Research Report:
Achieving greater resilience to major events - Organisational learning for safety risk management in complex environments

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1 INTRODUCTION TO THIS REPORT

1.1 BACKGROUND

Resilience to failure represents a cornerstone of effective risk management. It relates to the capacity to deflect, absorb and return from disruptive challenges to extant processes and systems. It is not a state with a defined end-point, rather it is about dynamic and continuous improvement. The challenge for employers and safety professionals rests with the capacity to identify vulnerabilities and to use the derived learning to inform strategy for maintaining current and enhancing future resilience.

The complexity of large-scale organisations is increasing. This is often manifest in terms of organisations' structures, systems and processes and exacerbated when combined with trends towards increasing specialisation, the resultant bureaucracy of knowledge and the ever-present scope for partisan agendas. This renders the recognition of vulnerabilities particularly challenging.

The capacity to recognise vulnerabilities, which invariably arise from interactions between variables, is challenging in itself. But even where recognised, the associated complexity can exceed the mental capacity of individuals or controlling minds, such that their recognition relies upon the quality of engineered and social systems put in place to gather and synthesise intelligence. However, bitter experience from major events has taught us that the presence of effective structures and systems alone may not prove to be sufficient where there are cultural barriers to effective learning, e.g. where critical voices are unwelcome, suppressed, or simply ignored, or where economic considerations dominate micro-political agendas and priorities.

Linked with the concept of safety culture maturity, the term 'learning organisation' has entered the safety and risk management lexicon. 'Learning organisations' are institutions defined as having reached a state of maturity in their approach to risk management such that they pro-actively seek out data and other evidence to test for vulnerabilities in their structural, engineered and social systems. Learning can take a variety of forms, and can be derived from an array of sources, key amongst which, are learning from incidents (within and beyond the organisation); learning from effective monitoring of the safety status of systems and processes, including behavioural components; intelligence gathering through meaningful engagement and, involvement of employees.

High profile, high consequence industrial accidents represent a key source of learning that other organisations can draw upon to enhance their resilience. Similarly, there is considerable scope to apply learning from incidents within one's own organisation in the same way. A unifying prerequisite, however, rests with the need for a strong, critical focus on identifying root causes and commonalities, underpinned by the need to be mindful of the illusion of retrospective determinism (Bergson, 1911) giving rise to an unduly narrow perspective. A key insight of deeper analysis is that causality is routinely non-linear, in the sense of a simple intuitive chain of events (see parts 1 and 3). This analysis suggests less transparent influences, that lie beyond engineered systems and arising from the interplay with structural, socio-technical and cultural elements.

Recent decades have witnessed a growing recognition of the need to understand and take account of these 'softer' components in incident causation. Doing so requires engagement with social science insights, notably from management theory, cognitive psychology, social psychology and sociology, as well as traditional human factors and ergonomics principles. Reflecting the engineering roots of the industrial safety tradition, the central focus has been on systems, rather than individuals per se, i.e. how the context (structural, engineered and social) of the workplace interact to impact on individual and group behaviour. This has given rise to a significant interest in both recognising and understanding such influences and finding ways of measuring their prevalence.

Of particular note is the work on safety climate/culture, as well as an array of auditing techniques, notably those focused on behavioural elements. The merits of the more commonly encountered approaches are discussed in Part 2. The focus on softer non-engineered elements has been widely justified by duty holders and some safety professionals on the basis of a claimed plateauing of safety performance attributable to engineered solutions. However, this premise remains contentious, and conceptually risks oversimplification and propagation of artificial separation between social, technical and structural elements, that are prone to

interact in complex ways that may not be immediately apparent. The capacity to recognise the subtlety of the relationships between these variables can be important, as exemplified in the discussion of major events in Part 1 and the modelling techniques discussed in Part 3.

Our perspective on the use of evidence to enhance resilience, however, extends beyond the identification of vulnerabilities, whether derived from lag or lead indicator sources, to the challenging arena of effective intervention design to produce improvement, specifically with respect to cultural and behavioural elements (Parts 2 and 3). A central premise is that learning through effective data capture is key to the design and delivery of successful change agendas, again, underpinned by a strong commitment to critical introspection.

This report commences (Part 1) with an account of findings and implications from an analysis of 12 major incidents within the petrochemical, nuclear, civil engineering, transport and space exploration sectors. Echoing findings from related foundation work within the University of Bristol Safety Systems Research Centre, the key finding is that these incidents share a number of common organisational and cultural weaknesses. The implications of this leads to the question of how organisations might go about detecting the presence of these and other vulnerabilities, and most pertinently, what steps they might take to address identified vulnerabilities, this being the focus for Parts 2 and 3. Part 2 provides a critical perspective on the use of incident and other safety performance data/evidence to detect organisational and cultural weaknesses of the type identified in Part 1, before moving to the challenging issue of intervention design and delivery. The scope for applying cutting-edge modelling techniques as a potential tool for organisations to desktop prototype the logic of their ideas for intervention is discussed in Part 3.

1.2 EXECUTIVE SUMMARY

1.2.1 Part 1: Cultural precursors to major events: good practice expectations

Part 1 reports on findings from a deeper analysis of the causative, organisational and cultural precursors for a sample of 12 major events drawn from a range of industry sectors. Ten 'themes' are identified that provide a means of classifying these important precursors to the events. These are:

1. Leadership
2. Safety Culture
3. The Business Environment - Commercial Pressures
4. Effective Communication
5. The Safety Management Systems
6. Risk Assessment and Management
7. Developing and Maintaining a Learning Organisation
8. Maintaining Competence
9. Management of Contractors - the Supply Chain
10. Oversight and Scrutiny

Within each of these themes, findings from the event reports, and some further points prompted by them, have been drawn together to form 'organisational expectations'. These should, in theory, allow organisations to integrate these, or benchmark against, their own operational and organisational requirements, e.g. policies, requirements or good practice guidelines.

The expectations (150 in total) are presented as a series of statements. The objective was that these should act as a source of reference that would enable organisations to assess ('benchmark') their own approach and expectations, either against the collective results or within specific areas where they have a particular interest or concern.

The expectations are complemented by a discussion and commentary designed to put them into context and to explain their importance.

The findings should also be of interest to regulatory bodies in considering their requirements on duty holders, and also to industry bodies and international organisations that have a role in promoting good practice.

A major recommendation of this review is that the set of expectations should be further developed into a set of 'penetrating' questions to assess operational 'reality'. This would provide employers and safety professionals with an important new tool that could be applied at a range of organisational levels to assess vulnerability to major industrial events, i.e. as a supplement to functionally similar 'tools' currently used to assess engineered vulnerabilities. Further development would be required.

If it is assumed that 'benchmarking' against the expectations identifies areas where potential improvements might be made, the key question then arises as to how the derived insights and learning might be used to inform corporate decision making over the design of interventions that address identified vulnerabilities. This is discussed in Part 3, drawing on examples from the learning identified in Part 1.

1.2.2 Part 2: Organisational learning and the design of evidence-based interventions

Part 2 provides a critical commentary on contemporary theory and practice in addressing behavioural and cultural elements. A core theme relates to the role of evidence within the related domains of:

- identifying structural, organisational and socio-technical weakness;
- setting priorities for intervention to enhance resilience;
- intervention options appraisal – theories of change and **what works**, and
- intervention design and delivery – intervention logic – **how will 'it' work** and impact evaluation.

Options are also discussed for data gathering, and the relative strengths and limitations of lag and lead indicators and their potential contribution to identifying priorities for informing managerial/safety function thinking over intervention and improvement.

Options for intervention are discussed, with reference to influential mainstream theories of behaviour change, supplemented by critical reflection upon the more widely encountered approaches to intervention within the safety domain. The commentaries on contemporary safety culture and behavioural safety practice are informed through the author's involvement in some of the foundation UK research on these topics.

The perspective on intervention extends to engagement with the under-articulated area of options appraisal, i.e. by what mechanism is change theorised to occur; what proportion of individuals might be predicted to make sustainable changes to their behaviour; what will be the roles of respective stakeholders, how much progress is required by when? etc. The scope for applying system dynamics modelling techniques to intervention options appraisal and design (see Part 3) is discussed.

Part 2 is supported by five themed annexes that offer a more detailed articulation of the history, assumptions and strength of evidence for the concepts, tools, techniques discussed within the body text:

- Annex A: The characteristics of high-reliability organisations - many of which maintain and sustain their resilience to failure in ways that align with the expectations developed from the learning from events presented in Part 1.
- Annex B: Safety culture maturity and how it can be assessed.
- Annex C: Strengths and weaknesses of behaviours.
- Annex D: Limits of training and communication interventions.
- Annex E: Considerations in the use of incentives and reward.

1.2.3 Part 3: System dynamics modelling

Part 3 presents the argument that the ability of an organisation to learn from past events and proactively improve resilience is often constrained by simplifications made in the way we conceive and model event causality. Part 3 explores the scope for using system dynamics modelling as a means of identifying, articulating and making transparent, vulnerabilities within complex socio-technical systems that balance some of the shortfalls of other existing approaches. Causal loop diagrams (CLDs) provide an intuitive graphical representation of how variables interrelate and align. Modelling is relevant to a range of complementary risk management domains, including:

- representation of incident causality;

- testing the resilience of established safety systems and control measures and,
- proof-testing the logic of change/improvement intervention ideas.

The scope for further development is discussed.

Following an introduction to CLD using simple examples, three case studies are presented to highlight the application of causal loop modelling (CLM) in relation to examples considered in Part 1. The first of these relates to the theme of 'oversight and scrutiny'. The second addresses 'incentives and indicators', while the third considers the causal factors relating to 'contractor and supply chain management'.

Through these examples, archetypal structures of organisational and cultural precursors to failure aligned with the themes discussed in Part 1 are presented. These reconceptualise elements of the precursors as being emergent from the interactions between multiple variables. This assists in ensuring not just that unhelpful or dangerous behaviours are prevented, but that the underlying systems that cause those behaviours are identified and treated. Efforts to control these variables as discrete from one another, or as simply part of a chain of causality, can result in ineffective interventions. It is thus through this re-conceptualization that better reflects the complexity of the organisations and systems in question, that potential interventions can be tested at a systemic level.

PART 1

CULTURAL PRECURSORS TO MAJOR EVENTS: GOOD PRACTICE EXPECTATIONS

2 INTRODUCTION TO PART 1

Part 1 sets out a series of 'expectations' for good practice. The expectations were developed based on reviewing the findings of published investigations into twelve important events that have occurred over the last twenty-five years across a range of industries that are engaged in 'process safety' (those engaging in activities that involve complex interactions between people, processes and engineered plant).

The expectations are presented under 10 broad headings that should enable organisations to assess ('benchmark') their own approach and expectations, either against the collective results or within specific areas where they have a particular interest or concern. The learning can be incorporated into major organisations' operational and organisational requirements – e.g. 'policies', 'requirements', 'standards' or 'good practice guidelines'.

The findings should also be of interest to regulatory bodies in considering their requirements on duty holders, and also to industry bodies and international organisations that have a role in promoting good practice.

Many of the findings should apply to 'occupational safety' (sometimes referred to as 'personal safety' or 'industrial safety') that refers to personal injuries or fatalities arising from day-to-day activities in the course of work such as slips, trips and falls, but the context of this report concentrates on the organisational and cultural precursors to major events that led (or could have led) to major loss of life, significant plant damage, environmental consequences, major costs, and a potential loss of corporate (and wider industry) reputation.

The development of the material presented in Part 1 relies for its content on the presented recommendations, conclusions and discussion in the event investigation reports used as source material and referenced in Section 3. In a few areas, prompted by the event findings, the expectations have been strengthened and further developed where it is judged that by doing so provides additional valuable insights or greater clarity regarding particular identified issues.

The events studied were deliberately chosen to encompass a wide variety of industries including chemical plant, nuclear installations, transport, and major civil engineering undertakings. This wide range reflects earlier studies of events (Taylor, R. H. and Rycraft, H. S., *Learning from disasters;* Taylor, R. H et al, *A study of the precursors leading to 'organisational' accidents in complex industrial settings;* Taylor, R. H. et al, *Understanding organisational and cultural precursors to events*) that had shown significant commonality in organisational and cultural precursors across a wide range of industry settings and contexts, including events occurring during 'normal' operation, during higher-risk operations such as start-ups and shutdowns, and in major projects to improve plant or construct new facilities.

2.1 POTENTIAL USES OF THE EXPECTATIONS

The expectations that have been developed may be useful in a number of ways:

a) They can be used as general 'reminders' of the organisational and cultural precursors to major events and thus to raise awareness of these important and sometimes neglected issues. They may be of particular value to leaders and senior managers who may not be fully familiar with some of the issues involved, and the information presented may enable them to ask informed questions about the areas discussed. It may also help them to recognise more clearly how their decision making can influence the issues identified and that could lead to poor or deteriorating standards of process safety performance if not adequately addressed. It may also be valuable in this context for introducing new managers and leaders to the key issues that underpin process safety as part of their initial training.

b) Another potential use may be as a checklist for those investigating events. Some investigations still 'stop' their analysis by concluding that, for example, 'levels of competence were not high enough', or that 'procedures were not followed' and do not go deeper into the causes to investigate why these issues arose. The expectations might, therefore, be valuable as an 'aide memoir' to investigators in order to prompt a deeper examination of organisational and cultural issues. A potential area of further work would be to

develop an investigation 'tool' aimed at promoting full and consistent investigation of relevant organisational and cultural issues following an event.

c) The primary consideration in carrying out this work, however, was to enable organisations to develop or review their expectations (or the equivalent) and enable them to benchmark them against what has been learned from the wide range of actual events studied here. This might be done either in specific areas considered as requiring review (e.g. contractor management or leadership) or more systematically to compare existing expectations or their equivalent, across the whole range of pertinent issues that have been identified here. Some regulators and other bodies have also developed guidance for their inspection teams that attempts to address organisational and cultural issues. For example, the Office for Nuclear Regulation (ONR) in the UK have published safety assessment principles (SAPs) that address many of the themes identified in this document (ONR, *Safety assessment principles for nuclear facilities*). The expectations developed here may provide an opportunity for these to be benchmarked in a similar way to that for industry.

d) Finally, it has been noted that there are already 'tools' (such as probabilistic risk assessment (PRA), human reliability analysis (HRA) etc.) that allow organisations to assess performance in engineering and human factors requirements and practice on a periodic basis, as part of their process of risk assessment for planned or existing operations. The expectations presented here should provide a basis for organisational and cultural issues to be assessed in the same way as part of that process. Some foundation work has been carried out to develop the expectations into sets of 'penetrating questions' that might allow analysis of these matters to be similarly explored. Preliminary work in the area of leadership (McBride, M., Taylor, R. H, and Sibbick, G., *Organisational and cultural causes of accidents - a pilot study*), for example, suggested that this could be a useful development that would enable industry and regulatory bodies to explore current practices. This may lead to interventions, and it is then important that the learning presented in the rest of this document on CLM and psychological and behavioural factors in developing effective interventions, should be fully taken into account.

The potential uses are illustrated schematically in Figure 1.

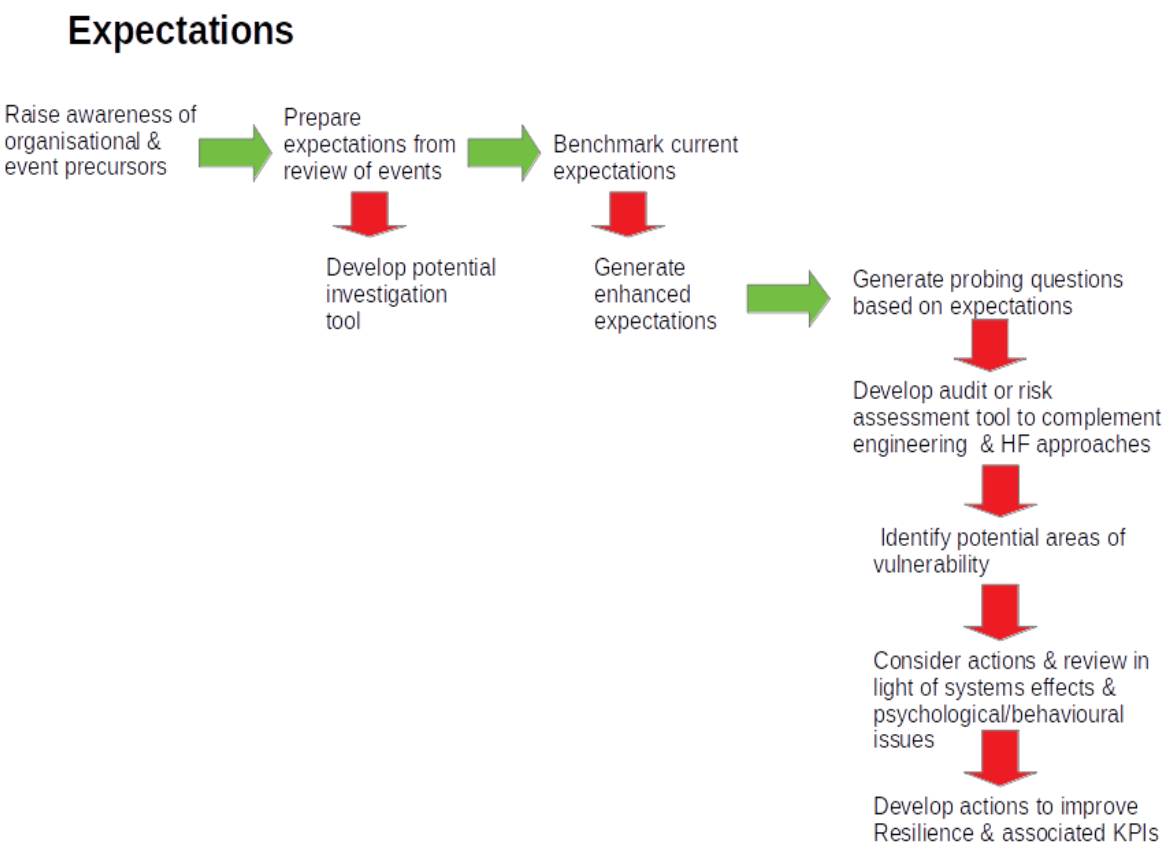


Figure 1: Potential uses of the expectations generated from analysis of the twelve events

3 METHODOLOGY

3.1 METHODOLOGY

This study builds on earlier work conducted since 2004 (Taylor, R. H. and Rycraft, H. S., Le*arning from disasters;* Taylor, R. H. et al, *A study of the precursors leading to 'organisational' accidents in complex industrial settings*; Taylor, R. H. et al, *Understanding organisational and cultural precursors to events;* McBride, M., Taylor, R. H., and Sibbick, G., *Organisational and cultural causes of accidents - a pilot study*). The methodology used for this study was based on the approach used in the foundation work (Taylor, R. H. and Rycraft, H. S., *Learning from disasters*, and Taylor, R. H. et al, *A study of the precursors leading to 'organisational' accidents in complex industrial settings*). This earlier work only considered the results in broad terms, whereas the current study provides a significantly more detailed and comprehensive analysis.

The review was carried out in several stages:

a) The various reports into the twelve events (16 in total, ~2000 pages) were studied, and relevant paragraphs and sections identified where these contained findings relevant to organisational and cultural matters. From this initial work, the headings or 'themes' under which the results were to be presented were formulated.

b) The relevant, identified material was then assigned to one or more of the ten identified 'themes'. Points arising from each report frequently covered the same ground, so areas of commonality were then brought together for the issues identified;

c) These points were then reviewed and summarised before assigning them to relevant sub-section headings (e.g. 4.2.1, 4.2.2 etc.), that were chosen to cover the full range of material identified under each of the identified 'themes'. These are spread over Sections 4-13.

d) Work then proceeded sequentially on each theme, turning the summary material into a coherent narrative account. This was designed to identify the expectations, but also provide a commentary that considered their context and significance.

e) The narrative account was then summarised and presented within each theme in the form of a set of expectations without the contextual material provided by the commentary. This was designed to allow those interested in obtaining an overview of the expectations and in a form allowing organisations to carry out a direct comparison of the expectations with their own existing equivalent material.

f) In carrying out such an extensive review, there is always the danger that relevant material may be missed and that the reviewer introduces subjective biases into the selection and filtering of the material identified. To minimise this, a second 'run through' of the material summarised from the reports studied was then carried out. This allowed points to be further clarified where required in the commentary, and a few further points were added that had not been previously identified. Other team members were then invited to comment and to use the expectations in draft form to identify material that might form a basis, and provide examples, for subsequent parts on modelling of proposed interventions, and behavioural and psychological issues.

g) Finally, an independent review was carried out by another member of the research team to provide an independent partial quality check. Here, a sample of the twelve event reports were read and an analysis parallel to that above carried out to check that no significant issues had been omitted and to review the commentary and summaries. This indicated that no major issues had been omitted based on the reports reviewed, but allowed the discussion of a small number of the expectations to be improved or strengthened. Before finalising, the final draft was then reviewed by independent specialists from two external organisations to assess suitability and provide comments.

The methodology used is shown schematically in Figure 2.

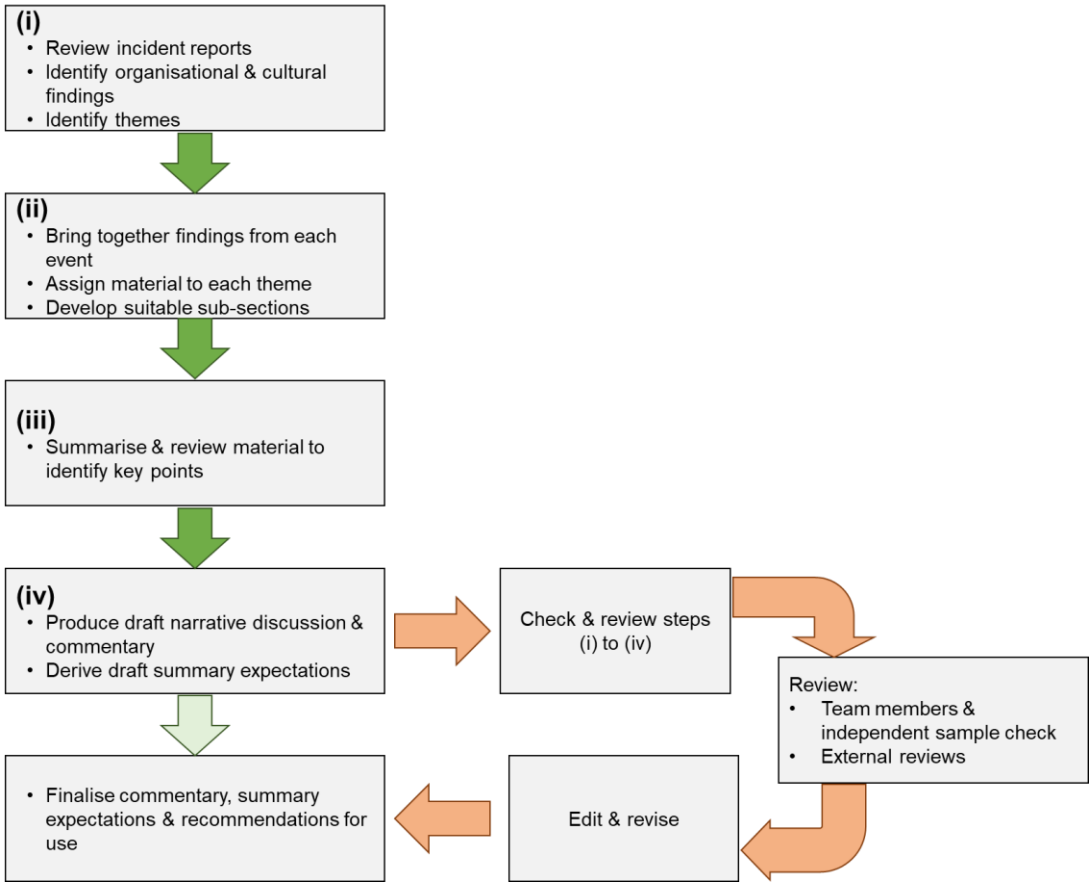


Figure 2: Representation of the method used to generate expectations

The events chosen were (in order of occurrence):

1. Port of Ramsgate walkway collapse – UK, September 1994 (Health and Safety Executive (HSE), *Walkway collapse at Port Ramsgate: A report on the investigation*).
2. Heathrow Express new Austrian tunnelling method (NATM) tunnel collapse during construction – UK, October 1994 (HSE, *Collapse of NATM tunnels at Heathrow Airport. A Report on the investigation by the HSE into the collapse of New Austrian Tunneling Method (NATM) tunnels at the central terminal area of Heathrow Airport on 20/21 October 1994*).
3. Longford gas plant explosion – Australia, September 1998 (Hopkins, A., *Lessons from Longford: The Esso gas plant explosion;* Royal Commission*, The Esso Longford gas plant accident: Report of the Longford Royal Commission*; State Coroner Victoria*, Inquest into the deaths of Peter Brubeck Wilson and John Francis Lowery and the fire at Longford gas plant number 1*).
4. Tokaimura criticality accident – Japan, September 1999 (International Atomic Energy Agency (IAEA), 1999, *IAEA report on the preliminary fact finding mission following the accident at the nuclear fuel processing facility in Tokaimura, Japan, 26 November 1999;* US Nuclear Regulatory Commission, Safeguards, D of F.C.S, *NRC review of the Tokai-mura criticality accident*).
5. Hatfield railway accident – UK, October 2000 (Office of Rail Regulation, *Train derailment at Hatfield: A final report by the Independent Investigation Board*).
6. Davis Besse pressure vessel corrosion event – USA, February 2002 (US Nuclear Regulatory Commission, *Davis-Besse reactor vessel head degradation lessons-learned task force report*).
7. Loss of the Columbia Shuttle – USA, February 2003 (Columbia Accident Investigation Board, *Columbia Accident Investigation Board report*).
8. Paks nuclear plant fuel cleaning event – Hungary, April 2003 (IAEA, 2003, *Report of the expert mission conducted under the IAEA Technical Co-operation Project*).
9. Texas City oil refinery explosion – USA, March 2005 (Baker, J. A. et al, *The report of the BP U.S. Refineries Independent Safety Review Panel*; Chemical Safety Hazards Investigation Board, *Investigation report: Refinery explosion and fire*; Mogford, J., *Fatal accident investigation report - Isomerization unit explosion final report*).
10. Loss of containment at the thermal oxide reprocessing plant (THORP) Sellafield reprocessing plant –

UK, April 2005 (Health and Safety Executive, *Report of the investigation into the leak of dissolver product liquor at the thermal oxide reprocessing plant (THORP), Sellafield*).

11. Buncefield Fuel Storage Explosion – UK, December 2005 (Buncefield Major Incident Investigation Board, *The Buncefield incident, 11 December 2005 - The final report of the Major Incident Investigation Board*).
12. Loss of the Nimrod XV230 Aircraft – Afghanistan, September 2006 (Haddon-Cave, Q. C., *The Nimrod review - An independent review into the broader issues surrounding the loss of the RAF Nimrod MR2 aircraft XV230 in Afghanistan in 2006*).

A brief description of each of these events is presented in Annex F. This choice of events was determined by a range of factors:

a) The availability of formal reports that looked in some depth at the organisational and cultural precursors to the events. Some candidate events were the subject of reports that took a more superficial view of such factors and these were therefore not used as input to the current study.

b) Events that had occurred relatively recently, so that the applicability of learning would still be relevant to current operations. More recent events may still be subject to continued investigation, analysis and (in some cases) legal action, so these were precluded from the study. Some earlier events had been considered as part of foundation work (Taylor, R. H. and Rycraft, H. S., Le*arning from disasters*), where they suggested precursors that were strikingly similar but were not included in later studies because they occurred some considerable time ago.

c) Events that industry partners, professional bodies, and academic sources had suggested were of considerable interest and from which they had derived learning.

