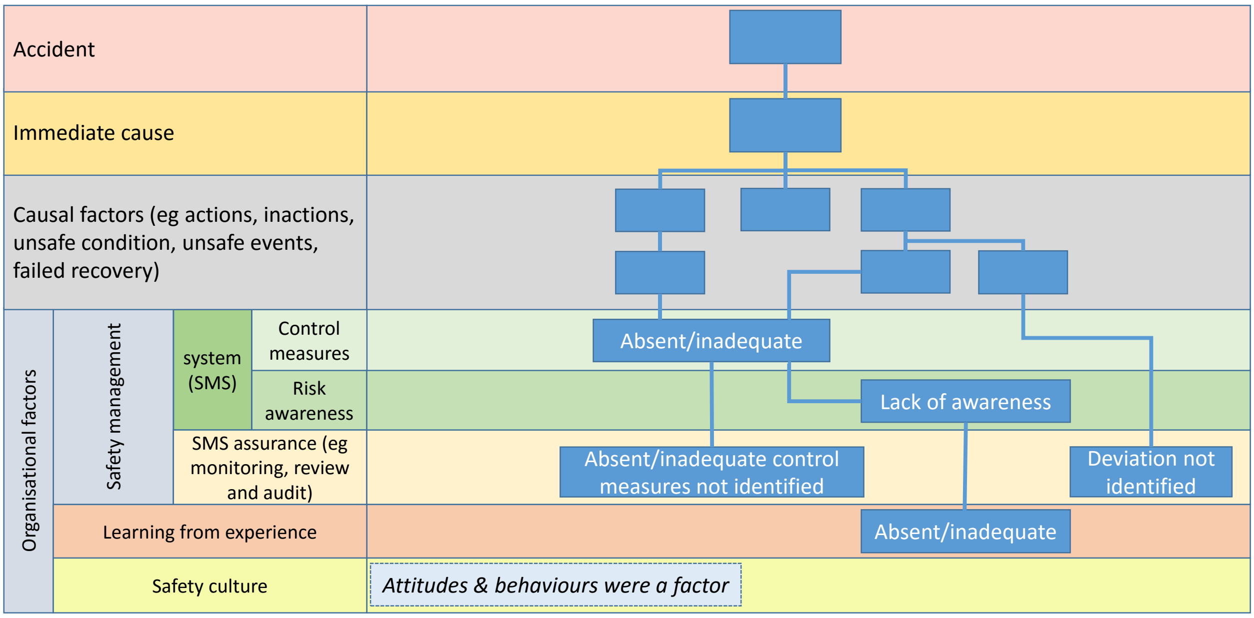
If any of the answers are as shown below it can be concluded that the SMS may have been a factor in the causation of an accident:

1. What were the relevant control measures defined in the SMS? How were they documented, understood and applied?
2. To what extent were the hazards and risks understood?
3. What mechanisms were in place to monitor and review the efficacy of the safety management system?
4. How did the organisation learn from previous experience, and then use that experience to improve its safety arrangements?
5. How did the prevalent attitudes and behaviours within the organisation contribute to the accident/incident?

Box 1. **Typical indicators that SMS was a factor in the causation of an accident**

1. Control measures were absent or inadequate.
2. Hazards had not been identified and/or the risk was not understood.
3. The organisation had not recognised that its control measures were deficient or had failed to detect non-compliance with its safety systems.
4. The organisation had not learnt lessons from previous experience or had not taken previous learning into account.
5. The safety culture created the conditions that allowed the accident to occur.

Figure 5. **The investigation of safety management systems and safety culture: A simple model**



Conclusions

Many transport organisations in the developed world have now developed a safety management system as a means of managing their organisational risk. Furthermore, most are committed, to at least some extent, to the promotion of a positive safety culture. This means that investigators in countries with developed economies rarely find the complete absence of a safety management system but are instead discovering gaps and areas of weakness in the documented safety defences. These discoveries do not always stem from a detailed examination of the safety management system itself, but will often to arise from a thorough application of classic techniques of causal analysis.

It is recognised that investigators need to be more aware of the role of safety management systems if they are properly understand the means by which transport organisations are managing their risk.

Since this paper was written by experienced investigation practitioners it is perhaps inevitable that its conclusions are practical in nature and are presented in the form of a list of issues for consideration by the investigator:

- There is no universally agreed list of issues to be encompassed within a safety management system. For this reason investigators need to be aware of the legal framework under which the organisation they are investigating is operating and any guidance generally considered to represent good practice in the country (or countries) concerned.
- Good accident investigation is a powerful tool for revealing the underlying reasons for accidents. However, it is not for accident investigators to verify the quality of entire safety management systems – their job is to understand the underlying reasons for an accident. This will often take the investigator into the domain of safety management systems or require an understanding of the prevalent safety culture.
- It is not the job of investigators to merely check compliance (that is a matter for the auditor). Non-compliance with a defined process does not guarantee a dangerous outcome but may be indicative of a problem with the safety arrangements. Compliance with a defective process may also give rise to an accident. Investigators may conclude that multiple instances of non-compliance provide evidence of a problem with the underlying safety culture, alternatively it may also indicate a wide spread lack of competence or the absence of workable procedures.
- When performing causal analysis it is important for investigators to always look for the reasons why those involved deviated from the defined process, or why the defined process was inappropriate. This requires an understanding of the contextual drivers that influence decision-making such as goal conflicts, local adaptations and non-compliance with formally documented rules, procedures and safe practices.
- Fox (2008) provides useful guidance on the underlying causes of accidents, expressed in organisational terms. Her grouping of these provides a useful checklist for investigators: adaptations/drift, goal conflicts, non-reporting incidents, identifying hazards and mitigating risks, resilience and multiple accidents (see section “A wider perspective).
- An important theme to be explored by investigators is the extent to which hazards and risks were properly understood by organisations in the period before an accident. This is particularly important when considering the influence of organisational or technical change.
- The power of accident investigation as a tool for seeking safety improvement is highly dependent on the product (i.e. the investigation report) being seen as reliable. For this reason all findings should be based on the best evidence available and areas of uncertainty need to be clearly identified to the reader of the report. It is therefore vital that any evidence of deficiencies in the safety management system is carefully assessed and corroboration sought. Particular care should be taken to assess the reliability of witness evidence since this can easily be affected by the emotions that often accompany a serious accident – it is always best to avoid wide-ranging conclusions on the basis a single uncorroborated interview.

- A deficiency in one area of an organisation's safety management system does mean that the entire SMS is defective. Exaggerated claims about the poor health of a company's management systems will do no end of damage to the credibility of an investigator. For this reason, investigators should only make recommendations for major change to a safety management system when they have evidence of a major structural flaw in the exiting regime, or a weak safety culture throughout the organisation.
- Safety culture is particularly difficult to evidence since by its very nature it is dynamic and will be affected by a recent accident. It is also the case that attitudes and safety behaviours can differ greatly in different parts of the same organisation. However, following the various strands of causal analysis in a methodical manner can often reveal indicators of a weak safety culture. These may include:
    - the absence of suitable documented safety systems or effective informal safe ways of working
    - a tendency for staff or managers to deviate from safe practice and/or procedures
    - a marked difference between the model of reality presented by managers and the perceptions of those whom they manage
    - a lack of awareness of hazards and the risk they pose (an "uninformed culture")
    - an unwillingness, or inability, to explore the ways that the organisation's risk management arrangements can fail, particularly at times of change ("a lack of requisite imagination")
    - a focus on production at the expense of safety
    - an absence of reporting of previous incidents and/or the absence of a process for learning lessons from the past (a "non-reporting culture" in an organisation that does not learn from the past)
    - rigidity and a failure to adapt to changing circumstances
    - a tendency to look for someone to blame when things go wrong.

As Stauch pointed out, the way forward when considering safety culture is for investigators to focus on those organisational factors that are identifiable and assessable and to consider how these factors in turn will provide insights into an organisation's culture.

- Well-crafted recommendations are capable of bringing about major change in a company's safety management system. However, to have this effect recommendations will need to meet the following criteria:
    - They must be well supported by evidence.
    - They must be capable of delivering a tangible improvement to safety.
    - They must be proportionate to the risk they are addressing.
    - They should target the area of proven deficiency.
    - They should never propose a definitive solution to the safety issue that has been identified (since this places the investigator in the role of risk manager).

Recommendations relating to safety management systems can have far reaching effects (including unintended consequences) and should therefore always be the subject of extensive consultation with the organisation concerned and the safety regulator.

Annex 1. Examples of SMS requirements for different transport modes

Chapter 5 of the ICAO Safety Management Manual

1. Safety policy and objectives
    - 1.1 Management commitment and responsibility
    - 1.2 Safety accountabilities
    - 1.3 Appointment of key safety personnel
    - 1.4 Coordination of emergency response planning
    - 1.5 SMS documentation
2. Safety risk management
    - 2.1 Hazard identification
    - 2.2 Safety risk assessment and mitigation
3. Safety assurance
    - 3.1 Safety performance monitoring and measurement
    - 3.2 The management of change
    - 3.3 Continuous improvement of the SMS Chapter 5. Safety Management Systems (SMS)
4. Safety promotion
    - 4.1 Training and education
    - 4.2 Safety communication.

Annex III of the EU Railway Safety Directive 2004/49/EC

The basic elements of the safety management system are:

(a) A safety policy approved by the organisation's chief executive and communicated to all staff.

(b) Qualitative and quantitative targets of the organisation for the maintenance and enhancement of safety, and plans and procedures for reaching these targets.

(c) procedures to meet existing, new and altered technical and operational standards or other prescriptive conditions as laid down in TSIs; or in national safety rules referred to in Article 8 and Annex II; or in other relevant rules; or in authority decisions, and procedures to assure compliance with the standards and other prescriptive conditions throughout the life-cycle of equipment and operations.

(d) Procedures and methods for carrying out risk evaluation and implementing risk control measures whenever a change of the operating conditions or new material imposes new risks on the infrastructure or on operations.