Where specific events are cited, this is because of the learning opportunities that they present, rather than criticism of the organisations involved.

3.1 THEMES

The expectations were aggregated and considered under ten 'themes' that were chosen to cover the main findings and that were considered likely to reflect the key areas of interest to industry and regulatory bodies:

1. Leadership
2. Safety Culture
3. The Business Environment - Commercial Pressures
4. Effective Communication
5. The Safety Management System
6. Risk Assessment and Management
7. Developing and Maintaining a Learning Organisation
8. Maintaining Competence
9. Management of Contractors - the Supply Chain
10. Oversight and Scrutiny

It should be emphasised that in the analysis of events involving significant complexity and behavioural influences, learning may often need to be categorised under several of the themes. This is illustrated in Part 3, where CLM has been applied. For example, one of the case studies presented draws out in a very clear way potential interactions between various themes such as safety culture, oversight and scrutiny, business environment, communications and the safety management system (SMS) in terms of the wider 'knock-on' effects, as change taking place in one area impacts much more widely. The introduction to each of the Sections in Part 1 identifies where there is 'overlap' in the expectations and the associated commentaries.

In exploring the findings from the events studied and then developing the expectations under each theme, it was recognised that behavioural and psychological influences often played a key role in the causation of the events. Part 2 of this report discusses a range of such influences and where these appear to be particularly relevant to the issue under consideration, they are signposted in the commentary and discussion related to each theme in Part 1.

The order with which expectations relevant to these themes are presented reflects, in very broad terms, a hierarchy of organisational influence. Thus, leadership is presented first since this has the ability to 'shape' the other themes. Safety culture and the effectiveness of communication within the organisation are areas where corporate leadership commitment and example have a considerable influence over the way that these issues are treated across the organisation. The business environment (e.g. commercial or 'political' pressures) can strongly influence this leadership approach. The SMS contains requirements relating to risk assessment, reporting and learning, maintaining competence, and managing contractors and although these should again be influenced by the attitudes and behaviours of corporate leaders, the way that they are set and promoted in practice is primarily determined by 'business' or project leadership and management. Finally, oversight and scrutiny, which includes monitoring and audit, as well as broader organisational oversight (often carried out through the relevant safety function), ensures that expectations at all levels are both being communicated and effectively-being put into practice.

This approach to the ordering of the themes is illustrated in Figure 3. It should be noted, however, that in this illustrative representation, the interactive nature of some important issues are not fully drawn out (but are reflected in the text in Part 1). For example, leadership should strongly influence the safety culture of the organisation but there should also be feedback from the culture on the effectiveness of leadership. A very important matter such as learning from near misses requires effective and encouraging leadership, a strong safety culture, and effective management systems that are mutually supportive and reinforcing. The reference to 'encouragement of learning/improvement' and 'reporting and learning from events' within individual boxes within Figure 3, for example, does not mean to imply that interdependencies between elements of the diagram are not of very considerable importance.

Earlier studies used a slightly different set of 'themes'. In the present report, 'safety management systems' (previously considered along with safety culture) has been brought out as a separate theme and 'management of contractors', that had been previously been subsumed within several of the themes, was likewise separated, reflecting its importance as a major contributory factor in over half of the events studied. These changes were made in the light of re-analysing the various reports, and reflect the fact that both weaknesses in the SMS (and non-compliance with it), and issues with the drawing up and management of contracts, were both such major issues in many of the events that they should be recognised and addressed as separate themes.

Each theme is divided into sub-sections. These attempt to draw together the main areas of interest or 'topics' within the expectations. These are summarised in an introductory section to each theme. As discussed in 3.1, the sub-sections were identified as a result of aggregating the collective findings of all of the sources studied within a particular theme and then identifying suitable sub-sections based on the material available.

The material under each theme is developed in three main sections: an overview, the expectations in summary form (presented in tables), and a discussion and commentary on the expectations that puts them into context and explains their importance. There are between 10 to 21 expectation in each theme, and amount to more than 150[1] in total across the ten themes. It should be noted that there is strong correspondence between some of the identified expectations and the attributes ascribed to high-reliability organisations (HROs). These are discussed in Annex A.

Expectations under each theme have deliberately been grouped in order to ensure that each theme is 'self-standing'. Thus, if there is particular interest in certain themes where there may be the need to review current organisational expectations (or their equivalent), all relevant material should be contained within that theme. This does, however, mean that taking the expectations presented as a whole, there should be some duplication and overlap between material presented. Other approaches were considered in presenting the material, but the need to ensure that each theme remained 'self-standing' was considered to be of primary

[1] The fact that 150 expectations are considered necessary is, in itself, indicative of the complexity of the topic.

importance. Some cross-referencing at the end of the introduction to each theme has been provided, however, so that other relevant material can more easily be identified and considered.

The expectations presented in Part 1, provide a basis not only for benchmarking current organisational requirements against findings developed from events as mentioned above but provide a basis for the potential development of 'probing' questions within each of the key areas that would enable organisations to review or audit the degree to which operational practice meets organisational aspirations. Just as audit and oversight are important practices in ensuring acceptable standards in engineered systems and operational processes, it is anticipated that the current material could be able to provide a basis for a similar approach in reviewing organisational and cultural factors (see 'potential uses' in 1.1) - the importance of which are amply demonstrated by the events studied. Some successful earlier work has been carried out for one of the themes (leadership) (McBride, M., Taylor, R. H, and Sibbick, G., 2012, *Organisational and cultural causes of accidents - a pilot study*).

When improvements need to be made as a result of such a review, it is important that great care is taken in assessing the potential for unintended consequences in closely coupled and complex systems involving people, plant and processes. A systems view should be taken. Indeed, this is a finding from the reports on several of the events studied. As noted above, Part 3 of this report considers and provides examples of the application of CLM and shows how this has the potential to enable the identification of actions and performance indicators that take into account and address potential 'knock-on' effects.

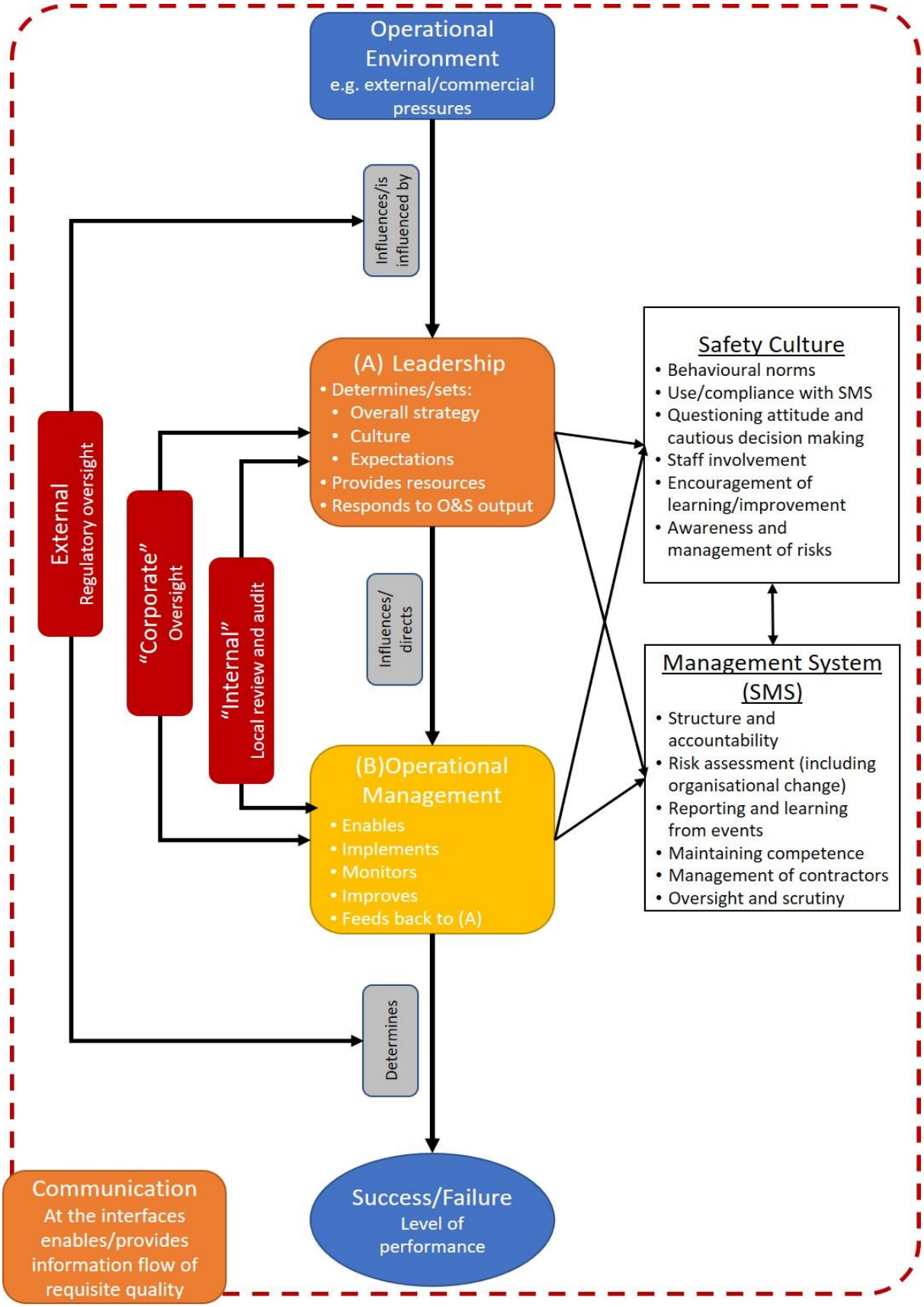


Figure 3: Schematic of the interaction between themes reflecting their order of presentation

4 EXPECTATIONS: LEADERSHIP

4.1 OVERVIEW

Effective leadership is arguably the most important factor influencing process safety performance in an organisation. Leaders set the tone of the organisation, and what they demonstrably and visibly regard as important gives a clear message to the workforce about organisational priorities.

It is recognised that in some sources, leadership is sub-divided into:

a) executive leaders, whose primary role is to determine business strategy and ensure independent oversight of performance;

b) line managers whose primary role is to ensure effective delivery of leadership objectives by ensuring, inter alia, that the workforce is able to meet the objectives being sought together with the planning, monitoring and auditing of work and,

c) supervisors, whose primary role is to provide direction and support to teams in the context of day-to-day activities.

In this document, the term leadership has been interpreted broadly to cover all of these roles, except where it is explicitly stated that reference is being made to a particular role.

In order for leadership at all organisational levels to be effective, many of the organisational systems discussed elsewhere in Part 1 (e.g. communications, maintenance of competence, etc.) have to be fully effective. The overall process is thus interactive and interdependent since leaders should not only have an important role in determining and maintaining these systems, but the success of their leadership roles should also depend upon the effectiveness of them.

Leaders should communicate their strong commitment to improving process safety and ensuring that risks are adequately addressed. This is particularly important when there are business pressures on the organisation and changes taking place that may impact on the process safety priorities of the workforce (including any contractors). Nearly all of the events studied occurred during periods when there were substantial business pressures. It is essential that senior leaders review the impact of the business environment on process safety and act to ensure that safety is not being adversely affected. Where pressures are being externally imposed, the potential impact on safety should be made clear to those imposing requirements on the business.

Leaders should also ensure that all required management systems are in place with adequate support and resource, together with a strong underpinning safety culture. It is very important that in their communications, their approach to safety culture and establishing organisational systems, a precautionary approach to process safety is taken that starts from the assumption that 'things can go wrong'.

Other sections in Part 1 where leadership related issues are discussed include sections 5, 6, and 13, with some references in sections 7, 8 and 11.

Table 1 - Summary of leadership expectations

L1	Business leaders should make it clear that safety is a core value and takes precedence over all other matters. This should not only be reflected in communications (including 'policy' documents and expectations) but also convincingly demonstrated by the attention given to process safety by all leaders. Boards should ensure adequate time at their meetings to review process safety and performance against expectations.
L2	Leaders should ensure that they are sufficiently knowledgeable about process safety to inform decision making, facilitate understanding of risks, and to ensure that all plant and projects conform to organisational requirements. They should engage in effective two-way communication with the workforce making clear their safety priorities, but also listening and responding to concerns raised, and ensuring effective follow-up action. They should lead by example and maintain high visibility in supporting a strong safety culture, effective implementation of the SMS, good working conditions and plant integrity and, 'defensive' systems such as audit and oversight in their various forms.
L3	Communications and subsequent actions should make it clear that ensuring excellence in process safety takes precedence over cost and resource considerations if and when there is any conflict between requirements. This should be demonstrated by ensuring sufficient resources for all operations and support roles, and in maintaining competence.
L4	Encouragement should be given for safety matters to be reviewed at plant and project level with a demonstrable openness and responsiveness to improvement suggestions and concerns, even when the latter may provide 'unwelcome' news that may affect production or costs. Any concerns (including inadequacies in the SMS) should be raised within a 'just' reporting system that is not unnecessarily constrained in its reporting criteria, and concerns raised should be prioritised and followed up, with feedback on developments given to staff. It should be made clear that compliance with the SMS is mandatory.
L5	In ensuring competence, attention should also be given to promoting expected behaviours and people skills. This is particularly important in ensuring investment in supervisory roles. Supervisors should be encouraged and supported to promote excellence in process safety by ensuring compliance, encouraging reporting of ideas and concerns, and maintaining a questioning attitude.
L6	Well understood roles, responsibilities and accountabilities should be assigned with clear lines of reporting. These should be kept as straightforward as possible to minimise overlap and unofficial hierarchies. Acting roles (including 'step-ups'), outsourcing of key roles, and processes for delegation and approvals should all be suitably controlled and subject to authorisation and other safeguards where relevant. Leadership and team stability should be maintained, wherever possible, to ensure that actions are seen through. The potential impact of incremental changes should be regularly reviewed.
L7	Leaders have a central role in maintaining and improving safety culture through their actions and personal commitment - particularly during periods of organisational change when safety culture commitment may be more vulnerable. Support should be given for the promotion of learning, open communication, a questioning attitude and a willingness to stand back and assess biases (including any conditioned responses and behaviours). They should be attuned to any developing deficiencies in these areas and others, such as organisational structures, work pressures leading to non-compliance, and loss of staff in key safety areas. Leadership issues and their implications for safety culture should be regularly re-assessed and action taken to address weaknesses.
L8	Before embarking on major organisational changes (including acquisitions and mergers), leaders should consider the potential impact on process safety. This should be reinforced by a rigorous and effective management of organisational change process with independent scrutiny that considers the potential impact of specific changes and potential unintended

	consequences. In addition, oversight and scrutiny during the process of change should provide checks of the change process and identify any unintended 'knock on' and incremental effects.
L9	Particular attention should be paid to controlling the change process such that 'initiative overload' and other working pressures do not lead to a loss of focus on process safety risks. Managers should be provided with assistance and advice, where required, to achieve effective prioritisation.
L10	Leaders should not only understand process safety risks, but have an appreciation of the requirement to reduce risks as far as is reasonably practicable. They should ensure that risks are reviewed regularly, with issues of importance brought to their attention, and that there are clear priorities for action. They should be assisted in this by a well-resourced and competent independent safety function. This capability is particularly important where a 'de-centralised' business structure is in place, in order to ensure that corporate expectations and policy priorities are being met.
L11	Where incentives are provided to staff for meeting performance objectives, process safety performance should be recognised. However, this should be done in such a way that reporting of concerns, 'events', and emerging issues is not adversely affected.
L12	Process safety-related risk assessments should be carried out using appropriate up-to-date techniques. this should enable the maintenance of an effective safety case in the form of a 'living' useable set of documents that informs operations, reviews and risk assessments. Follow up should not be deferred because of budgetary or resource constraints. Particular attention should be given to new or unfamiliar technology and to minimising complacency in dealing with more familiar risks - in particular, avoiding their 'normalisation'. They should also cover emergency provisions within all credible scenarios.
L13	Leaders have a further responsibility to ensure that an up-to-date and suitable SMS is in place that is in line with any safety case, that there is a 'process owner' for each part, that the workforce understand its requirements and conform with it, and that any changes or waivers are adequately controlled. The SMS should be as comprehensive as is necessary, but over-complexity and bureaucracy minimised to ensure understanding and effective use.
L14	The SMS should be regularly reviewed particularly in relation to higher risk activities. Changes should not be merely 'bolted on' but reviewed in order to ensure that they are appropriately integrated. Staff should be trained to understand the importance of key steps relating to process safety and encouraged to act cautiously, seeking advice and halting work safely if deficiencies arise - particularly during higher risk operations or when alarms are initiated.
L15	In employing contractors, leaders from participating organisations should ensure understanding at an early stage in establishing the contract of all process safety-related obligations that they may be expected to meet and these should be 'scoped' to ensure that adequate resources and systems are in place. Contracts should not include potential disincentives that may deter the communication of safety concerns and associated necessary action to reduce risks as work proceeds.
L16	When acting as a client organisation, an ability to act as 'intelligent customer' should be retained with a client project leader providing oversight of all process safety-related issues. The resources and skills to ensure that this is effective should be retained, including those that may be required in the longer term. As work progresses, effective communication between all involved parties should be maintained, and emerging risks and any potential conflicts of interest identified. Formal 'hold points' should provide the opportunity to stand back and review project status and any process safety concerns or potential conflicts of interest, allowing remedial actions to be agreed and their effectiveness monitored.
L17	Leaders should ensure that arrangements, underpinned by necessary resource and competence requirements, are in place to ensure that learning from internal and external events can be used to enable necessary improvements. This learning should include

	organisational and cultural issues. It should be shared in a directed way such that recipients obtain relevant information that can be understood and used, and that they are not 'overwhelmed' with material that is not relevant to their needs. Steps should be in place to ensure that learning is incorporated in training, that it is maintained in the 'corporate memory' and the development of any organisational 'silos' where there is a reluctance to embrace wider learning is minimised.
L18	Resources should be available for the investigation of events and their follow-up (including checks on effectiveness), with consideration of the need for wider communication and training needs. Any recurring issues should be given particular attention. Root causes and wider 'system' impacts should be fully considered.
L19	Overall process safety performance and trends in key indicators should be regularly monitored by leaders at all levels as part of a well-defined oversight and scrutiny process with input and advice from an independent safety function. The review should include suitable process safety indicators, learning from any 'events', and the output from both independent and 'line management' oversight findings. Over-reliance should not be placed on occupational safety performance data. The process should not only allow emerging risks to be understood and assessed by leaders at corporate, business and plant or project level but should also include a review of the effectiveness of follow-up. It should also provide evidence to executive leaders and board members as to whether organisational expectations for process safety are being met.
L20	Where an operating organisation (duty holder) is part of a 'parent' organisation, it is important that leaders in both organisations ensure that there is an effective relationship between the two parties. Requirements, expertise and oversight from the 'parent' organisation should be in place where agreed and required, but the operating organisation as duty holder should be able to meet the obligations of its licence etc. without undue interference. Clarity about responsibilities and roles between the organisations should be maintained.
L21	Leaders should maintain appropriate and effective contact with their counterparts in regulatory bodies in order to ensure that they are kept fully appraised of the organisational strategy with respect to safety and any changes to it, and should ensure that interaction and regulatory contact at plant or project level meet the requirements of all parties.

4.2 DISCUSSION AND COMMENTARY

4.2.1 Commitment

Leaders should make it clear that safety is a core value and that it should take precedence over all other matters. Whilst committing to maintain and improve occupational safety, it is very important that process safety is also given prominence. This should be reflected in strategic documents such as corporate policy, 'vision' statements and in performance expectations. The latter should be translated into measurable criteria where possible. These should all be 'living' documents that are well known and understood by the workforce.

The importance of process safety should also be demonstrated by the attention that the matter receives from leaders. It should be regularly reviewed and discussed at corporate and business level in the same way as other important issues such as finance and business development. At board level, process safety should be regularly scrutinised with effective support from an independent safety function. In some organisations, a board member takes a lead role in safety. This should not reduce the input and commitment of other members.

Leaders should develop a strong knowledge and understanding of company and business process safety performance, including appreciation of the higher and emerging risk areas and how these are being minimised. They should actively endorse a strategic evidence-based approach to setting priorities rather than just reacting to events. They should demonstrate that they act on concerns that are brought to their attention through an 'open' process in which important issues are not 'lost' or minimised during upward transmission. Their views and conclusions, wherever possible, should be communicated effectively to all levels of the

organisation and checks carried out to confirm that leadership requirements are being followed. Effectiveness should be reviewed with feedback encouraged on any concerns that may arise.

Leaders should maintain high visibility to the workforce at sites and demonstrate their interest in process safety performance by addressing the issues with staff and gaining an understanding of working 'reality'. They should lead by example and, wherever possible, reinforce the importance of safe working, the need to maintain a questioning and cautious, measured and reflective approach in all safety matters, and the need to follow the requirements of the SMS. They should make it clear that tolerance to degraded assets and infrastructure, poor working conditions, and recurring problems is not acceptable.

It is also important that messages are not given that the workforce might perceive as indicating that cost efficiency and organisational effectiveness are being valued more highly than safety. For example, unexplained changes to well established and recognised safety-related posts can give unintended messages about the importance attached to process safety.

Resources to support safety commitments should be sufficient, with competent staff in all process safety matters backed up with adequate support. This should transmit the message to employees that leaders are taking a longer-term view rather than dealing only with short term objectives. Staff should not feel 'abandoned' and left struggling to meet objectives with inadequate resources. Assistance should be provided to plant and project managers to ensure that they are not left to make decisions on process safety related priorities against competing organisational demands.

Attention should also be paid to all plant which is no longer central to operations (so-called 'orphan' plant) and to plant which is not regarded as likely to present significant risk (e.g. newly constructed plant which is not expected to fail).

Leaders should encourage and allow time to be taken for process safety to be reviewed at working level. This should include feedback on concerns and suggestions for improvements. They should show openness to 'unwelcome' news - for example where deficiencies are identified and require action that may affect production. Leaders should also ensure that ideas and concerns are followed up as part of a coherent and prioritised plan with staff involvement and feedback.

Workforce reporting of deficiencies and 'near-hits' should not be narrowly constrained by management and supervisors and should take place within a 'just' reporting system agreed with staff and their representatives. Leaders should encourage and show demonstrable support for this approach and take care not to undermine it by apportioning blame. This applies not only to operations but to support functions such as engineering, maintenance etc. Failure to work to procedures or failure to report 'events' which fall into clearly defined categories should be clearly understood by the workforce to be unacceptable.

Competent team leadership and supervision should be in place, with attention given to the promotion and demonstration of expected behaviours and people skills. Leaders should maintain an awareness of the overall competency requirements and whether these are being met across the organisation. This should include inter-personal skills and the resolution of sources of conflict that may impact on safety. These may emerge from historical conflicts or from differences in approach - for example as a result of individuals coming from very different business backgrounds.

The role of supervisors is particularly important in ensuring a timely and effective response to emerging concerns. Their teams and managers should understand and support this.

Leaders should respond to (and where necessary strengthen) defensive systems such as audit, oversight and scrutiny, and their response to findings should again enable their commitment to be demonstrated throughout the organisation.

4.2.2 Roles, responsibilities and accountabilities

Unambiguous management roles, responsibilities and accountabilities should be assigned with clear reporting lines. This should be done in a way that minimises overlaps and conflicting interests. Dual or multiple 'hatting' should be avoided. The impact of outsourcing should be carefully considered in terms of potential loss of expertise. Accountabilities should not be delegated to more junior staff without formal agreement and authorisation.

Where possible, teams should be kept stable with the retention of core skills and key posts. Excessively rapid turnover of management should be minimised. This is particularly important at project or plant management level so that continual disruption through changes in priorities and approach can be minimised. 'Acting' roles, particularly where post holders may lack sufficient experience and competence, should be kept to a minimum. The effect of incremental changes should also be reviewed.

Leaders have a responsibility to ensure that the overall organisational structure is kept as simple as possible and to minimise the development of organisational 'silos' that inhibit effective communication and can lead to the development of 'unofficial hierarchies'.

The organisational system should also ensure that those accountable, personally 'sign off' work as complete and satisfactory. They should be suitably qualified and experienced (SQEP) to do so and should have satisfied themselves that the work carried out meets requirements and that due process has been followed.

4.2.3 Developing and maintaining a strong safety culture

Maintaining and improving safety culture is central to ensuring good safety performance and leaders have a key role in achieving this. They should be willing to commit sufficient time and resources, and ensure that their personal commitment to improving safety culture is seen to be strong by the workforce (including, where relevant, contractors). They should avoid giving conflicting messages that might undermine this.

The commitment to seek improvement in safety culture should be reinforced by initiating and objectively responding to safety culture assessments and ensuing improvement measures including those that arise from leadership inadequacies. Leadership attention to safety culture should be particularly important during periods of organisational change when other issues may be perceived by the workforce as being given higher priority.

Emphasis on reinforcing and encouraging a questioning attitude and a cautious and compliant approach in all matters affecting safety should be reinforced by support for openness to learning and the encouragement of full and honest feedback. The need to 'step back' and gauge potential biases in making safety-critical decisions should also be encouraged.

In maintaining awareness of safety, leaders should avoid being conditioned by past success or a lack of appreciation of operational reality. They need to remain vigilant to any slow and insidious decline in safety culture and should be prepared to explore the reasons for this should it begin to occur - with regular independent reviews.

4.2.4 Impact of Organisational Change

Organisational change can arise from external business or 'political' pressures and from the need to improve efficiency and output. It is very important that before embarking on any programme of organisational change, leaders consider with an open mind and without bias, the potential impacts on process safety.

Whilst organisational change can have a positive impact on safety, it can also have serious adverse effects. These may arise, for example, through reduced resource, inappropriate changes to key posts, loss of important information and data, reductions in training, and in oversight provision. Leaders should, therefore, ensure that they are attuned to these issues and act as required to ensure that process safety standards are fully maintained.

Pressures arising from increased workloads or over-demanding targets can lead to an increase in short cuts and non-compliance with the requirements of the SMS. It is thus important that prior objective assessments are carried out on the potential impact of proposed changes on safety through an effective and rigorous management of change (MoC) process supported by leaders, carried out with sufficient independence to ensure that impacts are fully evaluated and addressed, and with independent scrutiny in cases that could have a significant potential impact on safety. As far as possible, changes should not lead to over-complexity in the SMS or in lines of reporting and responsibility.

Mergers and acquisitions can present particular challenges because of the need to align processes, ensure effective communication, assign clear accountabilities and interfaces, and recognise and address differences in culture. It is thus important that there is clarity about the system to be used and this should be reinforced

by training. Potential impacts on attitudes and behaviours consequent to the proposed change should be considered.

Following and during change, where potential impacts on process safety have been identified and action is taken to minimise any consequent increase in risks, it is important that this should be the subject of independent oversight and scrutiny with a remit that includes ensuring that unintended consequences are identified and addressed. This issue is specifically examined in Part 3 of the report.

Changes to staffing levels (including incremental changes) should be controlled. This should give confidence that workforce numbers do not drop below a level that is unsafe.

Changes and improvement initiatives should also be carefully controlled and prioritised to avoid 'initiative overload'. This can lead to a loss of focus on important potential process safety risks, and difficulty for line management at plant or project level to assess priorities. Advice and assistance to achieve this prioritisation should be made available where required.

4.2.5 Management of risks

All leaders should fully understand the contribution that they make to managing process safety risks and have sufficient overall competence and understanding to see their contribution in the context of overall process safety risks within the organisation. Leaders should also understand the obligation on them and others to do all that is reasonably practicable to reduce these risks and what this principle means both legally (where relevant) and in practice.

Risks should be periodically reviewed using the results of objective analysis, where appropriate, and based on specialist advice. Priorities for action should be assigned and any wider learning communicated within the organisation. In remaining alert to warning signals and event precursors, the role of human factors and people management, as well as 'hard' engineering risks, should be recognised and addressed. Risks should not be downgraded ('normalised') without full justification.

To provide the board and other senior leaders with an independent view of safety risks and authoritative advice, organisations should have in place a safety function that is independent of business line management. In order to ensure adequate coverage and understanding of the risks to be considered, it is important that this is led by an experienced senior person with a wide knowledge of safety risks, supported by a well-resourced, experienced and skilled team. The function should be able to assess on behalf of senior leaders, the extent to which businesses and major projects are meeting organisational expectations on process safety and provide feedback. It should also be able to provide, through its independent assessment and reporting, confidence that upward reporting of safety concerns is not being 'rolled up' or 'bad news' suppressed, and provide leaders with a good picture of the spectrum of process safety risks in the organisation.

In some organisations, a strongly de-centralised approach is taken in which businesses and projects largely determine their own approach to safety. Whilst this has advantages in potentially achieving greater 'ownership' and understanding, it is important that sufficient oversight is maintained on behalf of organisational leadership to provide assurance that businesses meet the expectations and policies set out by them.

Safety-related incentives and 'rewards' to staff (such as bonuses or performance-related pay) should not be based solely on objective measures of occupational safety performance but should include process safety performance. Such 'rewards' should be carefully formulated so that they do not lead to unintended consequence such as discouraging the reporting of 'near-hits' and non-conformances that would otherwise provide learning opportunities. This issue is considered further in Part 2 (in particular in Annex E) in terms of behavioural issues and in Part 3 as an example of the use of CLM in order to elicit potential unintended consequences.

Risk assessment processes such as design reviews, management of change assessments, and periodic safety reviews (including supporting processes for these such as hazard and operability studies (HAZOPs), qualitative risk analysis (QRA) and HRA), should be carried out in a way that aims to achieve transparency and avoid over-complication. Developing and maintaining a safety case as a 'living' document based on risk assessment is an important pre-requisite for ensuring that process safety is fully addressed by the organisation. Leaders should ensure that reviews are carried out in a timely way and are not deferred, for example, as a result of budgetary constraints. Where concerns emerge regarding the safety of a particular

process or approach, effective risk assessment by competent staff should be carried out that seeks out root causes. Timely precautionary action should then be taken. Particular emphasis should be given to repeat findings and the reasons for these occurring need to be fully assessed.

Actions arising should again be prioritised and supported by appropriate investment and allocation of resources. Particular attention should be given to new and/or unfamiliar technology, and steps taken to avoid complacency in dealing with more familiar risks. In developing prioritised action plans, the possibility of introducing adverse effects on the wider organisation (unforeseen knock-on or 'system' effects) should again be fully considered as addressed in Part 3, and leaders should be made fully aware of any that are identified.

Leaders should ensure that well-rehearsed emergency plans are in place that are understood by the workforce (including contractors), together with external agencies. These should cover all credible scenarios.

Effective contact with regulatory bodies should be maintained at both senior level and at plant or project operations level so that regulators are kept fully appraised of emerging process safety risks and how these are being managed and, where relevant, their advice sought.

4.2.6 Implementing and supporting the safety management system (SMS)

Leaders are responsible for ensuring that an up-to-date and suitable SMS is in place across the organisation and/or business, that there is a process 'owner' for all parts of the SMS, that the workforce understand its content and importance, are trained in its use, and understand the potential consequences of failing to comply with it. It should be made clear that conformance with the SMS is mandatory (rather than being merely for guidance), but that suggestions for improvement are welcomed. Changes to the SMS and any waivers to its application should be carefully reviewed and, if agreed, signed off as acceptable by an appropriate senior authorised person.

Whilst ensuring that the system is as comprehensive as possible in order to address all process safety-related matters, it is also important that over-complexity and bureaucracy are minimised and that the context and importance of key steps is explained (including effects on other work groups). This should add to the awareness of the workforce and their supervisors of the dangers of adopting 'work-arounds' or other non-conformances. Complexity can be introduced by 'bolting on' new requirements to reflect change and care should be taken in handling such new requirements and integrating them effectively in the SMS.

In addition to facilitating and encouraging the reporting of potential deficiencies and their timely follow up, leaders should emphasise the need for a cautious (safety first) approach in using the SMS and that when in doubt, specialist advice should be sought.

If there is uncertainty about continued safety, leaders should make it clear that they should support safely halting the work being carried out until uncertainties or concerns can be resolved ('stop and escalate'). For certain key process steps - e.g. start-ups, shut-downs, response to alarms etc. - the system and its application should be very regularly reviewed in order to ensure adequacy, understanding and continued compliance.

4.2.7 Contractor (supply chain) management

In inviting tenders and selecting contractors, it is important that the leadership of all involved parties understand the obligations that they should be required to meet in safety critical areas such as safety culture, resources and skills, reporting requirements, quality standards, oversight, communication and, conformance with agreed safe working practices. This should require all those involved to 'scope' the requirements of the project and, wherever possible, align client and contractor goals.

When establishing contracts, such requirements should be clear, and any potential difficulties or conflict of interests identified so that all parties are aware of these and suitable understandings are in place. All necessary documentation should be made available at an early stage to ensure there are no subsequent 'surprises'. Contracts should be established in such a way that there are not disincentives to meeting obligations - such as financial penalties that might deter the early communication of emerging safety concerns.

Leaders should ensure that the organisation is an 'intelligent customer' for work carried out by contractors and that it retains its competence both to fulfil this role and to understand the contractor input sufficiently to use it

safely. The use of contractors should be carefully considered by leadership in relation to the possible long-term loss of essential skills in the client organisation.

A client project leader should retain oversight in a way that enables project management capability and any emerging risks or concerns to be questioned and addressed - for example, any repairs or 'improvements' during construction should be assessed and agreed before proceeding.

As contractual work proceeds, attention should be given to ensuring that informed communication and discussion about safety risks takes place at all appropriate levels through identified and agreed channels - including between client and contractor leadership on strategic matters. This should include identifying any emerging risks and potential conflicts of interest that might not have been considered in establishing the contractual arrangements and which could be prejudicial to safety. Good practice usually involves the establishment of formal review 'hold points' or 'stage gates' in the contract, so that progress can be fully reviewed and any potential difficulties identified and resolved.

4.2.8 Developing a learning organisation

In nearly all of the cases studied, there have been earlier events or 'near-hits' either within the organisation or more widely, from which if relevant learning had been identified and actively used to produce enhanced resilience, the subsequent event might have been avoided. Thus, it is important that leaders become aware of- and act upon- the lessons learnt from these, and that they ensure that they are being widely communicated in a form that is intelligible and relevant to requirements. The flow of information and any subsequent need for follow-up should be managed so that recipients are not overwhelmed by a 'cascade' of learning material and actions that may then be very difficult to manage. These requirements will require adequate resources in each operational area to assess the relevance of the learning (including good practice) to their activities, to communicate it effectively, and to keep it 'alive'.

It is also important that learning from previous events, and how this has influenced the approach to process safety within the organisation, should be maintained within the corporate memory and reinforced by training to keep all relevant staff alert to the continued possibility of major events.

Individuals and teams that report deficiencies or make suggestions for improvements should be appropriately 'recognised' and feedback should be given to them on follow-up. Resource for investigation and subsequent actions, including the analysis of potential system effects and any required training, should be assessed. Implementation and effectiveness of actions following reporting should also be checked. Leaders should require particular attention to be paid to any recurring issues, as this may indicate deeper-lying organisational and/or cultural shortcomings.

Leaders should be aware of any areas of the organisation where there is an inward-looking or silo-based culture and take appropriate action. This is sometimes manifested by a 'not invented here' attitude that leads to a lack of response to wider organisational improvement and learning activities.

In addition to promoting the sharing of important learning internally, sharing between organisations on a reciprocal basis can be an important source of learning. This can sometimes be inhibited by legal constraints following an event, but, where likely to reduce the risks of similar events elsewhere, it is important that where ever possible effective communication is maintained.

4.2.9 Ensuring oversight and scrutiny (O&S)

An adequate range of process safety indicators (including leading indicators) should be reviewed and trends monitored at various levels including at boards and executive teams, as part of the O&S process. Good performance in occupational safety should not be assumed to be an indicator of good performance in process safety.

Oversight of process safety risks should be facilitated by a variety of approaches within a hierarchical, coordinated O&S process. This may range from local oversight by audit and operational random checks where required, to business or project O&S, and through to corporate oversight. This range of approaches should enable local management, business leaders and corporate leaders to obtain a clearer picture of risks and their management relevant to their responsibilities and requirements. The results should be used in conjunction with process safety indicators and regular reports from businesses and the corporate safety function to senior

leaders (including boards), to form a basis for assessing risks and their follow-up. Corporate O&S should also allow corporate leaders to assess whether 'expectations' are being met and whether the necessary resources are available to support their effective implementation.

Business/project and more local O&S should be able to provide continuing and detailed insights into cultural matters, and also into more specific issues such as the effectiveness of interfaces and associated communications; understanding of roles and training; work quality; compliance with the SMS; response to safety warnings (e.g. alarms); recording of safety-significant issues; working conditions; plant integrity and, the effectiveness of maintenance and engineering support. Consequent improvements should be part of a coordinated and prioritised plan with clearly assigned responsibilities and leadership, and with the checking of implementation and effectiveness.

4.2.10 Effective relationship between parent body and operating organisation

In some of the events studied, the operating organisation (duty holder) was part of a larger 'parent' body. In situations where this is the case, it is essential that a clear and effective arrangement exists between the two organisations. Whilst the 'parent' organisation may have a role in maintaining oversight and may be able to provide advice and expertise, it is important that this does not interfere with the duty holder's obligation to meet regulatory requirements and other obligations.

Leaders of all parties involved (including regulatory bodies) should understand and be completely clear about the relationship in place and should ensure that it is effective and meets requirements.

5 EXPECTATIONS: SAFETY CULTURE

5.1 OVERVIEW

The requirements that underpin a strong safety culture in an organisation have been widely discussed in various publications, but this section of the report draws out the key features of such a culture by reference to the conclusions of the reports of the events studied. Because safety culture is wide-ranging and is a vital component in ensuring safety, this section contains much material that overlaps with the discussion of other topics in the document. This is deliberate in order to ensure that safety culture is treated, as far as possible, holistically and in the context of its great importance in all safety-related matters.

Demonstrable leadership commitment; a questioning attitude among the workforce (including contractors); an approach where everybody works together to improve safety by, for example, reporting deficiencies and promoting improvements within an atmosphere of trust, and a common sense of purpose throughout the organisation, are essential features of a strong safety culture.

One point regarding terminology should be clarified: the reports into the events generally use the single term safety culture rather than safety climate and the same practice has been followed here. The use of the terms and their meanings is further discussed in Annex B that also discusses in depth the concept of 'safety culture maturity' and models to assess this.

In several of the events reviewed, organisations sincerely believed that they had an effective safety culture but this, on investigation, was found to be illusory and based on little evidence. In some cases, organisational pressures and influences within the specific business, plant or project had allowed this to degrade, with norms, values, attitudes and behaviours failing to conform to the standards required. This highlights the need to maintain vigilance and to examine and, where necessary, act to improve safety culture both within the organisation as a whole and within its constituent parts.

Safety culture related issues are also explicitly discussed in sections 7, 8, 10 and 12 with some references in sections 4, 11, and 13.

Table 2 - Summary of safety culture expectations

SC1	Leaders and managers should be committed to achieving a strong safety culture in all the areas for which they have responsibility. They should make clear the attitudes and behaviours required, communicate these effectively, listen to workforce views and feedback, and ensure that they retain an overview and remain aware of operational reality. Their own actions should act as a role model for others.
SC2	The primacy of safety should at all times be emphasised in a way that is not compromised by the pressure of commercial objectives. Sufficient support and resource should be available to ensure that safety culture objectives and activities can be fully met.
SC3	All staff and contractors should be trained to take a questioning attitude and precautionary approach to all matters affecting process safety, to adhere to procedures, and to seek advice where uncertainties arise. Clear interfaces, supported by effective communication, should be in place to enable this.
SC4	Leaders and managers should be aware of both specific and overall levels of process safety risk within their areas of control and the degree to which the organisational safety culture is enabling these risks to be effectively managed. In assessing emerging risks, it is important that an open-minded view is taken of their importance, which does not rely on previous success or good performance.
SC5	Where possible, measurable criteria including proactive (leading) indicators should be in place to assess safety culture performance. These should be carefully formulated to reduce any unintended 'knock on' effects and to minimise misuse to meet targets. Where initiatives are taken to improve safety culture, these should be prioritised and coordinated to avoid initiative overload.

SC6	Leaders and managers should work to ensure that a fragmented approach to safety culture does not develop, with some areas of operations taking a more closed 'not invented here' approach to required improvement. The role of supervisory staff is particularly important, and they should be capable and well trained in the skills required to support a strong safety culture within their work areas.
SC7	During periods of organisational change, commitment to a strong safety culture should be reinforced and its continued importance made clear, avoiding 'mixed messages'. A rigorous approach to the impact of change, including effective and visible management of change assessments and the presence of a strong and independent safety 'voice', should be used to reinforce the message that addressing safety concerns is strongly supported even in a changing working environment, and that staff views and feedback are welcome and should continue to be supported and taken seriously.
SC8	An important attribute of a strong safety culture is the reporting of all events and significant deviations, with agreed procedures for competent investigation and follow-up that reflects their safety significance. The response to recommendations should be timely and adequately resourced. Root causes should be sought and the effectiveness of recommendations verified. Reasons that may be inhibiting reporting and follow-up should be identified and addressed to assure staff of the importance that is attached to it. Against this supportive approach, it should be made clear that failure to report deficiencies and concerns is unacceptable.
SC9	Reporting should take place within a 'just' system that has been agreed with the workforce and their representatives and those reporting should be given feedback on their concerns and how they are being addressed. They should be appropriately 'recognised' for their action. Where required, a confidential reporting system should be available to staff.
SC10	The process of raising concerns should be clear and made as simple as possible with a minimum of bureaucracy. Issues raised should not be 'blocked' by supervisors or line managers, who should encourage minority views and act as role models in maintaining a questioning attitude and promoting effective communication.
SC11	Investigations should be carried out with engineering rigour, including the review of safety margins where appropriate. They should be performed in such a way as to listen to minority views and avoid 'groupthink' and mindsets, without a tendency to confirm the presumed cause. Action should be taken to ensure that results are not only communicated to all those who may be able to learn from them, but that they are reflected in training, and steps taken to maintain them in the corporate memory.
SC12	Within a strong safety culture, learning should be actively sought from all relevant sources and made relevant and useable for recipients. Application should take account of the spectrum of learning possibilities and should not be dismissed because it appears of limited immediate relevance. Learning in suitable form also should be made available to leaders and managers so that this can promote awareness, inform business decisions and guide oversight and scrutiny processes.
SC13	Promoting a questioning attitude (asking 'what if') is an essential feature of an effective safety culture. This should increase awareness of warning signs (including weak signals) and their implications, as well as more readily apparent faults in plant or instrumentation or deficiencies in procedures. It is vital that anomalies are not subject to 'normalisation' on the basis of previous results or unjustified assumptions, but are explored with an open mind with sufficient in-house expertise to achieve this. Particular care should be taken in responding to reports of faults in new or less frequently used plant where there is a danger of them being regarded as unlikely to be significant.

SC14	Workforce teams should be given 'protected time' to discuss process safety and safety cultural matters with a view to suggesting improvements and/or raising concerns. They should be kept informed about developments and feel involved. Teams should be encouraged to stop work if a compelling safety concern arises and to seek urgent advice. Such action should be supported by management.
SC15	The organisation should ensure that it is able to respond flexibly when the need arises, with decisions being taken by competent people at the right time. Thus, a balance should be maintained between the strongly encouraged 'norm' of relying on procedures, and the organisation being decisive and 'quick on its feet' when there is an overriding need to do so - such as in a rapidly deteriorating situation. This should not be used to justify the non-observance of procedures or taking short cuts where action is not urgent. The SMS should provide the 'norm' for decision making whilst not becoming a substitute for thinking. More flexible responses should be subject to suitable safeguards.
SC16	The SMS has a vital role to play in supporting and promoting a strong safety culture. It is therefore very important that it is not allowed to become degraded and is kept up-to-date, with staff strongly encouraged to report deficiencies and seeing it as relevant to operations. Strong scrutiny should be in place to ensure that 'casual' or non-compliance does not develop. How failure to comply can impact on other operations should be understood by users. It is particularly important that insidious degradation and non-conformance does not lead to an 'elastic waistband' effect where non-conformance becomes increasingly acceptable. The SMS should be recognised as an important 'tool' in supporting and enabling a strong safety culture.
SC17	Where contracting organisations are being employed, they should fully understand safety culture expectations before work begins. Their capability in this area should be a factor in initial selection. They should also be required to maintain a questioning attitude, act cautiously in the light of uncertainty, communicate effectively and with integrity to all involved parties (and especially the client), seek competent advice where required and, report and respond effectively to all deficiencies. They should be made aware that safety culture performance may be subject to client oversight and scrutiny.
SC18	Safety culture should be periodically reviewed by a dedicated specialist team to assess areas of strength and weakness using best practice techniques and reporting directly to senior managers and leaders. The process may be particularly important during periods of significant organisational change when maintaining safety culture standards could be under threat, and consideration should be given to strengthening the process in these circumstances.

5.2 DISCUSSION AND COMMENTARY

5.2.1 Principles and key attributes

Safety culture is generally linked to the prevailing wider organisational culture(s). This is underpinned by core principles and values leading to ethical principles that set out requirements for matters such as integrity, honesty, openness, transparency, respect and mutual trust. It is important that safety culture is consistent with these and recognisably derives from them.

Several (often inter-related) requirements have been found to be important in establishing and maintaining a strong safety culture:

a) leadership commitment, visibility, setting of clear expectations and maintenance of an understanding of workplace 'reality';

b) managing the impact of change on safety culture;

c) developing and maintaining a questioning attitude and critical thinking;

d) involving the workforce in improving safety culture;

e) encouraging the reporting of concerns and deficiencies within a 'just' framework and an environment of respect and trust;

f) an ability and willingness to learn from all relevant sources;

g) 'flexibility' in responding to change and unplanned conditions, and

h) effective review of safety culture within all parts of the organisation.

The development and maintenance of an effective SMS is an important pre-requisite for the support of a strong safety culture. There is a clear need to maintain effective interfaces including with any contracting organisations, and between teams and functions (e.g. engineering support and operations). Interfaces should be supported by clear accountabilities.

5.2.2 ‘Setting the tone at the top’

A strong and effective safety culture can only be established and sustained if those at the top of the organisation make it clear to the workforce (including contractors) what is required in terms of attitudes and behaviours ('setting the tone at the top'). These expectations or organisational norms should be communicated in a way that shows that leaders are listening to staff and understand the pressures and 'realities' of the working environment, and that all involved understand that severe accidents can happen. Effective communication of these behavioural expectations requires that leaders do not simply 'issue edicts', but show their commitment by being visible to staff, understanding and acting in response to feedback and concerns, and seeking to engage with them. Leaders should also ensure that parts of the organisation do not become 'detached' from the expectations and available learning, and that there is effective oversight and regular review of risks and their control.

Where the workforce perceives a lack of commitment from the top, with leadership communications regarded as 'management speak', and where safety messages are 'diluted' by what are perceived to be stronger messages about the need to meet production or improved efficiency targets, the likely result may be one of cynicism and distrust leading potentially to a negative impact on safety. It is thus important that leaders and managers) convey consistent messages and act as visible role models by demonstrating through their personal attention and actions the high priority with which the subject is being treated. One important aspect of this is to ensure that the support and resources required to achieve the necessary standards are made available - particularly during times of major change or business stringency.

The role of supervisors is also very important. In some of the events studied, organisations failed to develop the supervisory competences of those in the role. With the right approach, supervisors can play an important part in ensuring that standards are being met and alerting higher management to concerns and shortfalls. They are often in the position of needing to respond to both management requirements and those of their teams. They thus need the support and capability to feel confident that their safety-related decisions (e.g. stop the job until safety concerns are resolved) will be respected and supported by managers, and that they are not left in a position where they have to 'trade' safety for what are perceived by management to be more pressing objectives.

Those setting behavioural expectations should strive to understand the safety concerns of subordinate personnel and maintain strong awareness of such issues as the degree of adherence to procedures, and whether a precautionary approach and questioning attitude is being taken in all areas of activity relevant to process safety, including non-routine operations. Awareness should be maintained not only of specific areas of elevated risk, but also of the overall, cumulative level of process safety risk facing the organisation by taking an 'integrated' view and ensuring that there is an understanding of where current risk levels have the potential to escalate.

Some of the events studied have resulted from what has been referred to as 'organisational blindness'. Past success and a history of few, if any, significant negative events does not mean that a plant or process is not vulnerable to the emergence of new and significant risks. This mindset has also led to situations where what were intended to be open-minded assessments of aspects of process safety performance became confirmatory exercises to demonstrate acceptable safety, even where evidence pointed to an opposite conclusion. Other examples have included situations where those raising safety concerns were required to reverse the normal starting point for review by being required to 'prove that the plant or process is unsafe'

rather than establishing its safety. To counter this sense of complacency and invulnerability, again requires leaders to be in touch with reality, with effective feedback, measurement and oversight.

In some organisations, prior to major events, there have been initiatives to improve safety and aspects of safety culture, but these have not always taken root because too many initiatives were being introduced concurrently with a failure to prioritise or explain their importance and context to staff. 'Initiative overload' should be controlled - particularly where there is a danger that initiatives are being introduced by different parts of the organisation with little coordination or effective control. In some cases, a rapid turnover of site or project managers, each with a programme of improvements, has led to over-commitment and a failure to see them through to a satisfactory conclusion. The situation can be seen by the workforce as a constant barrage of initiatives in the form of 'flavour of the month', and the perception (sometimes justified) that their engagement is unlikely to lead to meaningful improvement because something else may take priority before very long.

Wherever possible, reliable and measurable criteria should underpin organisational expectations. Measurement and review of safety culture performance provides very important information on the 'health' of the organisation, but particular care should be taken in using overall safety culture review results as a key performance indicator (KPI) because general measurements can be influenced by wider organisational issues such as concerns about change. Particular safety culture improvement objectives may provide more suitable lead indicators. This issue is further discussed in Part 2.

More generally, the development of meaningful KPIs is important but requires significant care in formulation - particularly when incentives are introduced to encourage achievement. Reward systems have often been dominated by those for meeting commercial objectives (e.g. meeting production targets, schedules etc.). It is important that when introducing a suite of KPIs, that these are balanced, and that those related to safety are not seen to be dominated by production incentives. KPIs and associated incentives, should also be carefully thought through as there is a danger that unforeseen consequences could emerge. For example, a concentration on more easily measurable parameters relating to occupational safety may lead to a view that safety is improving, when in fact process safety is receiving less attention because incentives on performance do not exist. Furthermore, introducing what may be perceived as measures with an impact on safety culture and process safety (e.g. 'events' reported or training received) without careful controls, could lead to inappropriate use in order to meet targets. The development of suitable indicators is discussed at some length in Part 2 in terms the types, roles and use of indicators, and the need to consider the implications of related incentives is considered as a specific case study in Part 3 using CLDs.

When leaders decide to what extent the organisation is to be operated in a 'centralised' or 'decentralised' mode, this can also have an impact on the way that safety culture is managed. Whilst a decentralised approach may offer strong business advantages in some situations, it is important that there is clarity about accountability for leadership in safety culture and the degree of consistency to be sought in organisational expectations and their communication and follow-up. In the extreme, it is possible that requirements stressing the need for a cautious, questioning approach to safety culture may be delivered by corporate leaders, but this may be undermined by a more 'entrepreneurial' approach at the business level in circumstances where there is strong operational autonomy. It is thus necessary for clarity to be established about boundaries and consistency of approach with, for example, the corporate centre setting standards to which all are expected to conform, whilst allowing agreed operational freedom as to how these are achieved. Independent oversight then provides an ability to assess whether, in practice, expectations are being met.

Some organisations have developed a 'fragmented' culture with the existence of 'local cultures' and silos that become resistant to perceived corporate 'interference' and that leads to an approach that does not recognise or respond to developments that are 'not invented here'. In other cases, a lack of clarity on accountabilities has led to required actions being neglected or deferred, and a failure by leaders and managers to 'take a grip' on an evolving, potentially dangerous situation.

5.2.3 Capacity to recognise the impact of organisational change on safety culture

During periods of organisational change, it is vital that the attitudes and behaviours that underpin a strong safety culture and other 'defensive' systems such as audit and oversight are visibly and convincingly reinforced - with particular attention given to management and leadership commitment to safety and the avoidance of mixed and confusing messages. Approaches to business change can easily be perceived by the workforce

as being in conflict with the aspiration of maintaining a strong safety culture, with management focus and resources being seen primarily to reward and recognise efficiency, production, and budgetary control at the expense of the more precautionary and questioning ('safety first') approach that underpins safety culture.

It is important that there is seen to exist a strong and independent safety 'voice' within the organisation with power to ensure that safety priorities are maintained and not degraded (sometimes insidiously in a way that can be overlooked), and that defensive systems such as rigorous and well-implemented management of organisational change requirements and oversight on a searching and questioning basis, are both effective and visible.

A particular danger to maintaining a strong safety culture includes a possible reluctance by the workforce to report and respond to safety concerns and learning opportunities since they may perceive this as not welcome by management. This is a general point, but is included here because it is most likely to be the case when organisational priorities are seen very strongly focussed on business requirements, with a lower priority attached to safety. This is particularly relevant if as a consequence, there is a reduction of support to teams in their efforts to improve safety culture.

During substantial organisational change, the workforce may likely be attempting to respond to safety culture concerns in a business environment that involves turbulence, greater work pressures, uncertainty (including over jobs), and with managers distracted by other business concerns. Thus, it is important that leaders are fully aware of the potential impact of this working environment on safety culture and act appropriately.

5.2.4 Encouraging reporting of 'events' and learning from experience

An effective safety culture requires that all deviations from normal or expected operations or practice (actual events or 'near hits') are reported and investigated to the extent warranted by their significance. Investigations should be carried out by competent, well-resourced teams that follow agreed investigation procedures. These should include requirements for assigning significance and the depth of investigation; the level of internal and external reporting and sharing of conclusions required; exploration of 'root causes' - including organisational and cultural deficiencies, and, requirements for follow up of recommendations. This follow-up should not be subject to deferral or delay (e.g. by unnecessary re-testing) and verification of the effectiveness of remedial measures should be undertaken. Clear accountabilities should underpin these requirements, with advice being sought in the case of uncertainty.

There are many reasons why reporting does not always occur in practice. For example, the process of reporting is not always made as simple as possible. Undue paperwork and bureaucracy may be involved and the consequence of follow-up may be seen to involve a greater workload falling on the individual or team making the report. There may also be other behavioural disincentives, including the fear of attribution of blame when errors by the individual or team are involved; concern that others may be blamed (seen to be 'telling tales'); being seen to 'rock the boat' or 'make trouble' and, fear of being seen to be speaking out against the consensus. On occasions, the view may be taken that it is the responsibility of others to report, or where a deficiency has been apparent for some time and has not been previously reported, it may be regarded as being acceptable as established custom and practice. 'Living' with such deficiencies that have been apparent (such as procedural flaws) is common in many organisations, and a particular objective of a reporting system as it develops, should be to encourage the exposure of these often accepted shortcomings ('latent system pathogens').