(e) Provision of programmes for training of staff and systems to ensure that the staff's competence is maintained and tasks carried out accordingly.

(f) Arrangements for the provision of sufficient information within the organisation and, where appropriate, between organisations operating on the same infrastructure.

(g) Procedures and formats for how safety information is to be documented and designation of procedure for configuration control of vital safety information.

(h) Procedures to ensure that accidents, incidents, near misses and other dangerous occurrences are reported, investigated and analysed and that necessary preventive measures are taken.

(i) Provision of plans for action and alerts and information in case of emergency, agreed upon with the appropriate public authorities.

(j) Provisions for recurrent internal auditing of the safety management system.

The International Safety Management (ISM) Code (Annex to IMO Assembly Resolution A.741(18) – 1993

Every company should develop, implement and maintain a Safety Management System (SMS) which includes the following functional requirements:

- a safety and environmental protection policy
- instructions and procedures to ensure safe operation of ships and protection of the environment in compliance with relevant international and flag State legislation
- defined levels of authority and lines of communication between, and amongst, shore and shipboard personnel
- procedures for reporting accidents and non-conformities with the provisions of this code
- procedures to prepare for and respond to emergency situations
- procedures for internal audits and management reviews.

Annex 2. Rail Accident Investigation Branch References

Reference	Title
Kirklees, 04/2012	Boiler incident on the Kirklees Light Railway, 3 July 2011
Stowmarket, 25/2012	Road vehicle incursion and subsequent collision with a train at Stowmarket Road, 30 November 2011
Reading West, 02/2013	Freight train derailment at Reading West Junction, 28 January 2012
Stafford, 16/2013	Signal passed at danger at Stafford, 26 April 2012
Beech Hill, 17/2013	Collision between a train and a car at Beech Hill level crossing, near Finningley, 4 December 2012
Old Street, 03/2014	Penetration and obstruction of a tunnel between Old Street and Essex Road stations, London, 8 March 2013
Gloucester, 20/2014	Freight train derailment near Gloucester, 15 October 2013
Camden Road, 21/2014	Derailment at Primrose Hill / Camden Road West Junction, 15 October 2013
Chester, 26/2014	Buffer stop collision at Chester station, 20 November 2013
Stoke Lane, 02/2015	Derailment of a freight train at Stoke Lane Level Crossing, near Nottingham, 27 August 2013
Paddington, 03/2015	Derailment of an empty passenger train at Paddington station, 25 May 2014
Walkergate, 09/2015	Parting of the live overhead wire at Walkergate station, Tyne and Wear Metro, 11 August 2014
Angerstein, 11/2015	Freight train derailment at Angerstein Junction, 2 April 2014
Watford Tunnel, 12/2015	Train struck and damaged by equipment cabinet door in Watford Tunnel, 26 October 2014
Heworth, 16/2015	Freight train derailment at Heworth, Tyne and Wear, 23 October 2014
Windsor and Eton, 18/2015	Electrical arcing and fire under a train near Windsor and Eton Riverside, 30 January 2015
Channel Tunnel, ET/2016	Eurotunnel freight shuttle 7340, 17 January 2015
Froxfield, 02/2016	Collision between a train and a fallen bridge parapet at Froxfield, Wiltshire, 22 February 2015
West Wickham, 03/2016	Passenger trapped and dragged under a train at West Wickham, 10 April 2015
Godmersham, 05/2016	Derailment at Godmersham, Kent, 26 July 2015

Annex 2. Rail Accident Investigation Branch References (cont.)

Reference	Title
Market Street, 06/2016	Tram collision with pedestrian near Market Street tram stop, Manchester, 12 May 2015
Oakwood Farm, 07/2016	Collision between a train and a tractor at Oakwood Farm User Worked Crossing, Knaresborough, 14 May 2015
Wootton Bassett, 08/2016	Signal passed at danger on approach to Wootton Bassett Junction, Wiltshire, 7 March 2015
Bryn, 09/2016	Runaway and collision at Bryn station, Wigan, 27 November 2014
Logan, 13/2016	Freight train collision near Logan, East Ayrshire, 1 August 2015
Kings Cross, 15/2016	Collision with buffer stops at King's Cross, 17 September 2015
Knaresborough, 16/2016	Derailment at Knaresborough, 7 November 2015
Shalesmoor, 17/2016	Collision between two trams at Shalesmoor, Sheffield, 22 October 2015
Reading and Ruscombe, 18/2016	Two signal passed at danger incidents, at Reading Westbury Line Junction, 28 March 2015, and Ruscombe Junction, 3 November 2015
Knockmore, 20/2016	Collision at Knockmore Junction, Northern Ireland, 4 February 2016
Mount Sorrel, 21/2016	Collision between a train and a piece of equipment at Barrow-upon-Soar, Leicestershire, 14 February 2016
Lamington, 22/2016	Structural failure caused by scour at Lamington viaduct, South Lanarkshire, 31 December 2015
Grimston Lane, 23/2016	Fatal accident at Grimston Lane footpath crossing, Suffolk, 23 February 2016

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