To overcome some of these understandable concerns, strong support and encouragement should be given to those individuals and teams providing feedback. An atmosphere should be generated where discovery of a deficiency - whether an error or a shortfall in plant or procedures is seen as an achievement - even when it may adversely affect production or schedules. Those reporting should receive recognition and thanks, whilst management should make it clear that it is failure to report that is unacceptable.

Reporting should be part of a 'just' system where blame is not attributed, but each report treated as a learning opportunity that is appropriately shared in order to improve safety more widely. The basis for such a 'just' system should be agreed with the workforce and their representatives. Should the reported event draw out the need for re-training, this should not be done in such a way as to disadvantage those reporting. Disciplinary action may be required in extreme cases where there has been a failure to report or where there has been a flagrant disregard for safety, but such cases should preferably be considered independently (out-of-line) in an

atmosphere that is regarded as balanced and fair. Where confidentiality needs to be maintained in order to encourage reporting, a system should be in place to offer protection to the individual.

Follow up to internal reporting of events or near hits is an important aspect of successful organisational learning with clear corrective actions and recommendations that are 'seen through'. Businesses should work towards being responsive to learning from all sources. It is also important that dedicated engineering capability is available that identifies learning opportunities and ensures that it is available and understood by those parts of the organisation that are capable of benefiting from the learning. This should take account of the fact that whilst detailed plant or processes may be different, the broader learning may be applicable to another part of the organisation (the spectrum of learning opportunities should be considered). It is again important, however, that the organisation is not 'overwhelmed' by learning opportunities and a system of filtering and prioritisation is necessary.

A number of the events that have been reviewed in preparing this report occurred despite events with very similar root causes having occurred elsewhere in the industry or even within other parts of the organisation. Sometimes the relevance of these had been ignored or not appreciated and others lost from the 'corporate memory'. Learning should be drawn from (and shared) not only internally, but with other organisations in the industry sector and beyond - with the necessary arrangements made to facilitate this. It is important to identify tendencies towards insularity within the organisation and to ensure that 'all eyes are kept open' to the bigger picture.

Learning should not be confined only to relevant operations and support functions, but also to leadership and management, such that significant risks being communicated to senior levels are not 'censored' or 'rolled up' in the course of the reporting process. This is particularly important in considering learning in relation to organisational and cultural factors. Events and associated risks should not be seen in isolation but in a broader perspective within an integrated approach, and leaders and management should be helped to obtain this perspective in order to identify emerging risks and areas of more generic vulnerability.

Behavioural issues related to data reporting and the use of incident and incidence data are discussed in depth in Part 2.

5.2.5 Promoting a questioning attitude

A questioning attitude amongst all personnel is a fundamental requirement in establishing a strong safety culture. In nearly all of the events studied, there were prior indications (in several cases alarms or test results) that were inadequately addressed with a sufficiently questioning attitude. Sometimes warning signs presented as 'weak signals', such as developing trends in data which were not sufficiently questioned to minimise the likelihood of the subsequent event.

It is vital that all members of the organisation are encouraged to challenge assumptions, ask 'what if?', and to approach issues with vigilance and with an inquiring mind. The response to an off-normal finding also requires the exercise of engineering rigour to ensure that, for example, instrumentation and software are performing acceptably. Safety margins may also need to be reconsidered in the light of findings.

Faced with a range of possibilities when unexpected results or findings are observed, a precautionary, 'conservative' approach is required that avoids overconfidence (such as unrealistic optimism engendered by previous success) and considers the full range of possibilities that may have led to the result or finding. There should also be a genuine commitment not to normalise and defer action because previous occurrences have not led to unacceptable consequences (or in the terminology used by the National Aeronautics and Space Administration (NASA) at the time of the Columbia Shuttle disaster, regard an occurrence as 'in family'). They should be investigated in a way that attempts to avoid bounded 'mindsets', a shared world view that may sponsor 'groupthink' and a narrow focus - with consideration of symptoms rather than root causes. The results of investigations should not be predicated on the need to confirm the presumed cause and/or to validate previous thinking and conclusions. This often happens insidiously, sometimes arising from a view that the organisation, plant or process is so well designed or special that it could not fail ('the perfect place' or 'new plant' syndrome), or because a peripheral plant or well-established process is now no longer 'mainstream' and is not regarded as a source of significant risk ('orphan plant' syndrome). Ill-structured problems or issues (those that are not clear or well defined) have been noted to be particularly prone to being ignored or treated as not significant.

5.2.6 Involvement of the workforce

The workforce (including contractors) should be involved in seeking process safety improvements and in developing a strong safety culture. Those 'closest to the tools' are generally best placed to identify process safety-related problems and potential issues. Developing a culture where they feel empowered and where their ideas and concerns will be listened to is thus essential. Maintaining a dialogue with safety representatives is also important because they are often able to take a wider view and can represent worker concerns independently.

The workforce should feel more motivated to participate if they are given time in team meetings to discuss safety-related issues, can see results arising from matters that are raised, are kept informed about progress, and are provided with the time and opportunity to be involved in developments where appropriate. To ensure that visible actions result from matters that are raised by the workforce, it is important that there is sufficient resource available for those responding to safety-related concerns.

Clear routes and open channels for raising concerns and improvement ideas are essential, and steps should be taken to ensure that communications are not 'blocked' by supervisors or line managers - particularly if they feel that concerns raised may reflect on them.

Managers and supervisors should be trained in the necessary people skills so that they listen, are encouraging, seek out and provide a voice for dissenting or minority views, and are able to act as positive role models. Their approach to safety should form part of personal objectives and performance appraisals.

When safety-related matters arise that are judged serious and which require urgent action, staff should be able to obtain immediate advice and should feel empowered to stop work safely if there is a compelling safety issue. This should be consistently supported.

5.2.7 The role of the SMS in supporting safety culture

The SMS and related documents such as operating instructions, etc., have a vital role in ensuring excellence in process safety and in supporting a strong safety culture. Many of the events studied have involved a poorly formulated or degraded SMS with 'casual compliance', 'workarounds' and unapproved short cuts. These can result from a lack of understanding or as a result of custom and practice - especially when the workforce sees requirements as not meeting or conforming to their own experience. Where the SMS is wrong, out-of-date or inappropriate, it is important that staff are motivated to report this, and authorised changes are made - taking specialist advice on potential wider implications (knock-on effects) of the proposed change. In some cases, a situation has been allowed to develop where it has become accepted practice to work outside the SMS. This can lead to an unrecognised progressive increase in risk (sometimes referred to as the 'elastic waistband effect').

In the lead up to some events, there has been a tolerance to deviations and a lack of operating 'discipline''. In some cases, there has been evidence that the workforce has not understood the need to comply - particularly in regard to the effect a failure to do so can have on other operations. It is therefore important that everybody in the organisation understands the importance of the SMS and receives adequate training on not only its structure, content and relevance to their own and other roles, but also its importance in supporting a strong safety culture.

5.2.8 Developing a 'flexible' organisation

A sometimes neglected attribute of a strong safety culture is to maintain flexibility in the organisation's response to safety concerns. Whilst the importance of an SMS that assigns clear accountabilities and which provides well-understood procedural requirements that are respected by the workforce is a vital component of maintaining a strong safety culture, in some cases those involved have 'hidden' behind protocol and bureaucracy or blamed faulty paperwork, and have spent so much time following hierarchical rules, that flexibility of response to unexpected or important 'signals' has not been achieved. A clear view of 'essentials' has been lost. It is important that a balance is maintained between procedures and the ability, when required, to respond flexibly - ensuring in changing circumstances that decisions are taken by competent people at the right time when a compelling need arises. This requires a free flow of information to those making decisions, and the need to ensure that minority or dissenting views are able to be heard.

In other words, the SMS should not become a substitute for thinking and self-critical awareness. In some cases, a 'tick the box' mentality has developed which provides 'comfort' and is seen as an end in itself. In other cases, the organisation has become so 'cluttered' by committees and process, that important interfaces have been degraded (e.g. with contractors or direct communication between operations, engineering and maintenance). Further examples of this failure 'to see the wood for the trees' have arisen because of requirements to collect more data and information even where this is not really necessary given a clearly deteriorating situation, and to defer decisions and remedial actions. This has led in some cases to serious consequences.

On the other hand, there is a danger in allowing too much flexibility, since in some circumstances this could be used to justify short cuts, failure to ensure that specialist opinion is obtained, and in leaving out vital links in the decision-making process. A balance is therefore required, with adherence to procedures as the required norm, but with arrangements in place (with suitable safeguards) to ensure that the organisation can be decisive and 'quick on its feet' when circumstances demand such a response.

5.2.9 Safety cultural interfaces when using contractors

Where contractors are being used in design, construction and in running operational projects, it is important that they understand the safety culture expectations of the client organisation and are able to meet them. This should play an important part in assessing bids. Before work commences the relevant staff and management of contracting organisations should be made fully aware of the need to operate to the same high standards of safety culture as are expected of staff in the client organisation. For example, the contractor workforce should be empowered to take a conservative view and questioning approach when anomalies are observed, raising and listening to concerns, and ensuring that issues arising are promptly reported to decision makers within the organisation and to the client. These should then be reviewed by the client to ensure that necessary checks have been performed (including the acceptable completion and testing of work and any subsequent modifications).

Where contractors are involved in the construction and commissioning of plant, it is important that observed deficiencies are communicated, where relevant, to all other parties in the project chain and satisfactorily resolved before proceeding further. In this process, it is important that the client organisation (or others appointed to help in the assessment of quality and the witnessing of critical plant and process), maintain strong and effective oversight. The role of all parties and communication routes should at all stages be clear, so that issues do not 'fall between the gaps' as the project progresses.

5.2.10 Review of safety culture

Given the importance of maintaining a strong safety culture, it should be the subject of regular specific measurement and review. Such review should be carried out by an independent group using a range of tools including questionnaires, staff surveys and interviews, observations, and focus groups. If such a team is established from within the organisation, there is a danger that it may not be sufficiently detached from the organisational culture and careful consideration should be given to achieving sufficient independence. The review team should report to business and corporate leaders, with clear recommendations on what may be needed to maintain and, where necessary, improve the existing safety culture.

When substantial organisational change is taking place and/or the organisation is subject to strong commercial pressure, there may be a temptation to reduce the review programme because of pressure of other commitments. However, the changes may themselves be impacting on safety culture. Thus, in these circumstances, rather than reduction, consideration may need to be given to strengthening the review process so that leaders and managers are aware of any impact on safety culture and thus process safety, and can take appropriate action. The use and effectiveness of review processes is discussed in Part 2.

6 EXPECTATIONS: BUSINESS ENVIRONMENT – COMMERCIAL PRESSURES

6 OVERVIEW

Most of the events studied have occurred during or after periods of major organisational change and accompanying organisational and commercial pressures. Whilst change is clearly necessary and can be beneficial in improving organisational arrangements, it can, if not carefully controlled, have a potentially adverse effect on process safety. For example, commercial pressures to get projects or work programmes completed to schedule (sometimes against extremely demanding requirements) have resulted in unacceptable safety standards.

Change requirements and production pressures should be balanced by defensive precautionary systems to avoid over-commitment relative to available resources and a short-term focus.

It is clearly a function of senior leadership to be fully aware of the imposition and build-up of commercial pressures and their potential impact on safety and to act accordingly to ensure that appropriate steps are taken to ensure that process safety risks remain acceptable. Where pressures are being imposed higher in the organisational structure or by external bodies (e.g. by government), it is important that leaders make clear the potential impacts and challenge these at an early stage. The importance of the issue is judged to be such that the topic is presented as a separate theme rather than an aspect of leadership - important though this is.

The reasons why interventions involving organisational change can fail and the need to adopt an iterative cyclical process with progress towards defined milestones and the active use of feedback to reconfigure the intervention where necessary is discussed in Part 3.

Other parts of Part 1 of the report where business environment related issues are discussed explicitly include Sections 4, 6, 7, 8, 10, 11, and 13.

Table 3 - Summary of the business environment expectations

BE1	Leaders making business decisions should retain an awareness of how these may impact process safety and ensure that appropriate steps are taken to ensure that resulting risks to process safety are acceptable. Where major changes are planned, a robust management of organisational change process should be in place that enables independent assessment of the impact of proposed changes on process safety.
BE2	Availability of resources should be such that process safety requirements are not undermined by budgetary and resource constraints. Performance incentives, where used, should fully recognise process safety performance. In particular, managerial incentives should not reduce their commitment to maintaining standards such as assessing and controlling process safety risk.
BE3	During the change process, communication with staff and visibility of senior management should be strengthened. Clear evidence should be presented that process safety continues to take precedence over other matters and that safety standards are being maintained. Communications should ensure awareness of any emerging process safety risks and facilitate an understanding of the safeguards being implemented to ensure safety.
BE4	The continued need for concerns to be openly raised and supported in regard to process safety should be emphasised wherever change is taking place. The pressures placed on staff and its effect on their health and performance should be monitored and action taken to provide support where necessary. Working conditions and plant, including maintenance provision and technical support, should not be allowed to degrade, and investment in safety critical plant should not be deferred without a strong safety case.

BE5	Work programmes and operational tasks should be carried out to agreed and realistic schedules, with clear procedures and quality requirements. The appropriateness of these should be monitored and the safety implications of schedules fully assessed and understood - particularly for outages and higher risk operations.
BE6	Client oversight of contractor performance and capability should be maintained to monitor effectiveness. The potential demands of schedules for the delivery of contractual work should be fully considered with providers. Assumptions about preparatory work and the maturity and transferability of the technology being used should be fully assessed.
BE7	Competence levels and associated training should be maintained at all times. Accountabilities and all aspects of the SMS should be kept up-to-date to reflect changes taking place. Staff should be informed and trained to take account of the impact of changes on their role.
BE8	Multiple initiatives for business improvement should be prioritised, and implemented in an ordered and effective way with careful consideration of resource requirements and pressures on staff - including managers, who may be under pressure to maintain safe practices with fewer staff and resources.
BE9	During periods of major change, audit and oversight processes should be strengthened where necessary, so that leaders have sufficient information on the evolving situation and action taken as required. Areas assessed should include such matters as: impact on the workforce and their performance; changes to the SMS - including ensuring that over complexity does not develop; clarity about roles and accountabilities and, the maintenance of competence and expertise.
BE10	The longer-term impact of outsourcing should be assessed including the organisational implications of loss of competence in business-critical areas. The cumulative effect on process safety of incremental changes should also be examined. An independent safety function should monitor potential impacts and have direct access to leaders and senior managers so that any concerns can be raised.
BE11	As appropriate, regulatory bodies should be kept adequately informed about change initiatives, their progress, and the safeguards being adopted to ensure that safety is maintained. It should be understood that they may need to resist pressure to accede to duty holder timescales when these are not compatible with carrying out a rigorous risk assessment.

6.2 DISCUSSION AND COMMENTARY

6.2.1 Potential impacts of major organisational change

To ensure acceptable levels of safety, it is essential that there are robust management of change requirements and procedures in place that are not merely a 'rubber stamp' for decisions that have already been taken. These should be independent of those making the decisions, and those reviewing the possible safety implications should not feel under pressure to confirm their acceptability.

Impacts that have occurred widely following major organisational change include weaker supervision and audit, and loss of capability in key support functions (e.g. engineering support, maintenance, training etc.). There is often a substantial increase in workload such that critical staff are placed under unacceptable pressure and can thus be tempted or encouraged to take short cuts in carrying out safety-related tasks; an SMS that no longer addresses operational reality; leadership instability (e.g. rapid rotation of post holders) such that the change process is not managed to completion; key staff taking on multiple roles ('dual hatting') with responsibility being assigned for multiple systems and, new duties leading to greater organisational complexity with a potential blurring of accountabilities and less effective communication. There is also a

danger that experienced and capable staff may be lost without due consideration of how their expertise will be replaced and passed on.

Multiple small changes ('salami slicing') can lead to the same long-term effect as a major change and it is important that provision for assessing the cumulative impact of these is built into the management of change process.

6.2.2 Avoiding unrealistic schedules

Commercial pressures can often lead to projects being carried out to very 'tight' (if not unreasonable) timescales. On some occasions such tight schedules have been justified by the view that the work to be carried out involves tried and tested techniques that therefore do not require major re-assessment or testing and can be compressed. On some occasions, however, alterations and extensions to plant or methods, or differences in the 'environment' in which they are to be used can, in effect, mean that the technology is 'stretched' such that it is more developmental than mature and consequently requires much greater analysis and scrutiny than envisaged. It is therefore important that requirements and procedures are in place to ensure as far as reasonably practicable that this possibility is recognised.

Pressures on timescales can also occur in an operational context when it is necessary to carry out work to a demanding schedule. This can involve specific operational tasks (e.g. outages, start-ups etc.) or activities such as inspection and maintenance for which a specific time has been allocated. Here, there is a danger that scheduled work, may fail to be completed or unduly rushed with consequent short cuts and poor quality. Work is also sometimes carried out against procedures that are not up-to-date or appropriate. It is thus important that before approving such operations, timescales and procedures are critically assessed

Aggressive schedules can also arise in work to be carried out by contractors. Here, there is a danger that to win a contract, those bidding may offer and then agree to carry out the work to a very tight and sometimes inappropriate schedule. It is therefore important for clients and contractors to be clear that schedule pressures should not be allowed to undermine safety. This requires clarity about contractual and associated technical requirements; project assessment and preliminary analysis; acceptable quality standards and, processes should be in place to ensure that the normalisation of deviations, the taking of short cuts and /or turning a blind eye to non-conformances do not develop. Audit and client oversight arrangements should ensure that the possible development of these potential concerns is carefully monitored during the course of the contract. The need for the leadership of all parties in a contractual relationship to understand obligations and goals is used as an example of how the use of CLM can develop insights into a complex issue in a case study in Part 3.

Where targets or specified timescales are imposed for work completion, it is important that the views of those involved are sought and considered, and that management reinforce their commitment that safety should take precedence. In particular, they should support those who raise a safety concern, even if this requires an extension to planned timescales, rather than directly or indirectly giving precedence to the need to 'get the job done'.

6.2.3 Impact of business pressures on the workforce

Major change, if not carefully planned, monitored and discussed with staff can have a significant impact on morale and as a consequence potentially on safety culture. If the message is conveyed, however unintentionally, that cost savings take precedence, this should be picked up by the workforce, including their line management, and a variety of negative consequences may follow. These include 'turning a blind eye' to signals of potential danger; the development of a 'mindset' that 'short cuts' are acceptable; that deviations from the norm can be accepted without investigation (normalisation) and, that it is pointless to raise concerns or challenge because this will not be welcomed. This change in attitudes can lead to living with inadequate systems of risk control, casual compliance, 'making do' and not 'making waves', and can ultimately lead to significant increases in risk that become self-reinforcing. Risks can also be compounded by under-investment, leading to deteriorating plant condition, inadequate maintenance, and deferred capital investment on important safety provisions.

Reductions in staff numbers and other resource reductions can lead to impacts on mental health (e.g. anxiety about jobs), overload leading to excessive overtime and sickness absence (as the inquiry into the Columbia

shuttle disaster succinctly put it 'The few, the tired'). Another result can be a reduction in training (resulting partly from cuts in the training function and partly from workplace time pressures) at a time when training may be most needed as a result of changed roles and new work patterns and processes. In addition, management may have to spend more time fighting for a sufficient 'slice of the cake' from those who control budgets and who may not fully understand potential impacts and the importance of the need to address safety concerns. This should also result in distraction from the technical and people-related problems that may be building up as a result of the mounting pressures. Furthermore, there is a danger that managerial attitudes may be shaped by performance contracts or bonuses that reward cost saving and meeting budgets more than by measures of process safety performance.

It is thus important that pressures placed on the workforce and their potential impact on health and operational performance should be monitored, with a clear commitment to minimise adverse impacts. It is also important to continue to provide adequate time for training and team discussion with a sufficient focus on safety issues, and to maintain acceptable working conditions.

6.2.4 Leadership and senior management actions

As noted in the introduction to this section, it is a primary responsibility of those leaders responsible for business decisions that lead to organisational change to consider how the changes and any consequent business pressures, may impact on process safety and to ensure that associated risks remain acceptable.

In addition to an effective management of organisational change process, priority should be given to communication with the workforce with visibility of senior managers and leaders. This may be viewed as difficult since they may feel 'uncomfortable' in discussing the envisaged major changes with those most affected. However, it provides an opportunity to reinforce corporate commitment to safety, explain the safeguards in place, and to encourage staff to raise concerns during a potentially higher risk period.

'Initiative overload' can lead to a loss of focus and 'change weariness'. Thus, it is important that support is given, where necessary, to ensure prioritisation of the changes to be made so that they can be implemented in an ordered and effective way.

Audit and oversight processes may need to be strengthened to monitor the implementation of the changes and to monitor the adequacy of the time and resources allocated to process safety. This should enable senior managers and leaders to stay in touch with the reality of the process and to be seen to be acting if issues arise. A well-resourced independent safety function with direct access to senior leaders can have an important role to play in advising on concerns, necessary improvements, and in facilitating the transfer of learning as changes proceed - so that 'mistakes' are not unnecessarily repeated.

Accountabilities should keep pace with the change process. For example, where changes are made to support functions, it is important that those managing operations and/or projects remain clear about where they can obtain support and that changing roles and responsibilities are understood by both users and providers.

Changes require the provision of up-to-date procedures that keep pace with requirements. If change requirements are merely 'bolted on' to existing systems, this may lead in some cases to an ineffective and over complex system. Provision therefore should be made to ensure that required changes are effectively integrated into the SMS, that they fully reflect the new requirements, and that users are not only aware of these, but are trained in their application.

The use of contractors to carry out some functions that were previously 'in-house' can present significant extra challenges to leadership. It emphasises the need for a longer-term view to be taken about loss of competence, over reliance on external resources and for strong client oversight in situations where there exists the potential for adverse impacts on process safety.

The need, where appropriate, to keep regulatory bodies informed and to listen to any concerns should be recognised. This may need to occur at various levels from strategic concerns about the nature of the change process and its impact on safety, to discussion about impacts at 'local' level and the management of the process. It should also be recognised that rigorous timescales for the approval of projects, where required, can place significant pressures on regulatory bodies and affect their own ability to carry out effective scrutiny.

7 EXPECTATIONS: EFFECTIVE COMMUNICATION

7.1 OVERVIEW

The effectiveness of communication within an organisation is often discussed in relation to safety culture. Whilst it is an important aspect of safety culture, the events studied in this research have arisen without exception, in part, as a result of ineffective communication. It has thus been presented here as a separate topic. The need for effective communication pervades all parts of an organisation and those with which it interacts.

Communication 'oils the wheels' of all aspects of safety management. The failures that occurred (sometimes multiple) in the events studied, all led to missed opportunities to mitigate or avoid the ensuing event. Thus, improvements in communication both in the longer term and during the lead up to an event, and understanding how to make it more effective, are an important aspect of minimising the organisational and cultural precursors to major events.

Five important situations requiring effective communication are addressed in the discussion and commentary on this topic in the sub-sections below. The first of these is the effectiveness of the communication that takes place 'downwards' from leaders through to those carrying out operations and the reverse 'upward' process (feedback). It then considers good communication in an operational context. This involves interaction between operators, control rooms, engineers (technical support), maintenance personnel, and between those working within each function - particularly during shift handover or in abnormal conditions. Where work is being carried out by contractors this adds an extra dimension to the communication process. When an organisation is undergoing major organisational change, this can have a substantial impact on the need and effectiveness of communication. Finally, communication with outside organisations is considered - this includes all parts of the supply chain, regulatory bodies, industry organisations and other external stakeholders.

It should be noted as a point of clarification not specifically mentioned in the reviewed event investigations, that communication can take place in a variety of forms. In this report, only 'official' communication is discussed. 'Unofficial' communication may be verbal or non-verbal. It may be very effective in making a point in a way that is intended to convey a 'message' whilst no formal communication has been made. Organisational expectations can be undermined or reinforced by 'a nod and a wink'. It is thus important that awareness is maintained and that the inappropriate use of these informal and potentially detrimental ways of 'communicating' are discussed in training and discouraged by leaders.

The specific issue of 'message' content and, in particular, the pathway from message transmission to behavioural impact is discussed in Part 2. This also considers the proportion of individuals who change their behaviour as a consequence of the communication process.

Other parts of Part 1 of the report where communication related issues are discussed explicitly include Sections 5, 10, 12, and 13, with some references in sections 4, 7 and 11.

Table 4 - Summary of effective communication expectations

Comms1	There should be clarity regarding communication routes for all operational matters. Communications should be timely, intelligible, and relevant to those in receipt of them, and recipients should not be 'overwhelmed' by communications such that key messages are lost. Communication and its importance should be included in training programmes.
Comms2	The workforce (including contractors) should be encouraged to provide feedback on any concerns and should feel that this is valued and acted upon and should know how to provide the feedback. They should be made fully aware of the process safety expectations of the organisation relevant to their role - such as the expected behaviours underpinning a strong safety culture and the importance of this to ensure safety.
Comms3	Effective communication can be achieved in a variety of ways including the use of modern communication media, but face-to-face communication should be a primary method. In the case of leaders and senior managers this provides an opportunity to stay in contact with operational 'reality' and can also help develop trust and respect - providing evidence that senior management are committed to listening and are genuinely concerned to achieve a high level of process safety.
Comms4	Leaders and relevant managers should receive regular briefings on process safety risks. They should be encouraged to remain open to information that does not conform with existing perceptions. It is thus important that the information received is not 'censored' or 'rolled up' such that they miss important concerns. Following discussion, leaders should satisfy themselves that effective actions are being taken on identified concerns, whilst retaining awareness of the 'big picture'.
Comms5	Where serious concerns arise regarding a major process safety issue, work should be halted, where it is safe to do so, until the matter is resolved with the input of specialist advice where necessary. This should be clearly supported by management. Such actions have the added advantage that they emphasise very effectively that maintaining process safety is an overriding management concern.
Comms6	Particular emphasis should be given to maintaining effective communication with all concerned parties during higher risk operations (such as start-ups). Engineering and supervisory expertise should be available at all times and support functions should be made aware of plant status. In emergencies, clear channels of communication should have been established and tested during exercises, such that confusion on what to do is minimised in the case of an actual event.
Comms7	The role of line supervisors and their managers in ensuring good communication is very important. They should retain full awareness of all current operational matters within their control, ensure that specialist advice is sought if concerns arise, and be aware of the need not to create a 'dam' against minority views or other 'uncomfortable' feedback. By maintaining effective communication routes, the existence of operational 'silos' should be minimised.
Comms8	Procedural requirements should explain the importance of key steps and should be presented succinctly - minimising paperwork and bureaucracy. Process safety-related matters, including the need for full procedural compliance, should be included in regular 'toolbox talks' and review meetings. Records should be kept of actions arising from these and their completion and effectiveness.
Comms9	Shift handover should be subject to rigorous procedures and a log kept of the process. Any plant changes or concerns should be covered, together with the status of current operations and monitoring provisions. Understanding should be confirmed. Trained deputies should represent supervisors if absent. Sufficient working time should be allocated for the process.

Comms10	During normal operations, it is also important for effective communication channels to be established and kept open. Important channels include those with and between supervisors, control rooms, maintenance and engineering teams, and any contractors involved. New work should not be started without clear instructions, awareness of any process safety issues that could arise, and information about assessments or changes to plant that have taken place or are about to take place.
Comms11	Team meetings (or toolbox talks) should be held regularly. Among other things, these should seek to remind staff of key plant issues and procedural requirements - including the need to conform to procedures and monitoring requirements and to listen and respond to feedback. Staff should also be enabled to maintain a clear understanding of the safe operating envelope, the prioritised actions to be taken in response to alarms, and the need to seek advice when concerns or uncertainties arise. Engineering support should be located at the plant or site and available at all times.
Comms12	Where contractors and subcontractors are being used, it is important that the client ensures that communication systems are sufficiently well aligned and effective at all levels of the organisations before work begins. This should ensure, for example, that changes to the organisation, processes and plant are communicated to all parties concerned. In addition, those involved should be kept up-to-date with developments at regular documented review meetings. All changes (including repairs carried out during construction) and results of risk assessments should be notified to the client and reviewed as necessary. Future users of project output such as operational staff, should be sufficiently involved to ensure a good understanding of implications for future operations.
Comms13	Consultants engaged to provide technical advice for projects should be kept fully informed about relevant developments. Their conclusions should be reviewed with assumptions carefully examined. Written reports should explain the basis of conclusions and recommendations and should be written in a form that should be intelligible to recipients. Where organisations are employed to provide project oversight, their role should be fully explained to all other involved parties.
Comms14	The safety significance of supplied equipment or plant should be clear to both supplier and client. The agreed specification, including quality requirements, should be fully met. Suppliers should be aware of the risks inherent in the application of the supplied goods and that any changes to specification should not be carried out unless fully reviewed with the client - who should also be fully aware of limitations and potential vulnerabilities.
Comms15	Communication processes can be seriously affected by organisational change and they should be reviewed to reflect any 'new reality'. This should ensure that the identification and discussion of matters such as staff feedback, monitoring data, and performance indicators 'get through' to those responsible for ensuring their effectiveness.
Comms16	Wider communication should be maintained with outside bodies to improve mutual learning. Output from this should be 'tailored' to the needs of those in the organisation to whom it may be relevant before it is made available and recipients should not be overwhelmed with information that is not relevant and that might affect identification and response to that that is important. Regulatory bodies should be kept informed of significant matters where appropriate.
Comms17	Staff should also be kept broadly informed of safety developments of potential interest through mechanisms such as organisational newsletters. This should help them feel more 'engaged' with wider learning, such as the results of investigations into serious events within and beyond their industry sector.

7.2 DISCUSSION AND COMMENTARY

7.2.1 Communication up and down the management hierarchy

There is a need for recognised and effective routes for communication with clarity regarding points of contact. These primary routes should not preclude other communication routes being established where judged to be necessary, but the agreed primary routes should not be neglected. It is also important that 'messages' are provided in a form that are timely, relevant and intelligible to those receiving them and that recipients are not so overwhelmed with communications that they lose sight of areas that should be of interest and concern to them.

One important area of communication is that staff understand the process safety expectations (or equivalent) of the organisation, including the behavioural standards that underpin safety culture. In some cases, management communication has not been consistent with actual working conditions, requirements and practices, and it is thus important that leaders and managers recognise operational 'reality' because, otherwise, their pronouncements might be regarded with cynicism by the workforce.

The workforce should also feel that their feedback on process safety concerns is valued and acted upon, and the results of consequent investigations fed back to the workforce. Feedback routes should be clear to all personnel on a plant or within a project.

It is important that communication is not just in electronic form although modern communication media may have an important place. Key process safety messages benefit from face-to-face contact wherever possible. By this means, managers and leaders should be able to get a better understanding from those 'closest to the tools' about safety concerns, with the opportunity to develop greater trust and mutual respect. It also provides an opportunity for leaders to reinforce safety messages, particularly when staff may feel that safety is becoming secondary to other business objectives.

Leaders and relevant managers should receive regular briefings on process safety risks, particularly from the independent safety function, and remain responsive to these even when their content may be 'unwelcome' or where it does not align with their previous perceptions. Information provided should not be 'rolled up' or over simplified, and leaders should be aware of emerging risks and understand the implications and actions being taken to bring specific risks to acceptable levels. They should ensure that responsibilities are clear and that a 'grip' is being taken of the ensuing risk reduction process. They should also retain a clear view of the 'big picture' of the hierarchy of risks facing the organisation.

A key message is that if there is concern about a major safety issue - including uncertainty about the potential for the development of a dangerous situation - work should, where possible, be safely stopped, advice sought and operations should not re-start until it is safe to do so and uncertainties have been resolved. Such actions should be strongly and consistently supported by management. This can play a major role in reinforcing staff belief that safety is a genuine priority.

7.2.2 Operational communications

In addition to up-to-date technical training reinforced by checks on understanding, communication skills should be included in training programmes with examples of how events can occur through communication failure.

All staff and contractors should be aware of the process safety risks relevant to plant and how to respond in the event of problems or concerns. This is particularly important during higher risk operations such as start-ups, or operations in non-standard conditions (e.g. a line of protection undergoing maintenance). Strictly enforced procedures and communication channels (e.g. to other relevant operations) should be in place, and staff should be reminded of requirements before proceeding. Safety advisors and engineering specialists should be aware of the relevant operations and should be readily available at all times, such that advice can be sought by operations staff in the light of any concerns or uncertainty regarding process safety.

If emergencies occur, clear channels of communication should be in place. Regular exercises should ensure that potential confusion about roles, procedures and reporting routes is minimised.

The knowledge, capability and communication skills of supervisors and their managers is particularly important and they should ensure that they remain fully aware of matters such as current plant status

(including any abnormal results or conditions), work in progress, and monitoring data. They should also be aware of routes for reporting and obtaining advice. Minority views should be encouraged and supervisors and managers should not create a 'dam' against dissenting voices. Open communication should be encouraged at all relevant levels (not just between managers) and thus the establishment of 'silos' within and between functions minimised. The complexity of reporting routes should also be minimised wherever possible to avoid the development of unofficial hierarchies.

Procedural requirements should be available in written form with clarity about why key requirements are important. They should be presented as clearly and succinctly as possible, minimising paperwork and bureaucracy as this can be a disincentive to use.

Regular team meetings, 'toolbox' talks and performance reviews should be part of the communication process and attendance should be a requirement of the job. Records of these and other relevant meetings should be kept, and it should be made clear who is taking forward actions and what checks are to be made on completion and effectiveness.

The need for strong communication in an operational context has many facets but particular areas have been highlighted by the reports into the twelve events studied. One of these is shift handover, and another relates to requirements during normal operation, including the need to maintain engineering/technical presence and support - particularly during higher risk operations or when unexpected problems arise.

a) Shift handover

Rigorous formal procedures should be in place at change of shift for both operational staff and engineering and technical support teams so that the status of operations and any possible problems can be reviewed and requirements clearly set out. A record should be kept of the handover process. This should be reinforced by management awareness of practices with checks on conformance. The process should involve a formal written log that is not 'cursory' but has meaningful, complete and intelligible entries, and face-to-face discussion between shift supervisors. If the incoming supervisor is absent from the plant at handover or at any subsequent time during the shift, a trained deputy should be available. As with all safety-related decisions, sign off at shift handover should not take place until the incoming team fully understand the current plant condition, including any elevated risks, and any checks that are to be carried out or that have been performed. Monitoring data on operations from preceding shifts should be fully available to the incoming shift and shared as required with support functions. The handover process should be carried out during work (paid) time and not rushed.

b) Continuing operations

During normal operation, there should be effective communication between all parties involved in day-to-day operations including operators and their supervisors, control room staff, those dealing with faults and maintenance, engineering (technical support), and any contractors involved. In particular, it is important that assumptions are not made about the status of plant or procedures, that changes are communicated in a timely and intelligible way, and that new work is not started without clear supervisory instructions and awareness of the process safety issues that could arise. For example, records of recent decisions about changes to the plant or to process, hazard reports, risk assessments and any recent repairs, should be briefed to all concerned.

Maintenance requirements should be part of a formal system within the SMS and should not be communicated on an informal basis. Requirements for this and other operational issues should be entered in an operational log that records and explains decisions. This should be a 'living document' and available to other relevant teams.

In regular safety briefings, individuals and teams should be kept up-to-date with any changed priorities, amendments to work instructions, and other operations that may interact with their work programmes. It is vital that at all times, operational and associated staff are enabled to retain a clear understanding of the safe operating envelope and the relevance and importance of alarms and their follow up - with a log kept of alarms and actions taken in response to them.

It is very important that effective communication is maintained at all times between operators and engineering support. This should be 'around the clock' so that if unexpected process safety problems, concerns or

uncertainties arise, there is always competent support and advice available. Engineering capability should be located sufficiently close to the plant or project so that open continuing contact between operators and engineering support is an accepted part of the operational process. Any proposed changes to procedures or plant should be appropriately reviewed and authorised by a competent, approved manager.

7.2.3 Communication with contractors

Organisations with different cultures, management systems and processes for communication should make provision to ensure that for process safety in particular, there is sufficient understanding and alignment of systems to ensure that communication is effective. This also includes subcontractors whose work might affect process safety.

Ensuring acceptable systems is an important role for the client. For contracts potentially affecting process safety, the communication pathways need to be clear at all levels in the organisation and for all project partners, with good liaison between teams. All relevant parties should be involved at an early stage following the establishment of a contract, to prepare arrangements that seek to ensure good communication at various levels in the organisations, including senior managers. This should ensure, for example, that changes during the contract to plant, organisation or process are communicated and discussed, and that all parties are briefed and kept fully up-to-date with developments. Regular review meetings should be held with all involved parties and with representation at an appropriate level of seniority. The meetings should review project developments, including quality and maintenance information. Output, including actions and decisions, should be documented.

If consultants are engaged to provide technical advice, they should be kept closely informed about project developments and their views made clear to all concerned so that existing assumptions can be reviewed as necessary. Consultant's reports should be kept fit for purpose without unnecessary detail that may influence readability and understanding. Assumptions on important matters should be reviewed before acceptance. Where organisations are employed to provide contractual oversight on behalf of the client, their role should be fully explained to all other parties so that there is no ambiguity about who is responsible for what.

If changes are planned or repairs are to be carried out during construction, the client should be notified and any necessary assessments carried out before work proceeds. Future users of project output should be involved, where possible and appropriate, in the project in order to ensure that they have a good understanding of matters relevant to subsequent operations.

Clients should also be aware of the potential motivation of contractors to obtain follow on work. Whilst this may encourage good performance, there may, on occasions, be an incentive to 'hide' difficulties or shortfalls in progress in order not to 'upset' the client. The latter should ensure, therefore, that adequate arrangements exist to monitor and challenge, and where concerns arise, to ensure that the matter is resolved at an appropriate level.

Communication about the safety significance of supplied equipment or plant in a process safety context should aim to ensure that the agreed specification is always met, there is good quality control and that suppliers understand that some components may be used in safety critical applications. In such cases, they need to understand the vital importance of conformity to specification with no changes, however minor, unless a mutually agreed risk assessment has been performed to a depth commensurate with safety significance. Equally, the end-user should be enabled to develop a sufficient understanding of the supplied product such that limitations and potential vulnerabilities are recognised.

7.2.4 Role in organisational change

Organisational change can have profound effects on established lines of communication and this should be recognised and addressed during the change process, and effectiveness monitored. Sometimes, however, organisational change can also enhance communication by simplifying structures and streamlining processes.

If an unsatisfactory communication system is implemented that does not reflect changed 'reality' and/or is not clear and simple to use, communication over important aspects of process safety can deteriorate. The consequence can then be that important data may be lost, weak signals missed, and engineering inputs and workforce concerns neglected. Furthermore, important feedback can fail to 'get through' as it progresses up the management chain.

7.2.5 Wider communication

Industry associations and other external organisations should frequently have available reports and safety-related information. It is thus important that sharing of available knowledge relating to process safety is made available to all who may find it of value. Where such learning is available, promulgation should be targeted so that recipients are supplied with information that is relevant to them. A recognised and competent part of the organisation to facilitate this should be established.

Regulatory bodies should, as appropriate, be kept informed of any matters that are relevant to their role. Apart from those matters that are formal requirements, there should exist a communication process that ensures that regular discussions occur and that there are 'no surprises'. This should generate regulatory confidence that the organisation is listening to their concerns and suggestions, and being open with them. It should also minimise unexpected regulatory action.

In addition to the specific requirements for effective communication over safety matters, staff should feel more 'engaged' and committed to the organisation if they are regularly updated on developments and other matters of potential interest through communications such as organisational newsletters. Ensuring that process safety issues are included in communications can provide added confidence that the issue is treated as high profile and is receiving continued leadership commitment.

8 EXPECTATIONS: SAFETY MANAGEMENT SYSTEM (SMS)

8.1 OVERVIEW

The SMS (SMS) should be a comprehensive, living set of documents containing sufficient detail to minimise ambiguity, whilst retaining clarity and intelligibility to ensure that control can be maintained (and thus high levels of process safety achieved) in operations. The SMS should ensure that operators understand the importance of key steps in relation to the goals to be achieved.

The SMS should be designed to ensure that all regulatory and legal requirements are met in construction, operations, projects, and decommissioning for all activities. It is also an important vehicle for ensuring that organisational expectations for process safety are translated into well-understood working practices that if appropriately supported and used, can reinforce and support a strong organisational safety culture.

In all of the events studied, there have either been serious inadequacies in the SMS and/or a culture of non-compliance arising for a variety of reasons. Often the need 'to get the job done' to meet schedules or as a result of poorly thought through changes, including reductions in resource below a level that is required to achieve acceptable levels of safety, have adversely affected the SMS and its application.

Other sections of Part 1 where SMS related issues are discussed explicitly include section 10, with some references in section 4, 5, 6, 7, 9, and 11.

Table 5 - Summary safety management system expectations

SMS1	The SMS should be formulated by specialist staff - applying risk assessment where appropriate. It should take into account human factors and the experience of users to ensure effectiveness in operation. It should be made clear where the SMS is goal based and where it is prescriptive.
SMS2	Promoting and checking of compliance and actual operating practice is an important role for supervisors and line managers. They should ensure that a 'tick-box' approach to the use of procedures does not develop. There should be clear accountabilities for the control of each part of the SMS with a clear 'process owner'. It should be kept up to date as a 'controlled' document. Operational 'waivers' that allow non-compliance with the SMS should be carefully controlled and authorised at an appropriate level.
SMS3	Leaders should ensure that they are able to maintain a clear overview of the management and adequacy of the system - receiving reports on any major issues. They should support and promote the importance of the SMS, encourage a questioning, cautious approach that takes full account of the reporting of user concerns, particularly during periods of organisational pressure. They should set an example through their own actions.
SMS4	The SMS should not be over complex or bureaucratic as this may discourage compliance and the process safety reasons for key steps should be made apparent. All SMS related documentation should be aligned and integrated within an accessible easy-to-use overall system. Periodic checks should be carried out to ensure that the SMS is fit for purpose and is meeting its objectives. It should align (or be suitably integrated) with other systems such as those relevant to quality (quality management system, QMS) and the protection of the environment.
SMS5	The SMS should also fully align with the safety case that should provide a basis for key aspects of it. For example, the safe operating envelope should be clearly presented to operators with an explanation of the need and approach required to stay within in it. Administrative controls should be identified, and systems that do not rely on human intervention as the primary mechanism to ensure safety should be introduced where ever it is possible to do so.

SMS6	The content of the SMS should address all matters relating to control of work, including roles and responsibilities, communications, maintenance requirements, and testing and monitoring. It should also set out requirements for upward reporting of concerns and their follow up, management of projects and contractors, risk assessment practices as well as records such as safety classification of plant, risk registers and authorisation of changes to the system.
SMS7	For safety critical operations such as start-ups, all plant should be confirmed as meeting requirements, and only then should formal agreement be given to proceed. Run-throughs and briefings should be in place to remind staff of the SMS and its requirements. These higher risk operations should be subject to effective monitoring with ongoing supervision.
SMS8	Anomalies and unexpected findings should not be 'normalised' and treated as routine, and 'signals' that challenge assumptions should be treated as learning opportunities and fully investigated. Requirements to respond to off-normal conditions and emergencies should be set out in the SMS.
SMS9	The SMS should aim to reduce identified risks as far as is reasonably practicable. The risk assessment process used should be kept up-to-date (dynamic) in the light of emerging findings and data, including the results of management audit and independent oversight processes. All identified risks should be addressed as part of a prioritised reduction plan. Particular emphasis in the SMS should be paid to new or less familiar technology.
SMS10	All changes to procedures (including those that are temporary) should be independently assessed, verified and appropriately authorised. This should include the need for the change and any potential 'knock-on' effects. Proposed changes should be discussed with relevant teams and those in interfacing areas, requirements for refresher training assessed, and compatibility with the existing safety case carefully considered and addressed. The process should not be over lengthy or bureaucratic, however, as this may act as a deterrent to effective reporting.
SMS11	In addition to line management checks and audits, independent oversight of the SMS should be carried out on a regular basis. This should enable a 'wider view' of the system to be taken drawing on experience and good practice. As well as more specific checks on coverage and content, the impact and response to changes, workforce and management attitudes, approaches and workforce views on the system, should all be considered. In addition to these, topics such as: the response to deviations from the expected; treatment of monitoring and test results; the build-up of backlogs in maintenance; the availability and use of engineering advice; the extent of supervisory control and, the effectiveness of the implementation of previous actions, should be addressed as appropriate.
SMS12	Rigorous training and refresher training should be in place to support the SMS and raise awareness of requirements and changes. The process should use a variety of approaches (not just information technology (IT) based) to allow 'simulations' and discussion where required. Records should be kept of training and individual and team needs updated. Understanding in training should encompass topics such as critical operations, contractor issues, the need for compliance and the reporting of concerns.
SMS13	The mutual requirements of contractors and the client relating to safety management should be addressed at an early stage in all projects in order to ensure mutual understanding of practices and requirements as part of a 'joined up' approach. The client should ensure that uncertainties are minimised, and that the requisite degree of control and oversight is in place to ensure acceptable practices.
SMS14	The client should require a questioning attitude with an agreed approach to such matters as the identification of deficiencies in the management system, remedial actions, required records and reporting of concerns. There should be an intolerance from all parties to proceeding with the presence of shortcomings in the SMS.

SMS15	Contractor self-certification of safety and quality, including the effectiveness of the SMS and conformance with it, should be appropriately overseen and monitored by the client. Any potential 'trade-offs' between the requirements of the management and quality systems against project progress should be identified and addressed before they are implemented. Client oversight should include all matters that might influence the SMS during the operational phase, including trial and test results and changes or repairs during construction. Alignment with the safety case, monitoring, and maintenance requirements of the as-built plant should be considered and provisions put in place prior to operations.
SMS16	Regulatory bodies should, where appropriate, be made aware of any major changes to the SMS and the results of major reviews. Their views and advice should be sought as appropriate.

8.2 DISCUSSION AND COMMENTARY

8.2.1 Formulation and role

The SMS should be formulated with specialist input based, where appropriate, on risk assessment at a suitable depth, but also with input from users. This input should help to ensure that procedures can be performed as written (thus minimising deviations), and more generally, should promote ease of practical application by taking account of human factors and other operational considerations. Control room practices and response to alarms are particularly important areas to be considered.

It is important that there are clear accountabilities for control of the SMS, including independent authorisation of changes with a clear 'process owner' for each part that takes into account interactions with other plant and processes. The development and promotion of the SMS, together with the need to ensure rigorous compliance and awareness of actual working practices, should be a key task for supervisors and line managers. Leadership engagement and support is very important and leaders should receive clear and transparent reports of important issues, enabling them to be aware of the 'big picture'.

Managers and leaders should act as role models in demonstrating:

a) the importance attached to the SMS by maintaining good working knowledge of its requirements;

b) keeping the system up-to-date as a 'controlled' document;

c) ensuring audit of content and use;

d) providing training to promote understanding of its role and importance among staff;

e) encouraging a questioning and cautious approach avoiding unwarranted consensus and,

f) by promoting effective reporting and 'uncensored' feedback of concerns supported by operational monitoring. They should systematically check continued compliance and ensure that an uncritical 'tick-box' response in that completion of paperwork takes precedence over actual practice does not develop.

In formulating the SMS, it is important to achieve a balance between a goal-based approach with sufficient detail to ensure compliance, and a more prescriptive approach with a significant level of detail. Complexity can create more ways in which failure can occur. In some of the events studied, a safety critical perspective was lost with the generation of paperwork containing 'impenetrable' detail and bureaucracy, and with the need to maintain 'hierarchy' taking primacy over the achievement of actual safety. The opportunity should therefore be taken regularly to examine whether the SMS is fit for purpose, taking account of the views of users.

Business pressures should not be used as a reason for failing to address important process safety requirements in the SMS. Management pressures should not be allowed to over-ride valid engineering concerns.

8.2.2 Basis, content and format

The SMS should derive from and be consistent with the relevant safety case. This is particularly important in ensuring that the operating limits and conditions that delineate the safe operating envelope are properly established and understood. It is also important in promoting an understanding of the importance of alarms and other critical control measures in alerting operators if the safe boundary is approached, and then in taking appropriate action.

Wherever possible, there should not be over-reliance on operator action to maintain control in safety critical operations. The SMS should promote awareness of where administrative requirements are present in order to control residual risk, and to the extent possible, these should be minimised and replaced by systems that are not reliant on human intervention.

The overall SMS, in addition to providing operating procedures such as 'tech specs' and method statements, should include or provide reference to a suite of associated documents. As far as possible, all of this documentation should be aligned and integrated and be understood, accessible, and easy to use.

The SMS and associated documents should contain clear requirements for matters such as:

a) maintenance and mechanical integrity (including the required approach to non-routine repairs);

b) control of work systems;

c) shift hand-over practices;

d) requirements for monitoring;

e) testing of critical equipment;

f) action tracking and,

g) verification.

It should also define: reporting requirements and follow up - including investigations; risk assessment requirements; arrangements for the management of contractors and projects and, roles, responsibilities and accountabilities of identified staff, teams and functions. Within the management system, there should also be requirements for the identification, specification and the safety classification of plant and components (with associated requirements for monitoring and trend analysis), and for inspection and maintenance. It should also define requirements for records, checklists, databases and systems for matters such as risk control, the making of changes to the SMS and associated authorisations.

All plant should be confirmed as working and effective before key operations such as start-ups take place and any deviations should be the subject of review. The SMS should also provide instructions for responding to off-normal conditions and emergency preparedness - with clarity about lines of authority for addressing more serious events.

It is important that when system failures occur, these are treated as potentially important precursors that could occur again with a different outcome. They should therefore not be normalised and treated as routine.

Risk assessment based upon both specialist and user input should provide the basis for the safety case and associated documents and thus for the SMS, and provide an understanding of specific and cumulative risks. Risks should be reassessed, where necessary, in the light of any emerging findings and data, and in response to the results of management audit and independent oversight. It is important to ensure that 'signals' that challenge assumptions about risks are recognised and analysed.

Risks should be addressed on a planned and prioritised basis. An overview should be maintained to ensure that risks are reduced as far as is reasonably practicable. Assessments should be up-to-date and 'dynamic', with particular attention being given to new or unfamiliar aspects of the technology. They should reflect changes in operational and organisational conditions.

The SMS is sometimes part of a wider QMS and, whatever the formal organisational relationship between the two in a particular organisation, it is important that their roles and interfaces are clear and that they are mutually

consistent. It should also align with systems in place such as those, for example, used to manage environmental matters.

8.2.3 Review of the SMS and control of changes

All changes to procedures, even those that may appear to be small - such as proposed extensions and temporary changes - should be independently assessed at an appropriate depth, verified and appropriately authorised before implementation. This should include understanding of the case for the change and the identification of any potentially wider consequences ('knock-on' effects) as part of the management of change process, with records kept of how and on what basis decisions were made. In this respect, procedural changes should be treated in the same way as proposed changes to plant or organisation. Proposed changes should be discussed with teams and their supervisors and systematically communicated to other relevant teams whose activities could be affected. This should ensure that a mutual understanding of management system requirements, and the potential importance of these at interfaces is achieved. Modifications such as changes to plant, or lessons learned from operating experience, should be reviewed to ensure that refresher training needs are identified and that relevant safety considerations are fed back into the safety case thus providing a 'reinforcing' system.

In carrying out these processes, it is important however that changes do not take too long to implement. Not only should this increase the time at risk from inadequate procedures, but a bureaucratic process may deter the workforce from raising concerns and increase the likelihood of non-approved 'fixes' and a culture of non-compliance.

In addition to management inspections, checks, and regular line management audit, the SMS should also be the subject of independent review. This should be carried out on a regular basis and to agreed criteria, with findings and actions recorded. The response should be commensurate with safety significance, and completion and effectiveness monitored. Review should include the approach of managers and supervisors to ensuring compliance, the extent that the SMS is up-to-date and reflects needs, and the level of understanding and effectiveness of feedback on identified deficiencies.

These independent reviews provide an opportunity for a view of the system to be taken that is wider and more holistic and which draws on good practice and learning from other sources. In order to ensure adequate 'defence in depth', a layer of protection analysis (LOPA) or equivalent has been used in some organisations. The frequency and depth of review should not be relaxed because significant problems have not become apparent in the past.

In carrying out reviews of the SMS, particular note should be taken of its ability to generate an adequate response to any 'signals' such as deviations from expected measurements (e.g. leakage rates or temperature excursions), increased rates or backlogs in maintenance, and test results that lie outside expectations. Maintenance procedures should not only require standard tests and defined periodic checks and servicing to be carried out, but the system should require checks to be performed on in-service behaviour and performance. These checks should take account of the experience of users and, where appropriate, the condition of components and associated plant. Other checks carried out on the effectiveness of the SMS should include such matters as:

a) the extent of supervisory control;

b) the availability of specialist advice when required;

c) the effectiveness of links between functions such as operations and engineering;

d) confirmation that actions arising from previous audits and reviews have been completed and their effectiveness verified;

e) the quality of work performed in response to the procedures (not just 'sign off') and,

f) the response to any emerging concerns - particularly in relation to 'defensive systems' that are designed to ensure safety.

By exception, and where there is a strong safety-related need to do so, there may be a need to seek an exemption to application of the requirements of the SMS. Such exemptions or 'waivers' should not be routinely

granted and where they are granted, they should be authorised at an appropriate senior level. The extent of the use of 'waivers' should be regularly reviewed to ensure that they are not becoming too prevalent.

Regulatory bodies should, where appropriate, be made fully aware of substantial changes to the SMS and the results of major reviews on an agreed basis. This can inform their own priorities for regulatory scrutiny. Regulatory bodies can also be an important source of advice, given their knowledge of good practice.

8.2.4 Maintaining user competence

In addition to rigorous initial training on the content and regulatory and cultural requirements for an effective SMS, all users and their supervisors and managers should undertake refresher training to ensure understanding of significant changes made, and the process safety reasons for them. It is important that reliance is not placed solely on 'learning on the job'. Records of training and certification, and particularly its relevance to authorised roles, should be kept up-to-date and used as input to assess training requirements as part of regular performance reviews. Refresher training should be carried out using a variety of approaches (not just IT based) allowing specialist input, simulation exercises, and discussion, as appropriate.

Particular steps may need to be taken to reinforce understanding of requirements prior to critical operations such as re-starts and shutdowns, the initiation of new projects (which may involve contractors and thus new interfaces) and, major maintenance activities. These steps can involve not only specific refresher training but run-throughs and briefing sessions to raise awareness of the importance of compliance with the SMS, key aspects of safety that may be of particular relevance, and the importance of reporting and dealing effectively with any concerns that may arise.

8.2.5 Compatibility of systems with contractors

There should be a clear system in place for the management of contractual work that is agreed in advance of the project being established. This should ensure that there is good mutual understanding of the requirements on the designer, constructor and operator (including intermediate phases such as commissioning), with feed-through and continuity of systems.

It is very important that management systems are adequately 'joined up' - particularly between contractors and the host/client organisation. A failure to achieve this can lead to potentially significant issues, particularly when contractor-led projects are being carried out on a client's site rather than at a separate location. In this case, there exists the potential for failure to appreciate areas of potential conflict or uncertainty between systems and approaches. Even if contractor activities appear separate from client operations, it is important that the requisite degree of monitoring, control and oversight is maintained by the client organisation, and any identified areas of overlap carefully examined to ensure acceptable procedures, mutual understanding and operational compatibility.

Any contractor self-certification of the agreed SMS, quality etc. should be subject to client monitoring and scrutiny. Also, any decisions regarding potential trade-offs between quality/safety and project progress should be discussed and reviewed on a timely basis before the project has moved on. Clients and any other organisations working under their control, should have sufficient knowledge of the contractor's management systems in order to achieve effective oversight of contractor work. This should include checks at agreed critical points on the design and construction process, the quality of construction, and the results of any trials and tests (with witnessing as necessary).

Several other matters relevant to SMSs should be considered as a project proceeds from design to build, and on to operations. The safety case and resulting SMS should reflect the 'as built' plant as distinct from original design intent, and the impact of any changes during design and construction considered before they are introduced. Maintenance provision and associated procedures should be fully considered in design and fed through to operations. Records should be kept of matters such as measurements and test results and the basis of safety-related decisions, so that this is available at subsequent stages in the plant or project life to inform the provision of management systems if required.

The client should require a questioning attitude with an agreed approach to the reporting, investigation and the timely correction of deficiencies that become apparent. Repairs and remedial actions should be carried

out in a controlled way with suitable recording and certification. There should be an intolerance from all parties to failure to report emerging concerns or to proceeding with the presence of faults or poor quality.

9 EXPECTATIONS: RISK ASSESSMENT AND MANAGEMENT

9.1 OVERVIEW

The process of risk assessment and management, whether applied to occupational safety or process safety, should follow the same basic approach. It involves identifying hazards, analysing and identifying potential consequences, and using the output to ensure that risk reduction measures are in place wherever reasonably practicable. Assessments should attempt to take an integrated view of risks, utilising both a 'top down' and 'bottom up' approach and looking at longer term potential process safety risks - as well as the short term.

Taking a broad perspective, risk assessment and management can be considered to take place at three levels:

a) holistic, structured assessments that aims to stand back and assess the risks from a plant or process as a whole. Techniques such as PRAs provide a basis for this;

b) operational management assessments that entail the use of hazard identification processes and the design of appropriate mitigation for identified risks. Techniques employed should include the use of check lists, operational reviews and HAZOPS, and

c) what might be termed operational risk control. This should involve approaches used by constructors and operators to identify and mitigate risks as part of their ongoing activities. This may utilise processes such as 'STAR' (Stop, Think, Act, Review) or 'Take Five' that involves stepping back and reflecting for five minutes on likely hazards and the potential safety implications of a particular task. The process should be reinforced by a strategic overview of the entire process.

Other parts of this chapter of the Report where SMS related issues are explicitly discussed include sections 10 and 13, with some references in sections 4, 6, 7, 8, and 12.

Table 6 - Risk assessment and management expectations

RA1	An open-minded view of what may emerge from risk assessments should be maintained at all times without preconceptions. Critical consideration should be given to relevant operational experience (such as observed defects and unexpected occurrences) and underlying causes carefully evaluated. Provisions should be in place to ensure that a 'tick box' approach without sufficient challenge and an over-simplified view is not being taken. Assessments should be carried out using a team approach where ever possible, so that diverse viewpoints can be considered (e.g. workplace experience).
RA2	Changes to safety provisions (such as monitoring programmes) should not be made unless fully risk assessed, and waivers enabling non-adherence to established procedures should only be granted after full consideration of risks and through an approved authorisation route.
RA3	Assessments should not be rushed or deferred to meet business requirements and should be carried out with sufficient competent resource and using approved standards. They should be performed under the direction of a designated suitably competent manager who is accountable for ensuring effectiveness and prioritised implementation of ensuing actions. Definitions of levels of risk should be agreed and set out for all risk assessments.
RA4	Assessments should be 'dynamic', avoid a narrow focus, and should be based on industry good practice and up-to-date standards. They should carefully assess the claimed integrity of safety critical equipment and any changes to plant or processes - including interactive effects, incremental changes, and the results of related assessments. Consideration should

	be given to any measures that can stop the escalation of a process failure or mitigate its consequences.
RA5	All of those involved in carrying out and interpreting risk assessments should have a full understanding of ALARP (and its legal basis where relevant) and how this can be achieved and demonstrated. All findings and the basis for decisions should be documented.
RA6	Issues such as ageing and reliability of plant, including any known or long-standing problems, should be subject to review. Assessments should also be carried out of less frequently used plant or processes of relevance to process safety. Particular attention should also be given to 'legacy' (inherited) plant and systems.
RA7	Investigations into important areas such as control room operations (e.g. response to alarms) and other operational human factors considerations should be fully taken into account in carrying out risk assessments.
RA8	Changes to plant and processes (including temporary works or modifications) and organisational change should be subject to rigorous management of change risk assessments and these should be periodically reviewed for independence and effectiveness.
RA9	A 'stand back', holistic view of risks using techniques such as PRA should be carried out at a designated periodicity. Critical issues such as assessment of fire safety, requirements for dealing with process upsets, and emergency response provision, should be regularly reviewed.
RA10	Duty holders should preferably retain the expertise to carry out their own risk assessments. If, however, contractors are employed, the client should ensure that it has the expertise and capability to act as an intelligent customer. This requires ownership of the process with sufficient 'challenge', awareness of the risks and assumptions used, maintenance of good communication with the contractor and, a questioning approach which ensures that there is sufficient rigour in the analysis.
RA11	Lessons and relevant findings from risk assessments should be used to raise awareness (for example through training) among designers, constructors and operational staff and support functions, about the importance of identifying emerging 'symptoms' and reporting anomalies.
RA12	Safety cases should be 'living' documents which reflect the findings of relevant risk assessments. They should be set out in a form that provides useful input to operational decision making. A record of identified risks and their mitigation that is of value to operations, can be provided by the establishment of a risk register.
RA13	In design and construction, particular attention should be paid to the risk assessment of new technology or novel processes. Good practice engineering principles should be incorporated with adequate safety margins. Likewise scaling-up or other significant alterations to existing plant or processes should be the subject of rigorous analysis. In all cases, suitable codes and standards, calculations and models should be used. Where possible, assessments should be based on actual data (e.g. from trials or proof tests).
RA14	Potential risks arising from construction defects, lapses in quality, or unexpected findings should be rigorously assessed (including any remedial work). In design, awareness should be maintained of the range of conditions in which the plant may be operated and suitable instrumentation made available to ensure that operation meets design specifications. Use of administrative controls in higher risk areas should be minimised with effective alternative systems introduced that do not rely on direct human input where possible. Consideration should also be given to ease of maintenance.

RA15	Oversight of design, construction and commissioning should be carried out in order to assess key process safety risks. Clear accountabilities should be in place for this. Effective communication should be maintained within a 'joined up' approach. The process should take account of the appropriateness of the analytical tools used and the results of trials and tests that should be witnessed where appropriate.
RA16	Independent oversight should also be carried out to confirm that risk assessments at all levels are being carried out thoroughly and effectively and should also seek to determine whether subsequent operations align with the output of assessments. Oversight should also be carried out to examine the quality of construction, the potential impact of any changes to design or construction, and the identification of critical components that require specific operational monitoring and maintenance provision to be established.
RA17	To ensure that leaders are fully aware of important process safety risks, a process should be in place to ensure that a 'corporate' strategic overview is taken of process safety risks and their management. This should allow senior leaders to maintain a better appreciation of risks and allow them to be managed alongside other business risks.

9.2 DISCUSSION AND COMMENTARY

9.2.1 Generic considerations

Risk assessments should be carried out for all plant or processes involving possible process safety risks. In carrying out risk assessments of all types, it is important that individuals and organisations approach the task with an open-minded view of what may emerge and, in particular, do not start from a pre-conceived, over-confident view of what should be found (e.g. that the plant or process is safe and the exercise should confirm this). This can lead to a 'tick-box' approach and a view that identified hazards and their associated risks are acceptable even when they are not, and thus to normalisation. A strong culture of challenge ('what if') should be encouraged throughout the process, including from more senior staff. This critical, precautionary approach, also should ensure that an over-simplified view is not taken in dealing with complex issues. In particular, critical consideration should be given to unexpected problems and findings, and their underlying causes assessed.

It is important that risk assessments are not rushed to meet business deadlines or constrained by lack of competent resource and, as a result, are not sufficiently thorough. Assessments should not be deferred except when there are compelling reasons to do so and an assessment should be carried out of the potential implications of any deferral.

Analysis should use approved standards and good practice. An ad-hoc approach should be avoided. Risk definitions should be agreed in advance and not adapted to suit circumstances. Where used, a common consequence - frequency matrix should be applied so that agreed measures of risk are adopted. The output from the assessment should be prioritised to reflect the seriousness of the risks identified, and ensuing actions should focus on the higher risks as a priority. Where appropriate, risk reduction actions should be incorporated in business planning.

Clear accountability should be placed on a competent manager (with adequate support and resources) to manage the process and to ensure that responsibilities for the assessment are not 'divided, dissipated and dispersed' in such a way that teamwork and communication is ineffective. Actions resulting from assessments should be closed out and implemented and their effectiveness confirmed.

A 'stand-back', holistic view should be taken to re-assess risks on a periodic basis using, for example, PSAs. Assessments should also be carried out on a regular scheduled basis of response plans for such critical areas as fire safety, management of 'process upsets' and emergency response. These should reflect all credible scenarios and pathways.

The risk assessment process should be 'dynamic'. Checks need to be carried out of safety critical equipment and its fitness for purpose and should ensure that any changes being proposed to safety-related plant or processes (including any temporary modifications) are subject to a risk assessment. They should include

interactions with supporting equipment and related processes (co-faults) - thus avoiding a narrow focus - and should take account of the results of previous risk assessments (whilst not allowing these to 'shape' the new assessment). Assessments should also consider incremental changes and any long-standing chronic conditions (e.g. leaks). Other operational information, including maintenance data and unexpected findings that have occurred (e.g. failure of plant or components), can also provide valuable sources of input for risk assessments.

Longer-term process safety issues arising from changes to accepted good practice and changes in standards should receive attention. The ageing of plant or components should also be the subject of review.

Consideration should be given to engineering or management measures that can be implemented to stop the escalation of a process safety failure or mitigate its consequences. Examples in petrochemical processes would include the provision of flare systems and measures to remove sources of ignition from areas where flammable materials may be present.

Independent oversight may also be required to confirm that the process has been thorough and effective - particularly where new plant or processes are being assessed or when significant changes are being made. Review should be carried out to determine whether actual operations align with the assumptions and results of the assessment - particularly in safety critical areas.

Areas for risk assessment should include less frequently used plant or processes and those that may be operational for short periods of time or outside the mainstream of the business (sometimes referred to as 'orphan plant'). 'Legacy' systems (those inherited from a previous site 'owner' or operating organisation) should be examined particularly carefully and any outstanding improvements or remedial work incorporated.

Risk assessments should be carried out where procedures or equipment are changed or where temporary modifications are to be introduced. They should also be carried out for organisational change, such as to levels of supervision and engineering support, using agreed and rigorous procedures designed to ensure that changes are not introduced that have a serious impact on safety - including those that may have been proposed at senior levels in the organisation. The need to encourage challenge and provide independent oversight to important proposals applies in the case of organisational change as well as for engineering or process change.

A team approach is valuable in conducting risk assessments as this can provide diverse viewpoints and a mix of skills, drawing on wider experience. For example, risk assessments during design, need to take account of construction requirements and operability and maintainability, whilst assessments of operational plant and processes should take account of experience from maintenance (particularly of critical components) and workforce experience and concerns. The results of more formal processes such as audits and inspections and any behavioural (human factors) investigations into issues such as control room operations and response to alarms, are also important potential inputs to analysis.

Those engaged in risk assessments and those managing them, should have a full understanding of the concept of ALARP (as low as reasonably practicable) and its legal basis in the UK, together with the necessary steps that need to be taken to establish that this has been achieved. This should be supplemented by an understanding of how regulatory bodies assess risk, which in the UK, is underpinned by a tolerability of risk framework (Reducing Risks, Protecting People: R2P2 - HSE's decision-making process).

Findings and decisions emerging from risk assessments should be documented. In addition to meeting legal requirements and providing an auditable trail of actions, the output in a suitable form can be of continuing value in raising awareness of risks, the importance of mitigation measures, and the need to adhere to procedures and work instructions.

9.2.2 Wider use of risk assessments

Lessons from assessments, suitably presented and incorporated in training, can raise awareness and further inform designers, constructors, and operational staff about requirements such as the importance of identifying and reporting emerging 'symptoms' (early signs of incipient failure) and anomalies, and can thus strengthen safety culture.

A valuable way of providing a record of identified risks emerging from assessments and how they are mitigated is through the use of risk registers. They can, if effectively presented and used, provide a useful input to operational and engineering staff and their managers.

Risk assessment is a vital input in the development and review of safety cases. These have, on occasions, been viewed as 'paper vaults' and not 'living' documents that can contribute substantially to improving process safety. They have also been used to give a false sense of security through 'paper safety and not real safety'. If proportionate, accessible and made intelligible to the user, they can also be very valuable to operational teams and their management - particularly in providing an integrated view of risks and promoting an understanding of the safe operating envelope and the most important risks.

9.2.3 Risk assessment and the role of contractors

Because of its importance to the control of process safety, organisations should preferably retain 'ownership' and sufficient in-house expertise to assess and fully understand the risks that they face. If, however, external bodies are asked to take on the role of carrying out risk assessment, the client needs to maintain an ability to act as an intelligent customer with awareness of the risks involved. It should therefore provide overall management of the process and retain control of it. For example, it should understand the depth of analysis required, ensure that all data and experience relevant to its needs is available, and provide sufficient specialist 'challenge' of the process, assumptions and conclusions - ensuring, for example, that short cuts are not being taken. With several parties involved, communication and project control become even more important and there should be clear accountabilities for all of those involved.

Contractors should be encouraged to carry out work rigorously and not present the client with the results that they believe the client wishes to hear. The need for succinct reporting and the avoidance of bureaucratic length (sometimes providing an illusion of rigour - the so-called 'thud' factor), should be made clear to those carrying out the process.

9.2.4 Role in design and construction

Particular attention should be given to design and construction risks where new technology or novel processes are to be used or where there are recognised challenges in the complexity of the project. Focus should be maintained to ensure that the key engineering principles of ensuring redundancy, diversity and resilience against single failure (including external events) can be fully demonstrated. Where possible, 'fail-to-safe' provision should be included.

If it is planned to scale-up existing plant or processes, this requires rigorous analysis and attention, and over-simplified extrapolations from existing practices should be avoided. It is also important that assessments are based on suitable codes and standards which are directly relevant to the design and are fit-for-purpose (where possible by calibration against data from trials). Any calculations or numerical models should be set out clearly and independently checked. Where possible, actual plant data rather than generic data should be used in assessments, and design and construction should draw on specific trials or proof test results.

In construction and commissioning, rigorous risk assessment should be in place to analyse potential risks relating to any defects, lapses in quality or unexpected findings, and to control remedial work. Ad-hoc redesign should be avoided. Attention should be given to ensuring that data is monitored and analysed to check conformance with assumptions incorporated in the final design, and any concerns assessed. Risks related to remedial work during construction, should be considered by competent staff and be subject to engineering control. In some projects, a register of safety critical equipment has been developed, maintained, and used to help identify requirements for operational requirements such as maintenance and testing.

In design there should be full awareness of requirements for end use - including full details of the environment in which the plant should be operated and the range of conditions to which it may be subjected - including loadings and the impact of fatigue and friction.

Account should also be taken of previous learning which might be relevant to the design. Designers and constructors should ensure that there are adequate safety margins and that operators are aware of critical components and potential fault sequences, and that suitable instrumentation is available with defined trigger points to ensure that actions are taken if operated close to or beyond the design intent or specification. The required actions should be incorporated in operational procedures.

It should be clear to all parties (including responsible managers) as to why safeguards (e.g. mitigating actions) are in place, with periodic checks on the understanding of their importance. Consideration should also be given to ease of maintenance and clear instructions made available to operators. The use of administrative controls should be minimised, but where used, their role, effectiveness and potential vulnerability as a line of defence should be fully understood.

Independent oversight should be in place at all stages of design, construction and commissioning to confirm assessment of key safety issues. This should be based on a fully joined-up approach (with requirements not falling through organisational gaps), and effective communication maintained between all of the involved parties. Accountabilities should be clear and, in particular, the role of those undertaking oversight should be fully understood by all others involved.

On a regular basis, a 'corporate' strategic overview should be carried out in order to draw to the attention of senior leaders the extent of process safety risks facing the organisation and their management. This should enable leaders to manage such risks alongside other business risks.

Organisations undertaking project oversight should have the competence to check the appropriateness of codes, standards and other analytical tools being used and that the final design is in conformity with test results (e.g. from trials and witnessed tests). They should assess the quality of construction and, in particular, any changes to design or construction which may have been undertaken to overcome emerging problems. The functioning of critical components identified in design should also be assessed in order to ensure that they meet specification, are correctly installed, suitable data for monitoring is provided, and that adequate operational requirements are established.

10 EXPECTATIONS: REPORTING AND LEARNING FROM EVENTS

10.1 OVERVIEW

In nearly all of the events studied there had been significant precursor events either in the organisation itself or in another part of the relevant industry. Had learning opportunities been taken from these, it is very likely that the ensuing events would have been averted. Thus, ensuring adequate reporting, learning and awareness has a vital part to play in establishing excellence in process safety.

There are three fundamental processes within a structured system that are required to ensure that organisational learning is effective in an operational experience system (OE). The first of these is a process for the reporting of events, near hits and non-compliances with the SMS and associated procedures. This should be in place during all phases of plant lifetime - from design, construction, commissioning, operation, maintenance and through to decommissioning. The second is that events are investigated to clear criteria reflecting their significance and learning is fully extracted. The third requirement is that all available learning (including good practice) is distilled, made relevant and promulgated in such a way as to maximise its effectiveness.

Several important aspects of the learning process - particularly the potential for adverse knock on effects when incentivising KPIs and the role of leading and lagging indicators - are also addressed in Parts 2 and 3.

Other parts of Part 1 of the Report where learning related issues are explicitly discussed include sections 4, 5 and 13, with some references made in sections 6, 7, 8, 9, 11, and 12.

Table 7 - Summary of reporting and learning expectations

RL1	There should be a systematic and effective process for the reporting of 'events', near-hits and non-conformance with the SMS that are relevant to process safety as an input to a wider operational experience programme (OE). This should apply also to any contracting organisations. The reporting process should be kept as straightforward as possible to use to ensure uptake.
RL2	Reporting should take place within a 'just' culture and should also be actively encouraged by management at all levels even when the input may not provide welcome news. Feedback should be given to those reporting in order to reinforce commitment. It should be made clear that failure to report is unacceptable. Anonymity should be respected where requested.
RL3	Teams should be encouraged to discuss findings of events relevant to their activities taking a broad view of applicability. The effectiveness of the OE process should be periodically reviewed taking account user views.
RL4	Other potential sources of learning (e.g. various operational records, effectiveness of communication, audit processes etc.) should be periodically reviewed and learning from these (including trends or recurring deficiencies and good practices) used to augment and check on the effectiveness of the learning process. Learning from other organisations (including regulatory bodies) should be incorporated in the OE system and contacts established and maintained in order to facilitate the exchange of important learning wherever possible.
RL5	Adequate competent resource should be available to analyse all learning material and to ensure that relevant material is made available to each business area that may be able to learn from it, taking account of the spectrum of learning possibilities but minimising 'overload'. Checks should be carried out to ensure that necessary actions have been taken and that they are effective.
RL6	The importance of reporting and learning should be incorporated in training to ensure understanding of events and their causes, raise awareness of the need for vigilance and effective reporting of deficiencies, and to explain how defences (e.g. the SMS and safety case) are designed to minimise the risks of repetition.

RL7	Action should also be taken to ensure that important learning is recorded and kept alive in the corporate memory, and that organisational 'silos' are not developing in some parts of the organisation such that learning is not given the attention that is required.
RL8	All events should be investigated to the extent warranted by their significance and requirements documented. For more serious events, or those that exhibit a repeat pattern of shortcomings, investigation by a competent independent team should be carried out that examines root causes, including any leadership or management shortcomings. Examples may include failure to address management of change requirements and other organisational and cultural issues. The approach to investigation should be clearly set out in the SMS.
RL9	Output from all investigations should be kept as relevant and useable as possible and made available to all for which it may be of value - including support functions, designers and constructors (where relevant), and other contractors for which the findings are likely to be of value. Consideration should be given in advance to resource requirements for competent follow up
RL10	A system should be established to check that actions have been prioritised, carried through on a timely basis, and that they are effective. When supervisory or management changes take place, incoming personnel should be made fully aware of findings, actions relevant to their area of authority, and the importance of ensuring continuity of support.
RL11	Learning, including its wider potential implications, should be fully taken into account in reviewing the SMS, processes for risk assessment (e.g. Hazops and PRAs), and the safety case and operating envelope. When changes are made, they should be incorporated in workforce training to raise awareness of the reasons for the changes and their importance.
RL12	Potentially adverse business influences on the OE process should be recognised and addressed wherever possible. This includes the potential impact of changes such as reductions in workforce numbers. Cuts to the OE process should be minimised given its importance in maintaining process safety, and 'ownership' of OE should be retained within the organisation as far as is possible. Any changes to the process should be subject to a rigorous management of change assessment. During periods of organisational change, leaders should reinforce their commitment to reporting and learning.
RL13	Leaders, including boards, should be kept aware of important events and emerging risks so that account can be taken of this in decision making. Leading indicators can be valuable to gain a measure of progress in seeking continuous improvement in process safety, but care should be taken in using KPIs to incentivise improvements as this can have the potential unintended consequence of adversely affecting the reporting process.
RL14	Leaders and managers should remain alert to emerging concerns and the possibility that things can go wrong. They should ensure as far as possible that they do not develop a mindset that fails to review evidence and maintain constructive challenge - especially when dealing with new plant where problems are not expected or plant with a limited projected remaining life. Previous success should not be used to justify inaction, and concerns should not be 'normalised' because they have not hitherto led to more serious consequences. Leadership teams should remain strongly engaged and should make it clear that concerns and significant risks should always be brought to their attention.
RL15	O&S processes should be used to review trends and patterns in reported events (e.g. recurring issues) and to take an independent view of where deterioration in process safety performance may be occurring. The O&S process should check periodically on the effectiveness of reporting, investigation, and the suitability and impact of output from the OE process.

10.2 DISCUSSION AND COMMENTARY

10.2.1 Reporting and learning sources

The overall process for reporting and follow up to 'events' and other shortcomings should be systematic and structured within an Operational Experience (OE) system that establishes clear criteria for both. The reporting process should be made as simple as possible, and the effectiveness of the reporting system, including workforce perceptions, should be periodically reviewed.

There should then be sufficient competent resource to ensure that the learning that emerges is distilled and communicated in an intelligible, prioritised and relevant way to those to whom it may be of value. If this is not achieved there is a danger that because material is not directly relevant, 'overload' of information may occur and recipients may not recognise and act on findings that are relevant to their activities.

Feedback should be given on actions taken and the contribution of those reporting should be 'recognised' such that they feel that their efforts have been worthwhile. Teams should be given the opportunity to discuss findings where relevant to them.

Managers and supervisors should welcome reports from the workforce and provide opportunities to listen to feedback and should not erect barriers to this process. The workforce (including contractors and key suppliers who themselves should be working to high standards of reporting) should be encouraged to achieve a culture in which reporting is supported, 'bad news' is not hidden, and in which blame should not be attached to individuals or teams or disciplinary action taken, except in the case of gross negligence or deliberately dangerous acts. It is important that the workforce and their representatives perceive the approach to be 'just' and consistent, and that they do not fear 'retaliation' for reporting of deficiencies. A parallel process that ensures anonymity may also be valuable to add confidence to members of the workforce that they will not be 'singled out' by line management as a result of reporting. Against such a supportive approach, it should be made clear that failure to report is unacceptable.

Other important sources of learning may also be found in the output from quality assurance (QA) and other audit processes, maintenance records, operational records covering key processes such as start-ups, mechanical integrity records and hazard logs, as well as organisational issues such as the strength of the interaction between operations and engineering support. Relevant databases should be periodically searched for learning opportunities and trends analysed. Interrogation of a variety of such sources can provide checks on the effectiveness of the various reporting routes, particularly in relation to recurring deficiencies/events.

10.2.2 Wider learning from events

In addition to learning from the 'free lessons' provided by internal reporting of 'near hits' and safety deficiencies, significant learning can be achieved from events outside the organisation. This can be from within the industry sector, where similar plant and processes may exist, and in other sectors, where although the technology may be different, the organisational and cultural deficiencies underpinning events may still be a source of valuable learning as this document seeks to demonstrate. It can often provide a basis for discussion on whether similar vulnerabilities exist, and provide a 'wake-up call' to challenge complacency.

Regulatory views and requirements can also be an important source of intelligence about good practice elsewhere and used as an input to standards and expectations.

The process of identifying, extracting, distilling and transferring learning should be integrated within the OE programme. This is sometimes centrally managed by the safety function, but with identified, dedicated personnel within each business or other activity (including contractors and suppliers of critical equipment) taking responsibility for promulgation and follow up in their area of responsibility. The learning should again be presented in a form which is relevant to recipients (from business leaders to operational teams) and it should be emphasised that in considering relevance, the 'spectrum of possibilities' should be considered in an open-minded way. Learning should also be transferred to designers, constructors and end users as appropriate. Where 'trials' have been carried out of new plant or processes, this should be available to those subsequently using them.

Learning from events should be incorporated in training, with advice and input from those who are knowledgeable about the events. This can also be used as a way of raising awareness as to why certain SMS

and procedural requirements are in place, and thus increasing understanding of the relevance of these and the need to observe them.

Sometimes, important learning from particular events fades from the corporate memory, even where it was once regarded as highly significant and may have led to damaging consequences. It is important to keep alive such learning and this should be periodically checked. Incorporation in training and team reviews are valuable ways of trying to ensure that the learning is retained. This loss of corporate 'memory' also has implications for record retention and requires steps to be taken, for example, to ensure that when key staff are no longer available, their experience is passed on as far as possible through an effective transfer process.

In some of the events studied, organisational 'silos' had been allowed to develop. Thus, learning that was satisfactorily recognised and applied in some parts of the organisation was not considered in others. Barriers had been erected for a variety of reasons. It is thus important that organisations not only remain aware of where this may be occurring and take measures to address it, but also seek to understand how and why the situation has developed.

10.2.3 Investigation and follow-up process

All reported events should be investigated to the extent warranted by their significance. This should also take account of whether the reported event is part of a pattern of shortcomings (for example repeat events or repeated non-conformance with procedures). This process should be documented within the SMS such that the requirements for follow up are unambiguous.

Investigators should not propose ad-hoc solutions or unnecessary requirements for re-testing such that investigation and remedial action is deferred for resource or other reasons.

For more serious events or those that recur, the organisation should appoint an independent team with the necessary expertise to investigate and propose timely, prioritised follow up actions. When the investigation is complete, or if there are important interim requirements for urgent action, findings should be suitably communicated to those for whom it has relevance, and checks carried out to ensure that action has been taken and that it has been effective. It is important that root causes are fully investigated and any weaknesses in the SMS (including the management of the organisational change process) and shortcomings in leadership and management, are identified and pursued. Newly appointed personnel (particularly supervisors and managers) should be made fully aware of any ongoing investigations affecting their roles and the concerns leading to them.

Carrying out effective investigations and ensuring that findings are communicated on an effective and targeted basis with checks on the effectiveness of resulting actions, requires consideration to be given in advance to resource and competence requirements. If this is not done, there exists a danger that short cuts may be taken, or the work not carried out systematically with full knowledge of its implications.

In some cases, events may originate from deficiencies in design, construction, maintenance or engineering capability. Such learning should be traced back and, where possible, those involved made aware of any shortcomings. It is also important that contracting organisations maintain an effective OE system that is audited to ensure that reporting and investigation of events, including those raised by the client, are receiving adequate attention.

10.2.4 Other potential uses of learning process output

The learning process can be a valuable input to other organisational processes affecting safety. It can provide information relevant to the risk assessment process during operations by introducing further appropriate checks. More generally, it can provide input to periodic risk assessments (such as HAZOPs and PRAs) by enabling operational experience to help facilitate the identification of risks. Likewise, the learning process can be used to re-assess the safety case by reflecting operational experience. This should again take into account not just 'narrow learning', but the spectrum of possibilities to which the learning may apply. It may also, in some cases, require the 'operating envelope' to be updated.

Important learning relating to the risk profile should be communicated to senior managers and leaders so that they are fully aware of changes, the underlying reasons for them, and the level of residual risk.

Changes arising from the learning process and the reasons for them, should again be the subject of staff training. Information about changes and updates should be made available, where relevant, to contractors, including designers and suppliers of safety critical components.

10.2.5 Impact of business pressures on the learning process

In addition to potential concern about attribution of blame, various other business factors may influence the effectiveness of reporting, investigation and follow up, and in ensuring learning from external events. Where there are strong pressures to increase efficiency such as reductions in staff numbers or design, construction and production pressures to meet short term targets, this may lead to short cuts being taken and a general weakening of safety culture - including less willingness to report deficiencies. Commitment to safety should be reinforced at such times and the need for continuous improvement sustained as far as possible.

Considerable caution should be exercised in making cuts to the OE system (including associated training and workforce involvement). Proposed changes should be subject to a rigorous management of change assessment. It is important that duty holders retain strong ownership of the reporting and learning process and support to it.

When business pressures are imposing particularly high workloads, staff may be reticent about reporting if they feel that consequent actions are likely to fall on them - thus increasing workload even more. Consideration of this should be taken into account in placing improvement and follow up actions and due allowance made for impacts.

10.2.6 Response to reporting and feedback - avoiding complacency

Significant issues should be reported to senior management and business leaders (including business and corporate boards) such that they are fully aware of emerging risks and so that any preconceived attitudes towards risk can be 'challenged'. This should lead to greater awareness of the 'health' of key processes and of the organisational safety culture, and enable leaders to consider the impact of organisational and policy changes on the standards of process safety that are expected.

If a high level of reporting can be established across the organisation to consistent, agreed standards, this can provide an important input to business and corporate safety oversight. Those in receipt of data should be made aware that as reporting improves, an increase in reports does not necessarily signal a decline in performance, but may reflect an improved reporting culture.

In some organisations, success in achieving continuous improvement is tracked and may then be incentivised. This is sometimes achieved by developing 'leading' indicators (i.e. actions being taken to achieve improvement, rather than measures of events that have occurred). Where such indicators are used and incentives offered to achieve improvements, steps should be taken to ensure that 'perverse' incentives do not then lead to unanticipated degradation of the reporting system in order to meet objectives.

The use of KPIs and potential 'perverse' incentives is the subject of consideration in Part 3 through the use of CLM. Behavioural issues relating to the use of indicators, the use of incentives and particularly the role of leading and lagging indicators and the care to be taken in their development and use, is discussed extensively in Part 2.

Events can arise for a range of reasons relating to managerial attitudes. In some cases, this involves 'sweeping concerns under the carpet' since perceived gains from ignoring them are seen to outweigh the risks of occurrence. This is sometimes particularly prevalent for new plant that is perceived to be without flaws and where failure is not thought credible. It can also arise in the case of short-term projects or older plant where time at elevated risk is viewed as likely to be of short duration.

It is important that signals are not missed or ignored and that a culture is established that remains open to constructive criticism and avoids the tendency to rely on previous success to justify lack of appropriate action. In some events studied, identified concerns (e.g. malfunctions or systems failures) were 'normalised'. Actual events, near hits or failures to conform to requirements that would once have been regarded as serious threats that required investigation, were 're-assigned' as issues that occurred on previous occasions without leading to major problems and were thus ignored - or classified as maintenance issues or lower priority concerns.

This has been referred to as 'the elastic waistband effect', where serious deficiencies are increasingly re-classified as expected deviations.

These behaviours can be exacerbated by supervisors and middle managers if they believe that senior managers and business leaders do not wish to receive 'bad news' and do not wish to be 'engaged'. Sometimes, unwelcome news is 'rolled up' such that its full significance is not made clear to senior decision makers and the impression given that significant problems are not present in a plant or project. This demonstrates again the importance of supporting constructive challenge at all levels in the organisation and ensuring that a competent, independent and well-resourced safety function is able to make its voice heard in situations where significant emerging risks are not otherwise being detected or acted upon.

It also emphasises the need, more generally, for a system of audit and oversight that is able to detect failures in the system by a variety of means, and can compare approaches in business units with corporate expectations and share good practice. Oversight also presents an opportunity to look collectively at the pattern of events that are occurring and to assess trends.

Line management audits, and independent oversight coordinated and scrutinised by an independent safety function, should be able to detect when degradation is occurring. In addition to enabling any necessary action to be taken, the presence of an effective oversight process should act as a deterrent to those who may, for whatever reason, be tempted to accept inappropriate risks or fail to report or act when required to do so, since it should be clear that there is a high probability that this should subsequently come to light.

11 EXPECTATIONS: MAINTAINING COMPETENCE

11.1 OVERVIEW

Achieving and maintaining competence in understanding and managing process safety risks in an organisation is an essential requirement to provide defence against major events. The requirement requires effective, up-to-date training not only for those performing safety critical roles, but for all roles with potential impacts on process safety from the boardroom through to supervisors, operational staff, support staff and all those providing contractual inputs. The need to address shortfalls in competence have been highlighted in the reports into all of the events studied - some as a major contributory factor in causation.

The process of skills acquisition and awareness raising and the role of mental models is discussed in the context of training in Annex D.

Other parts of this Chapter where competence related issues are discussed explicitly include sections 4, 5, 8 and 13, with some references made in section 6, 9 and 10.

Table 8 - Summary of competence expectations

C1	All staff (including contractor staff) with roles that could impact upon safety should be SQEP, with up-to-date training provision maintaining understanding of current process safety risks, signs of danger, and responsibilities and interfaces. Job roles should have defined competence standards relating to the process safety risks attached to them, and these should be kept up-to-date.
C2	Requirements for training in process safety risks should include those with wider roles such as leaders at all levels, and others with influence on the organisation and on resources. Particular attention should be paid to ensuring the process safety competence of staff taking on new roles and those with newly assigned responsibilities (e.g. 'step-ups').
C3	Potential loss of capability/competence in safety critical posts should be monitored, particularly during significant organisational change. Monitoring should include ensuring sufficient numbers of staff and the potential effect of incremental changes. Reliance should not be placed on single key specialists or the use of 'cross-trained' staff with potentially inadequate process safety knowledge and experience. When staff with roles important to process safety leave an assigned post, provision should be in place to ensure retention of knowledge, and fully trained and competent staff should be available to carry out their former role.
C4	Engineering and other technical support staff should maintain close contact with operational requirements and should be located close to operations to ensure availability.
C5	In selecting contractors (including designers and suppliers of safety critical equipment), competence for the work carried out and its potential impact on process safety should be an important factor in selection. Where sub-contractors are employed, equally rigorous requirements should apply.
C6	Contractors with a potential impact on process safety (including suppliers of safety critical equipment) should retain their knowledge about process safety requirements and fully understand the continuing relationship between their input and process safety risks. Clients should ensure that this is maintained as part of their role to act as an intelligent customer for work being carried out.
C7	Leaders at all levels should be trained in the importance of retaining awareness of process safety risks and how their decisions and actions can affect these. This should include the need to demonstrate their commitment to excellence in process safety standards and culture

	and how this should be supported by their actions. This should include initial training for those who are newly appointed.
C8	Leaders, including those at the most senior levels in the organisation, should be informed and advised by competent safety specialists. Input should include the results of independent oversight and scrutiny. This is particularly important in ensuring informed decision making during major organisational change and in maintaining awareness of emerging issues.
C9	When decisions are delegated, this should be to those with the required competence and level of assigned authority. Sufficient resource, and advice and support, should be made available to support decision making.
C10	Training in process safety should be well-resourced, systematic, mandatory for all process safety-related roles, and carried out against defined standards with input, as required, from supporting expertise to ensure that the training reflects up-to-date requirements. For key defined roles, certification of competence should be required.
C11	Training should be periodically reviewed for effectiveness. A balance should be maintained between different forms of training (face-to-face, IT based etc.). Staff should have access to refresher training and mentoring/coaching, and training needs should be assessed in appraisals/performance reviews. Particular attention should be paid to changing training needs, particularly during organisational change or with the introduction of new technology.
C12	People-related issues and communication skills should be included in training provision and guidance given to senior managers and leaders on how conflicts of interest or different management approaches can impact effectiveness.
C13	Learning from events should be incorporated in training. This should not only raise awareness of events and their direct causes and consequences, but also highlight the relevance of important matters such as safety culture (particularly maintaining a questioning attitude, seeking advice and raising concerns); effective communication; awareness of interfaces, accountabilities and where to seek advice; the importance of procedures and compliance; the role of audit and oversight and, approaches to risk assessment and management.
C14	Decision makers should be fully aware of relevant legal obligations to take all reasonably practicable steps to ensure safety and what this means in practice.
C15	Staff awareness should be reinforced regarding the important role of procedures and the importance of safety critical equipment in minimising the risk of events - including response to alarms and other indicators of unsafe conditions. The need to seek advice when there is any uncertainty over safety matters should be emphasised.
C16	Training provision should extend to dealing with 'off normal' and emergency conditions and ensuring safety during less frequent operations such as start-ups and shut downs. It should also be available for incident response teams, those conducting exercises, and for those investigating events.
C17	All staff should be trained to understand the impact of stress and fatigue and its potential effect on performance and thus potentially on process safety, and how to recognise and reduce it. In particular, managers and supervisors should be trained in how to respond appropriately to the issue as part of their 'duty of care' towards staff.

11.2 DISCUSSION AND COMMENTARY

11.2.1 Competence and training requirements

All staff with responsibilities that might affect safety should be SQEP for their roles and all specific tasks that they undertake. Even those who have considerable experience should receive refresher training, not least since experience alone can itself sometimes lead to complacency.

Competence standards and associated training requirements should apply to all safety-related posts and should be regularly reviewed. These requirements should apply not only to personnel designing, operating and maintaining technology and systems important to process safety, but also to those who make decisions that can affect it, such as leaders and managers - including those making decisions on investment and organisational change. All relevant personnel should be able to demonstrate a thorough understanding of the risks that are being controlled; the importance of safety-related plant and procedures; the interface between their roles and that of others and, signs of danger in process safety-related activities. This applies not only to the staff of duty holders but to all relevant parts of the supply chain. Particular attention should be paid to new personnel and those changing roles (including temporary 'step-ups' and those with newly assigned safety responsibilities).

11.2.2 Declining capability

Awareness should be maintained of any incremental decline in capability/competence, and acceptable numbers of SQEP personnel for identified safety critical posts should be maintained at all times. Particular vigilance in this respect is required during, or as a result of, significant technical or organisational change. Particular consideration should be given to avoiding reliance on single key specialists in safety critical areas and, the use of 'cross trained' or general engineering staff, without full and specific knowledge of key areas in planning, carrying out, supervising and monitoring safety critical processes and procedures. When key personnel are to leave an assigned post, steps should be taken to ensure retention of knowledge, and action taken to ensure the presence of competent staff to cover any period of absence.

Engineers and others providing technical support should maintain close contact with operational staff and their requirements and should not, wherever possible, be located remote from operations, otherwise there is a danger that their expertise may not be fully up-to-date and immediately available when required.

11.2.3 Contractor competence

Where contractors are to be used to design, construct or operate plant (or carry out any other work that affects or interacts with safety critical plant or processes), they should be trained to the same standards as those required of duty holders and have sufficient knowledge of the wider context of their input. Duty holders should ensure that they maintain adequate control and engineering capability to act as an intelligent customer for all contractor work.

In selecting main contractors, competence for the full range of requirements on them should be fully taken into account as well as the specific requirements of the assigned task or project. Arrangements should then be in place to ensure that competence and associated standards are maintained. Where contractors 'fill gaps' in capability by sub-contracting other organisations to provide input, the client should ensure that suitable arrangements exist to ensure that the necessary standards of competence in all aspects of the role are met and maintained. The competence of suppliers, designers and other service providers with potential impacts on process safety should also be ensured.

11.2.4 Leadership roles

Leaders, from supervisors/team leaders and their managers, through to executive leaders and board members, should be trained to be aware of the risks involved in the technology and how their decisions and actions (or lack of action) may influence these risks or introduce new ones. Training in these issues should be given to those who are newly appointed so that they also understand the systems and processes used to identify and control risks within the organisation, including the importance of their own actions and commitment.

Boards should have sufficient collective experience of the technology to make informed decisions and should understand the importance of maintaining excellence in process safety as well as occupational safety. Senior management should be made fully aware as part of their training of the importance of ensuring that a rigorous process, with independent scrutiny, is in place to examine the potential impact of organisational change on process safety and that no changes should take place until it can be shown that they should not adversely affect it.

Leaders should have access to independent advice and support in making decisions that could affect safety and in addressing safety concerns. Where decisions are delegated, this should be to those with the required competence and level of authority.

Training for leaders at all levels should include ensuring that they understand the importance of demonstrating their commitment to safety and the need to support this by their actions. In particular, they should be aware of the importance of promoting and maintaining a strong safety culture and effective communication.

11.2.5 Training capability and review

Adequate resources for process safety training should be maintained at all times. Training programmes should be systematic, carried out against defined standards, and periodically reviewed for effectiveness. This review should include assessment of the degree to which training programmes address new and emerging issues. Those designing and delivering them should have full access to the necessary supporting capability where required (e.g. availability of simulators, specialist advice etc.).

A balance should be maintained between 'face-to-face', IT based, and structured 'on-the-job' training without over reliance on any one of these. Coaching/mentoring resource for individuals when performing new roles should also be available. Attendance at training should be mandatory and for identified roles, certification of competence should be established with refresher training requirements specified. Discussion of training needs should be formally included in personnel performance reviews/appraisals, so that further training needs can be identified and actioned.

Training programmes should be subject to regular review to ensure adequacy (resource, balance, coverage etc.). Particular attention should be given to changing needs - particularly in those areas where new developments and/or changes are occurring and where new or unfamiliar technology is being applied. This requires a strong interface and good communication between training providers and users, to ensure that all parties involved understand needs and have access to up-to-date information and specialist input.

Learning from actual events and 'near hits' should be integrated into training. This should include learning from those that have occurred not only within the organisation itself, but also in the wider industry and other relevant industries. It should include examples where important learning is still relevant and those that have influenced current safety requirements (e.g. procedures).

11.2.6 Competence in broader issues

Training for all relevant roles should extend beyond understanding and capability in engineering and technical matters. It should also include broader issues such as 'people issues' and safety culture; the importance of effective communication between those involved at all levels; the need for clear accountabilities and awareness of the role of others; procedures and the importance of compliance; audit and oversight, and risk assessment. In addressing 'people issues', guidance should be given to senior managers and leaders on how conflicts of interest or different management approaches can impact effectiveness. These conflicts may arise from historical issues and/or from different approaches to management arising from differences in business background.

The understanding and awareness of personnel at all levels of the need to maintain vigilance and a questioning attitude in all areas with potential impacts on process safety should be highlighted in all training.

The workforce should know when to seek advice and help in the case of uncertainty, and where to obtain this support. Decision makers should understand their obligation to ensure that all reasonably practicable steps are taken to minimise safety risks at all times in design, operation, maintenance and decommissioning and

what this means in practice both in terms of the organisational approach and in the context of legal requirements where relevant.

11.2.7 Abnormal conditions

Training provision should extend beyond normal operational conditions to include 'off-normal' and emergency conditions. Particular attention should be given to less frequent operations such as start-ups and shutdowns. It should involve participation in simulated 'off-normal' conditions - including emergency exercises.

Training programmes should include an understanding of how systems may fail, the reason for specific safety critical equipment and procedures, and should enable staff to recognise the importance of alarms and other indications of abnormal conditions and the consequent risks of not responding effectively to these. Training for event investigation should be in place for relevant staff.

Operators and engineers should be trained to understand the importance of asking for advice and help from others when they are unsure of the safety importance of monitoring data or alarms or the potential consequences of actions. Competent incident response teams should be available at all times and have clear accountabilities.

11.2.8 Stress and fatigue

Staff at all levels in the organisation should understand the potential impact of human performance and behaviour on safety and, in particular, the impact of stress and fatigue on performance. Ways of recognising and dealing with it, particularly in those that they manage or supervise, should be part of training programmes.

Managers should provide support and take appropriate action where possible - particularly where stress and fatigue may be affecting those with important safety-related roles. The duration and rotation of shift systems is an area that may require particular attention.

Along with working conditions and a responsive listening approach, attention to matters such as these is an important way for leaders to demonstrate their duty of care to staff and that business related priorities are not their only focus.

12 EXPECTATIONS: MANAGEMENT OF CONTRACTORS (THE SUPPLY CHAIN)

12.1 OVERVIEW

The majority of the events studied involved significant shortfalls in contractor management. This section highlights the need for the client to act as an intelligent customer, setting out and maintaining acceptable standards and specifications for the services or products to be supplied. In particular, it emphasises the steps that should be taken to ensure not only technical capability, but strong management processes, and a culture which establishes reporting of deficiencies, constructive challenge, and a questioning and cautious approach to managing risks - all underpinned by effective audit and oversight arrangements.

Other parts of this chapter of the Report where management of contractor related issues are explicitly discussed include Sections 4, 5, 6, 7, 8, 10 and 13.

Table 9 - Summary of management of contractor expectations

MC1	Those submitting tenders for work that could affect process safety should be made aware of client expectations regarding safety management, safety culture, risk assessment and oversight arrangements, in addition to all relevant information regarding the project design, context and associated risks. This should enable those tendering to appropriately 'scope' the requirements of the contract.
MC2	Evaluation of tenders should include the approach and record of those tendering in terms of their commitment to meeting high standards in process safety and meeting organisational and cultural requirements.
MC3	Timescales for contracted work should be realistic and compatible with the achievement of continuing high standards of safety, and contractual requirements should not act as a disincentive to the identification and reporting of emerging risks.
MC4	Suitable mutually understood interface arrangements should be established with the principal contractor and all other parts of the supply chain, including any sub-contractors, in order to ensure 'joined up' communication; suitably aligned and mutually understood procedures; a compatible approach to safety culture - including the need for openness and a cautious and questioning attitude; risk assessment and, project audit, oversight and review.
MC5	Full consideration should be given to the skills that need to be retained in order to be capable of challenging and verifying contractor assessments and to act as an intelligent customer meeting all regulatory requirements. The retention of the skills required to be a competent end user of project output, and to respond to any emerging engineering concerns without over-reliance on contractual input, should also be ensured
MC6	A client project manager should be appointed supported by competent resources for the duration of the contract, to independently assess emerging project risks and to provide overall project control. This includes ensuring acceptable safety provisions; effective communication within the supply chain; acceptable quality; clarity about roles and, provision of effective monitoring, audit, oversight and project review. Any third parties given the role of overseeing aspects of a project should have a defined remit that is made clear to all parties involved.
MC7	Verification should be sought for contractor safety claims with the potential to affect process safety. Any changes to design or specification should be identified and risks assessed, with all relevant parties kept aware of these. For all contractual work, the client organisation should have the competence to carry out its own independent oversight and retain a clear

	picture of emerging risks, so that it is not reliant on contractor judgement and self-verification.
MC8	'Signing off' work as acceptable should be carried out by authorised competent personnel, and independently verified for higher risk work. Those carrying this out should have sufficient technical and managerial support, and should not be placed under pressure to give approvals to meet rigid project timescales.
MC9	An integrated process should be established for audit and oversight that minimises duplication and overload. Audit should go beyond paper systems and include operational practice. Wider learning resulting from the process should be made available to all parties in the project. Key steps such as important tests or commissioning relevant to process safety should be witnessed by the client or competent representatives. An independent safety committee should be established, where appropriate, to carry out review and provide advice.
MC10	All project participants including management teams should be suitably qualified and experienced for their roles. Tasks relevant to process safety should not be delegated to less skilled staff and where additional specialists and/or subcontractors are appointed, their competence should be assessed and maintained.
MC11	Adequate competence of project participants should be ensured for the duration of the contract and sufficient team and leadership stability maintained to ensure continuity in decision making and follow up. For innovative work, discussion with others with relevant experience should be encouraged and facilitated.
MC12	Operational staff should be involved in any project to the extent necessary to ensure that the output can be used effectively and safely. Provisions for maintenance should be addressed on the basis of the as-built plant and taking account of operational requirements.
MC13	The processes for risk assessment should be agreed and output shared between project participants. They should be underpinned by a questioning attitude and precautionary approach to process safety risks. In particular, pre-conceived assumptions regarding project risks should be recognised and challenged, and minority views properly considered.
MC14	Designers should be aware of the operating environment of the project. Codes and standards etc. and provision for redundancy and diversity and other engineering principles, should reflect rigorous process safety requirements with adequate safety margins. They should be independently verified where necessary. Constructors and the client should be made aware of any matters (e.g. test results; assumptions made in design etc.) that could affect safety at a later stage.
MC15	The entire supply chain (including suppliers and subcontractors) should be aware of the process safety standards required. Sourcing of safety critical plant should be carried out by specialists. The specification for goods and services should be complete and consistent, validated and verified by the purchaser and understood by the supplier. Any changes to specification should be fully assessed before acceptance. It should be subject to rigorous quality control procedures, with witnessing of key construction steps and testing as appropriate.
MC16	Risks should be reviewed at regular progress meetings where contractor assessments and claims can be evaluated by the client, paying particular attention to emerging risks; changes being made or proposed; innovative features of the project, and the results of risk assessments and oversight. Senior management should be kept informed of important emerging issues. In carrying out risk assessments, wider 'systems' implications should be considered in order to minimise unintended consequences arising from changes that could potentially lead to undesirable consequences (e.g. the taking of short cuts) at a later stage in the project.

MC17	All regulatory requirements, including the ability of the client to act as an 'intelligent customer' should be met, and liaison maintained with regulatory bodies as appropriate and they should be kept informed of any major contractual changes. Formal reports to regulatory bodies can also provide a further opportunity to review the project, including contractual interfaces and associated risks.

12.2 DISCUSSION AND COMMENTARY

12.2.1 Formulating contracts

In describing the work to be carried out and its context, together with the role and responsibilities of the supplier in achieving this, those submitting tenders should be provided with sufficient detail to be fully aware about the risk profile of proposed work. It should also make clear client expectations regarding contractor safety culture, reporting, oversight arrangements, safety management and, risk assessment requirements. Suppliers should thus be clear before entering into a contract about requirements on them relating to safety standards for process safety. By this means, they may be able properly to 'scope' the required work and understand the resource and competence requirements required. They should also be furnished with other important information such as specifications and design briefs (including foreseeable operational and environmental conditions) at an appropriate stage in formulating the contract.

If the contract is 'turnkey' rather than one in which the client is fully involved in the project management, it is particularly important for the client to be satisfied that the work does not have implications for any other process safety aspects of their operations. If identified, action should be taken to ensure that suitable interface requirements are in place (e.g. clarity about roles and assigned tasks, and fully 'joined up' procedures and communication processes in the areas affected).

The client should evaluate tenders not only in terms of cost, technical capability and ability to meet timescales, but the submission and record of those tendering in demonstrating understanding and commitment to meeting the organisational and cultural requirements to achieve high standards of process safety.

Timescales for the work should be realistic and pressure should not be placed on contractors that could lead to shortcomings in design and/or to shortcuts in construction being taken. In requiring the open reporting of emerging risks as the work proceeds, it is important that provisions in the contract should not act as a disincentive to reporting these, because contractors may incur financial penalties.

Some of the key issues that may arise in formulating contracts and the interactions that may occur - in particular, the need for all parties to align goals in order to avoid disincentives in meeting their obligations is the subject of a specific case study in Part 3.

12.2.2 Client role

Before contracting out work, it is important for the client to consider whether in doing so it may lose valuable skills and capability that it may require as the end user of the contracted work or in undertaking future similar undertakings. It should also satisfy itself that it is not (or may not become) too dependent on the chosen contractor, such that its competence to respond to emerging safety concerns is impaired.

The client should ensure that it is fully aware at all management levels of the need to meet regulatory requirements for contracted work (including project management arrangements) and the requirement for it to be an 'intelligent customer'. These obligations cannot be delegated. In order to achieve this, the client should maintain competence to assess risks, assess the quality of contractor input, provide monitoring and oversight, and ensure overall project coordination and control. This requires good communication with all other parties involved in the work (e.g. suppliers and subcontractors) about key issues and the vital importance attached to achieving high standards in process safety. As part of its capacity to be an intelligent customer, the client should not become too dependent on contractor claims and judgement, and should be in a position to challenge and verify all matters important to process safety.

12.2.3 Management of the contract

An overall project manager representing the client should be appointed. The client project manager should have responsibility and authority to ensure suitable management arrangements and overall project control. This should ensure that the arrangements set out in the contract are translated into working practices and procedures that are clear and agreed by all participants. The project manager should be empowered to take appropriate action if deficiencies or non-compliances are identified. To the extent possible, arrangements and reporting routes should minimise complexity.

The role should include setting requirements and ensuring compliance for all project teams in matters such as: reporting of deficiencies or emerging risks and taking action - including upward reporting where non-compliance occurs or more serious risks emerge; challenging unsafe acts or conditions; ensuring agreed and effective roles and communication channels; checking that competence meets the standards required; agreeing a system for witnessing of key steps; ensuring that acceptable quality standards are maintained and, ensuring that effective monitoring, audit and oversight is carried out. These arrangements should apply to all participants - including sub-contractors and relevant suppliers. The project manager should emphasise the requirement for openness in raising and discussing potential difficulties or delays and maintain an environment where constructive challenge is accepted.

Regular coordination meetings and more formal review points should be agreed at which, among other matters, any emerging potential conflicts of interest affecting the contract can be discussed, resolved (or reported upwards for higher level resolution), and faults and emerging design or construction concerns can be fully assessed and discussed. The meetings should be attended by relevant management and key staff, and attendance should not be routinely delegated. Verification should be sought by the client for contracting party statements and claims where these could impact on process safety. Changes to design or variation from specifications during implementation should be identified and consequent risks assessed. All parties should be made aware of agreed changes.

In facilitating the management of the contract, the client project leader should ensure that there is alignment and full mutual understanding of SMSs and procedures, and that safety cultures are compatible across the project such that openness, a questioning attitude, and reporting of deficiencies or unsafe conditions are given high priority.

'Signing off' satisfactory completion of work should only be carried out by those authorised to do so, and important steps should be independently verified. Those carrying out these functions should have sufficient technical and managerial support to make the necessary decisions, and should not be placed in a position where they feel obliged to accept the work because of other pressures or through insufficient skilled support.

Where third parties are given the role of overseeing aspects of the project, it is important that their role is defined and made clear to all parties involved in the project.

Where required, arrangements should be made to ensure that regulatory bodies are kept fully informed about project progress and particularly about any major changes to the agreed programme or technical requirements. Formal reports provided to regulatory bodies can provide an additional opportunity to critically review project risks.

12.2.4 Oversight arrangements

Clear arrangements should be established for witnessing key steps, monitoring, auditing and providing broader oversight. Both audit and independent oversight should go beyond paper systems and include how these are being put into practice. Each component of the overall process should be integrated into a coherent system that minimises 'audit overload' and is understood by all the parties involved, and from which results and the associated learning can be shared. A dedicated safety committee should also be established for major projects to review and provide guidance. Its role should be understood by all parties.

Those responsible for each part of the oversight process should be competent to undertake the work. Depending on the safety significance of the work being examined, the client should carry out its own oversight and scrutiny and not rely totally on contractor engineering judgement and self-verification. The client project leader should develop a clear picture of emerging risks and other important developments, so that matters of concern can be addressed and wider and deeper implications of any shortcomings fully examined as part of

the oversight process. The involvement, where necessary, of the senior management of the parties involved should be obtained to ensure their understanding and agreement to any significant changes required.

12.2.5 Ensuring competence

Competent individuals and teams should be maintained for the duration of the work being carried out with major changes to management and key personnel kept to a minimum to ensure project 'stability' and continuity in decision making and follow up.

The client should be in a position to satisfy itself that all leaders, managers and supervisors, together with key members of the workforce, are SQEP for their assigned roles and that changes during the course of the project do not dilute this requirement. Controls should also be in place to preclude delegation of key tasks/roles to insufficiently skilled staff.

For less familiar (or new) technology or for some specific tasks, capabilities may need to be enhanced by further specialist expertise and/or specialist subcontractors. Their competence to carry out the assigned role should also be fully assessed and steps taken to ensure that it is maintained.

Projects may require operational staff to develop a sufficient understanding so that resulting output can be used effectively and safely in subsequent operations. They should thus, where possible, be appropriately involved, thus facilitating a more effective transfer of knowledge at completion. They should also be in a position to advise on issues such as maintainability, and provide a deeper understanding of the working environment in which the output should be used.

Those engaged in a project, or aspects of it which are innovative, should be encouraged to discuss it with others who have relevant experience to ensure as far as possible that learning from previous use of the technology is understood and fully utilised.

12.2.6 Risk assessment

The process of risk assessment should be understood by all parties with the results of risk assessments shared between participants. They should be underpinned by the need for all parties to maintain a questioning attitude and precautionary approach to potential risks that may affect process safety. It is thus important to ensure that any pre-existing or developing inappropriate assumptions towards the project, such as 'this is a low risk project' or 'risks may be acceptable because the technology is well understood', are identified and challenged. Searching questions and minority views should be welcomed and concerns visibly acted upon.

Designers should ensure that they fully understand the environment in which the facility is to be operated and that the design is approached on a 'conservative' basis - including requirements for redundancy and diversity in safety critical plant. Steps should also be taken to ensure that any design issues and assumptions are fully understood by constructors and the client. Codes and standards (including analytical software) should be fit for the analysis being performed, with adequate safety margins. Where appropriate, they should be independently verified. Constructors should be aware of any test results and their significance.

The entire supply chain (including suppliers of safety important components and any sub-contractors used) should be made fully aware of process safety requirements, quality requirements and the need to comply with specifications - together with the safety-related reasons for these. Any changes from specification should be approved and reported to all parties involved in the project.

Requirements should extend to the suppliers of equipment that could impact process safety. Sourcing of safety critical plants and components should be carried out by competent specialists. A clear specification should underpin the supply of goods or services and should be subject to validation and verification by the purchaser. Steps should be taken to ensure that the supplier fully understands the significance of all aspects of the specification. Supplied equipment should be the subject of agreed QA procedures and, when safety significant, tested - where possible at the point of use with supplier participation. For equipment vital to process safety, consideration should be given to witnessing key steps in the manufacturing process.

At review points, not only should project progress be reviewed openly and with full disclosure, but a 'stand back' view taken of any emerging risks that could affect process safety. Contractor methods of analysis and any remedial actions taken to faults should be reviewed and, where appropriate, be subject to verification.

Assessment at review points should again pay particular attention to new or unfamiliar aspects of the technology, seeking independent specialist views as necessary. Senior management should be kept informed of emerging risks that are identified in the reviews and asked to take action when high level agreement on action is required.

In carrying out risk assessments and implementing identified improvements, wider 'system' implications should be evaluated as discussed fully in Part 3. Unless recognised in advance, it is possible to generate a 'bow wave' of unintended consequences arising from 'knock on effects' that were not considered at the time when the actions were taken, and these can lead to serious implications for later stages of the project and beyond. Their emergence can introduce the danger that short cuts or cost saving measures may then be introduced to try to meet budget and/or project deadlines.

13 EXPECTATIONS: OVERSIGHT AND SCRUTINY (O&S)

13.1 OVERVIEW

The term oversight and scrutiny is used in this chapter to cover a wide range of activities relevant to process safety from monitoring, quality checks and audit carried out within a particular operational context to the requirements of 'local' management, through to wider, more holistic business and corporate oversight processes. Exact details may depend on the structure of the organisation. The overall system should provide an integrated, hierarchical approach which taken together provides confidence that all process safety-related activities are carried out to acceptable standards. It should also ensure that emerging trends and developing concerns are identified, investigated and understood. It can thus act as a vital line of defence in minimising the risk of major events and in ensuring that a balance is achieved between production and 'defensive' systems.

This section of the report concentrates primarily on business and corporate oversight. This may involve more holistic scrutiny in areas of potential vulnerability and concern. It provides a means of alerting managers and leaders at appropriate levels to emerging risks and serious shortcomings so that timely remedial action can be taken. It can also ensure that work being carried out conforms to good practice and up-to-date standards, and that it also meets organisational requirements and expectations. It provides a means of checking that safety critical actions and monitoring at local level have been performed adequately and that there has been full compliance with the requirements of the SMS within a strong underlying safety culture.

Ensuring Oversight and Scrutiny is modelled using causal loop diagrams in Part 3 in the context of both understanding specific events and the complexity and value of the expectations presented in this section of the report. Part 2 also discusses issues relating to the use of audit and its follow up.

Oversight related issues are also discussed in sections 4, 10 and 12, and some references in sections 5, 6, 7, 8, 9 and 11.

Table 10 – Summary of oversight and scrutiny (O&S) expectations

OS1	A 'joined-up' O&S programme should be in place comprising monitoring, audit (which goes beyond paper systems) and higher level scrutiny. O&S should be carried out by well-trained staff who are not subject to potential conflicts of interest, to agreed schedules, and to a depth commensurate with the risk. Findings should, wherever possible, be made as straightforward as possible and bureaucracy minimised to ensure ease of follow up.
OS2	O&S should be carried out by both personnel reporting to 'local' line management and independently by representatives of the business centre or corporate leadership, depending on organisational structure. Each should have clearly defined terms of reference and be independent, but remain aware of mutual activities and findings.
OS3	Output should be reported at an appropriate level in a form which highlights risks and actions to be taken so that leaders are clear about operational reality, emerging risks, and follow up - even when this may challenge existing perceptions. More serious risks should be addressed promptly within a prioritised process, and the effectiveness of actions taken should be assessed.
OS4	Where deficiencies are identified, root causes should be examined, including deeper-lying organisational and cultural issues such as any developing tendency towards insularity, complacency or a decline in safety culture. Any impacts of organisational change should be assessed and awareness maintained of any evidence for 'organisational drift', overconfidence in decision making, and the impact of any pressure to conform to established views.

OS5	Areas for audit and wider oversight should be chosen on the basis of their risk to process safety and may involve general or 'themed' assessments. Specific operational parameters subject to review may include 'local' monitoring and quality processes; logs and records of various types; maintenance and testing; trends in data and, the views of staff. Themes for wider, more holistic review may include such topics as: the effectiveness of the SMS and its use and modification; risk assessment processes; approaches to decision making; change management; training and accreditation processes and, the effectiveness of interfaces and communication (including with and between contractors). The O&S processes should make clear the extent to which organisational expectations are being met.
OS6	Findings should be entered in a database that is kept up-to-date and is easy to use. This should be available across the organisation to facilitate learning. If certificates of compliance are required, these should only be issued when remedial actions are complete and their effectiveness confirmed.
OS7	Particular attention in O&S should be paid to any operations that have taken place outside the safe 'operating envelope', the reasons for this, and the process of authorisation. If justified by arguments regarding time at risk (e.g. maintenance activities or short remaining plant lifetime), these should be carefully examined.
OS8	In addition to regular examination of trends in data, KPIs specific to process safety should be developed. These should contain a combination of lagging and leading (proactive) indicators and should be tracked at appropriate organisational levels as an input to performance review and to prioritise areas for potential action.
OS9	Members of boards and other senior leaders should receive regular reports as a result of O&S activities. These should have sufficient 'edge' to alert them to areas of concern (including in specific plant or projects) and should not 'hide' concerns or be 'rolled up' as they are communicated upwards, such that they are not fully aware of important issues and actions being taken. The reports should enable them to challenge where necessary, stay in touch with operational reality, and inform their interactions with staff.
OS10	High level review of process safety should involve the assimilation of O&S findings, KPIs, and investigation into event reports. This can provide a company-wide picture of process safety performance and culture, whilst highlighting specific areas of concern and emerging risk. The process should be facilitated by an independent, well-resourced and competent safety function with 'authority' and a strong organisational 'voice'. It should be able to offer compelling process safety and associated safety culture advice at all levels.

13.2 DISCUSSION AND COMMENTARY

13.2.1 Structure, coverage and key challenges

An effective O&S process should provide an integrated ('joined up') hierarchical system that is carried-out in sufficient depth and to an agreed schedule from which deviations are kept to a minimum. It is particularly important to maintain (and potentially strengthen) processes during organisational change or when major projects are in progress. O&S processes should be carried out by well-trained and experienced personnel to clearly defined terms of reference - wherever possible minimising overlap and bureaucratic complexity

Feedback to 'local' management on the adequacy of process safety in operations (including support functions) can be provided by specialists reporting to line management, whereas the primary focus of corporate and business centre activities may be to obtain an independent (outside the operational line), more holistic view of performance, highlighting any particular areas of vulnerability and concern.

Effective reporting routes should ensure that leaders - from those in specific businesses or projects, through to the board of the organisation - are aware of important findings relevant to their roles. To achieve this, findings should not be aggregated or 'rolled up' in upward transmission in a way that reduces the clarity of

concerns relating to a specific plant or process, and leaders should ensure that they are clear about the risks present, actions proposed or being taken, and the effectiveness of their implementation.

It is important that those carrying out O&S activities are in close contact about planning and findings whilst retaining their own independence and reporting routes. It is also important that those carrying out and managing business centre and corporate O&S do not have other operational roles ('dual hatting') or be subject to pressure that might lead to a conflict of interest between 'production' or project progress, and process safety.

Oversight and scrutiny processes should not just identify deficiencies and suggested remedial actions, but should also verify that these have been implemented and seek evidence that the change has been effective. It is important that the root causes of deficiencies should be identified. Those carrying out O&S should thus have not only technical and systems capabilities, but be able to identify deeper-lying organisational deficiencies and any human factors and behavioural factors.

Those responsible for O&S processes should have sufficient influence and authority, with appropriate reporting routes, to ensure that important findings are dealt with promptly and thoroughly, and that remedial activities are not deferred or under-resourced.

A further important role is to challenge the view that confidence in continued good performance is justified by past success. Thus, those carrying out O&S should remain alert to evidence of 'organisational drift' and should ensure that business and corporate leaders are helped to maintain awareness of the 'reality' of how operations are being carried out and the associated organisation and culture. This should be made apparent even when there may be real or perceived pressure to conform to the accepted view.

For some events studied, it was found that organisations had become insular and did not properly consider industry good practice and the findings from previous relevant events. This is one indicator of a weak safety culture. Those carrying out O&S should have the competence to identify and respond to deficiencies in safety culture and to ensure that learning opportunities are being taken.

13.2.2 Implementation and sources of data

O&S may be focussed on specific areas of concern ('themed inspections') or aimed at obtaining an overall view of the performance of a plant, process or project. Results should be benchmarked against organisational expectations.

- Various sources of information are available as input, depending on the nature of the review process. These may include records, observations, trends, and the views and concerns of the workforce. Sources and areas for potential review that have been highlighted in the reports into the events studied include the following:Conformance of management systems with the safety case and related documentation, and how conformity is achieved in practice;
- Adequacy, understanding and compliance with the SMS. This requires, in particular, that procedures and work instructions, and the processes used to keep these relevant and up-to-date reflect operational requirements and are regularly reviewed. This should include processes for revision, and the authorisation process for changes to the SMS. Review should also include the potential impact of the aggregated effect of many small changes. In assessing performance, note should be taken of the number and importance of short-term deviations from the SMS or periods of operation outside the safe operating envelope, the reasons for this, and the process by which authority was obtained (e.g. a waiver system). Particular note should be taken of reductions in process safety provision justified by a reduced period at risk (e.g. the projected remaining lifetime of plant or equipment);
- The adequacy and implementation of processes for risk assessment at all levels of application;
- The views of staff (including contractors) on issues such as the adequacy of- and compliance with-procedures; whether decisions are being made on a precautionary basis; pressures on staff and working conditions; the reporting of concerns, and staff views on prevailing attitudes and behaviours more generally;
- How decisions have been reached and recorded (for example, the response to safety concerns and processes for management of organisational and technical change), sources of advice received, and whether decisions have been made at an appropriate level;
- Reports into witnessing of key safety processes and the response to findings. This should include

the installation and testing of safety-related equipment, and less frequent operations (such as start-ups). It should also include the practice for obtaining associated authorisations;
- The effectiveness of operational monitoring and audit systems (including inspection, checking and verification). This should also include the extent to which review has taken place of actual operational behaviours and not just paper systems, and the extent to which trends have been monitored;
- Plant condition and maintenance records, including issues of reliability, alertness to plant degradation, backlogs and the access of operational staff to engineering support;
- Processes employed in the authorisation and implementation of changes to plant both during construction and operation, and the implication of these for safety cases and management systems;
- Records of training and authorisation for roles (including for abnormal conditions and emergencies);
- Operational experience records such as logs of hand-over practices, response to alarms, and emergency exercises;
- The effectiveness of reporting and investigation into 'near hits' and operational anomalies, with identification of root causes and any potential for wider implications. This should include the closure and effectiveness of actions;
- The adequacy of processes at the interface with contracting organisations (including designers and suppliers) in areas with the potential to impact on process safety - particularly clarity about standards, culture, communication, and audit (including the rigour of quality assessments). Particular attention should be paid to novel plant or processes. It should also include assessing the adequacy of the client role in providing oversight, as well as that of contracting organisations;
- The effectiveness of interfaces and communication between work groups and functions (including business and corporate centres) and,
- The extent to which previous findings and recommendations have been followed through, and checks carried out on effectiveness.

In some industries, certificates of compliance are issued following a satisfactory audit or review. These should not be provided until identified issues have been satisfactorily dealt with and their effectiveness confirmed or a caveat included that this remains an open matter.

A common central database of findings and actions has been found to be valuable. This should be kept up-to-date and as simple to use as possible to ensure ease of use.

13.2.3 Examining trends and measuring performance

Obtaining a more holistic view of process safety performance at senior level and examining trends is particularly important because in many cases over-reliance has been placed on more easily obtained occupational safety performance data. This does not generally provide a good indicator of process safety performance.

It is thus important that performance indicators (KPIs) are developed to monitor process safety performance. These may be in the form of 'lagging' indicators that enable performance in key areas to be reviewed retrospectively (e.g. number of 'events' in a defined category), or 'leading' indicators that provide proactive information by allowing a measure to be obtained of the extent to which important actions are being taken to make improvements. A balance between leading and lagging indicators should be achieved and over-reliance not placed on one type. KPIs are an important input to the overall review of process safety performance and can provide valuable input to assigning priorities for action, both within the organisation as a whole, or in specific operational areas or projects. The selection, development and use of KPIs, including the selection and role of leading indicators, is the subject of more in-depth discussion in Part 2.

13.2.4 Board and senior leadership role

Reports with clear findings and recommendations should be made available to leaders at an appropriate level in the organisation. In particular, corporate and business boards and other business leaders should receive regular reports and critical overviews from independent safety functions. In some cases, board safety committees and members with assigned responsibilities for process safety are appointed, and they should also provide informed views and raise concerns where necessary.

Reporting should have sufficient 'edge' to provide a clear understanding and view of key vulnerabilities and areas of emerging risk as they relate to identified areas such as plant or projects, so that leaders can take an informed view as to whether appropriate action is being taken and whether risks are being effectively

controlled. This should include the way in which 'deeper' organisational, management and cultural issues are being addressed. Their understanding may also enable boards to take account of the potential impact of their business decision making on process safety.

The knowledge and information received should also enable leaders to reinforce and focus their commitment to process safety and to 'inform' their interaction with staff. The view of performance that they obtain may challenge existing views and perceptions, and they should be alert and open minded to the possibility that operational reality does not always support previously held perceptions.

Taken together, management reports, O&S findings on process safety, KPIs and relevant event reports can provide a valuable overall picture to senior decision takers and to safety committees. Assimilating this data and helping to interpret it for leaders is again often an important function of an independent safety function. Given their role in both conducting reviews and interpreting the data, along with their other roles in providing a challenging view of performance and proposed actions, it is important that they are well resourced with capable and experienced staff and with a leader who has, if required, direct access to the most senior leadership in the organisation. It is also important that their views are well respected within the organisation and that they retain a strong 'voice' and ability to offer compelling advice and guidance at all levels.

14 CONCLUSIONS TO PART 1

Part 1 of the report has shown that organisational and cultural factors have been very important as precursors to a range of major events across a range of industries that rely for their safety on the effective management of interacting engineering, people-related and organisational (process safety') issues. The factors involved are often 'latent' and require dedicated attention to be paid to their identification and remediation.

The collection of findings in this context from the twelve major events studied have been drawn out, interpreted and used as prompts to enable further discussion and to provide insights that should allow greater understanding and awareness of the issues involved to be obtained by decision makers and those involved in the development and use of the processes and systems. Presenting the material in the form of 'expectations' or good practice guidelines with associated discussion and commentary should provide an opportunity for current approaches across a range of industries to be assessed ('benchmarked') and action taken, where necessary, to make improvements to how these organisational and cultural factors are currently identified and addressed. It should also provide an opportunity to be taken to develop new 'tools' for the oversight and scrutiny of these sometimes neglected areas that would complement existing approaches used to assess engineering and people-related issues. The identification and presentation of these precursors may also enable more effective investigation of events and 'near hits' within organisations in order to facilitate improved learning.

Developing suitable courses of action to improve resilience in these areas requires careful attention to be given to the behavioural and psychological influences involved, and also requires approaches to be developed that take fuller account of the interactions that very frequently occur within the complex systems involved. Part 2 of the report addresses some of the key factors involved in dealing with the people-related issues, many of which are relevant to the findings above. Part 3 describes and illustrates the use of a potentially very valuable approach using CLDs to enable interactive effects to be better identified and addressed, and to provide the opportunity to develop more effective performance measures in complex systems.

PART 2

Organisational learning and the design of evidence-based interventions

15 INTRODUCTION TO PART 2

Whether arising from the analysis of major events, such as those discussed in Part 1, incidents within ones' own organisations, or other intelligence highlighting weaknesses and deficiencies in SMSs, the need to engage with behavioural and cultural components is likely to constitute a key element of the process of enhancing resilience.

Effective risk management in the workplace is about intervention, i.e. to change the natural or prevailing order of things, whether in traditional domains, such as machinery guarding and manual handling (reduction) systems, or more challenging areas such as human error and safety culture. Proactive intervention is about finding ways to effectively manage the potential for undesired outcomes, and thereby mitigate the risks to employees, the public, and employers.

Intentionally setting aside the veracity of widely encountered claims of a plateauing of safety improvement attributable to engineered controls justifying an increased focus on behavioural issues over recent decades (a premise that remains contentious), Part 2 focuses on the challenging issue of socially engineering cultural change.

Finding ways to motivate managers and employees to behave in ways counter to their default inclinations is routinely challenging. Potentially *problematic,* or otherwise *undesirable,* behaviour can have its basis in: natural reinforcement (i.e. it is simply easier and less effort to do it *this* way); the product of cognitive bias's (section 3.6.1, Box 8); recourse to cognitive short-cuts (heuristics); habit; incomplete mental models (see section 3.6.1, Box 7), and, the intersect with normative influence (custom and practice) in the workplace. Importantly, under a wide range of circumstances, ostensibly non-rational behaviour, can simply reflect employee coping strategies*,* in response to a hostile choice architecture (see sections 3.3.3, Box 4; 5.1.2; & Annex C), e.g. conflicting organisational goals / managerial priorities or sub-optimal systems (structural, social and technical).

Recognising what needs to change, in behavioural and cultural terms, can be challenging for work organisations, particularly where there is a desire to determine root causes. However, this can represent a relatively modest objective relative to the challenges surrounding realisation of any desired change, particularly where this requires influence in rather nebulous and opaque domains, e.g. safety climate, safety culture, human factors, and psycho-social elements.

Part 2 sets out to provide a critical perspective on the use of evidence to inform corporate decision making over identifying priorities for intervention and effective intervention design, to enhance system resilience though addressing behavioural and cultural components. It focuses on the evidence gathering in the related domains of:

- Identifying structural, organisational and socio-technical weakness.
- Setting priorities for intervention to enhance resilience.
- Intervention options appraisal – theories of change and 'what works'?
- Intervention design and delivery – intervention logic – how will 'it' will work?

The term 'evidence-based practice' has seemingly become a central tenet of the lexicon of business speak over the last two decades. While the concept of using evidence to inform practice undeniably predates this, the contemporary narrative can perhaps be traced back to the philosophical underpinnings evident in the New Labour white paper *Our healthier Nation* (1999). A central and enduring legacy of the perspective on evidence within that document was that social and behavioural science evidence should play a more integral role in informing public policy strategy and intervention design. The vision was that these principles should be applied to a broad array of public health and social problems, notably lifestyle health, crime, road safety, environmental 'greening' behaviour, including occupational health and safety in the workplace.

At first encounter, the reader might be moved to ask 'Why is this relevant to risk management in high hazard sectors?'. The answer is that the intense focus on behaviour change within the public policy domain led to a number of advances in thinking and practice in social engineering science. Specifically, the following:

- Enhanced practical relevance of academic research into behaviour change.

- Increase in funded research on behaviour change and intervention design.
- New theories and new applications of established theories of behaviour change.
- An intensified focus on 'what works' – and techniques for determining this.
- An enhanced body of robust review evidence available within the public domain.
- Wider adoption of robust techniques for determining priorities for intervention.
- More systematic approaches to intervention options appraisal.
- Intensified focus on the need for quantifiable evidence of impact.

Part 2 provides a commentary on the relevance of these and related developments in the use of evidence with a view to harmonisation with established human factors and behaviour science perspectives on intervention within the occupational safety domain. The principal topics discussed are:

- Measuring health and safety performance.
  - What do we mean by data and evidence?
  - Incident and incidence data.
  - Contemporary perspectives on lead indicators.
  - Audits and climate surveys - reflections on practice.
- Techniques for priority elicitation.
- Setting an agenda for improvement.
  - Establishing a robust and defensible case for intervention.
- Considerations when designing behaviour change interventions – the challenge of social engineering in the workplace.
  - Theories of behaviour change.
  - Intervention logic modelling.

In the interest of brevity, the body text contains signposts to a set of annexes. The annexes are provided for readers wishing to gain a deeper appreciation of the history and strength of the underpinning science relating to insights, concepts, tools, techniques, and models referred to within Part 2:

- Annex A: High-Reliability Organisations
- Annex B: Safety culture maturity
- Annex C: Strengths and weaknesses of influential behaviour change perspectives
- Annex D: Training and communication interventions
- Annex E: Incentives and rewards

15.1 Identifying priorities for health and safety improvement and investment

Many would recognise the potential pitfalls of the following:

i. A corporate health and safety agenda dominated by reactive responses to incidents in which priorities and resource allocations that lurch from one crisis to the next.

ii. Safety management agendas dominated by a focus on high frequency/rate, relatively low consequence workplace safety failures (e.g. slips and trips).

Most mature organisations would aspire to a more strategic approach.

The use of appropriate, high-quality evidence to inform decision making over priorities for improving risk control and where to invest and in what way(s), benefits from strong intuitive appeal. Success, however, hinges upon:

- the nature and quality of the data gathered;
- distilling this into a form that is accessible to decision-makers;
- the scope for achieving change;
- technical knowledge of what works to achieve the desired result, and

- the capacity to measure the impact of arising initiatives and interventions.

An observation is that many, perhaps most, organisations exhibit weaknesses in the following areas:

- feedback on the effectiveness of investment in current risk control measures;
- insight into latent (hidden) weaknesses/failures in risk management;
- identification of root causes of past failures / near misses;
- the capacity to use evidence to identify priorities for investment, and
- the capacity to design appropriate, durable, high-quality interventions with demonstrable impact of their effectiveness in meeting headline objectives.

The case for basing decision making and investment in health and safety on good quality evidence requires consideration of the relative strengths and limitations of alternative sources of data.

16 MEASURING HEALTH AND SAFETY PERFORMANCE

Deciding what to measure, what constitutes a reliable measure of performance and how best to go about measuring it is far from trivial.

At a basal level, mature, pro-active organisations, committed to continuous improvement need to be able to:

- benchmark current performance;
- monitor performance over time and identify trends;
- identify priorities for intervention and improvement, and
- measure the effectiveness of their interventions.

16.1 WHAT DO WE MEAN BY DATA AND EVIDENCE?

Data capture represents a cornerstone of effective learning. However, before proceeding it is perhaps useful to pause and consider what is meant by data and evidence, their boundaries and potential roles.

Traditional perspectives on health and safety learning have tended to be bounded by a focus on accidents and incidents; this being true of employers, trades unions, regulators and governments. Recognition of the limitations of incident (lag[2]) data, has sponsored significant interest in developing lead[3] indicators.

Organisations with mature health and SMSs routinely use a combination of multiple lag and lead indicators to:

- inform their decision making over identifying root causes;
- set priorities for improvement, and
- monitor the status of controls and progress towards realising safety objectives.

However, scope for evidence-based practice within the risk management domain extends beyond the capacity to recognise vulnerabilities. Having recognised **who** is at risk and determined **what** needs to change, the focus necessarily turns to the question of **how** this might be achieved. Drawing upon the amassed social science evidence on 'what works', the latter embodies the dual challenges of identifying an appropriate:

- theory of change – by what mechanism/technique will behaviour change occur? (Section 5.1; and Annex C)
- intervention logic – the logistics of making it happen – i.e. the design considerations for an effective intervention (Section 5.2).

16.1.1 Incident and incidence data

It is important that the approach to data gathering is proactive and purposive. At first encounter, this may present as a statement of the obvious. However, common experience is that while most, if not all, large organisations are awash with data, a high proportion of that gathered tends to be of limited utility from the perspective of purposive data-mining.

Likely reflecting regulatory reporting obligations (e.g. Reporting of Injuries, Diseases and Dangerous Occurrences Regulations 2013, RIDDOR), employer incident classification systems tend to be focused on manifest consequences, rather than immediate or latent causality, e.g. uncontrolled release, struck by moving object or, within the health domain, psychological stress.

Summary data relating to such events offer little beyond the capacity to compare rates between one accounting period and the next, one site and another and similar and, even then, low frequencies tend to limit confidence in findings (see below).

Few would deny the intuitive benefits of capturing contextual elements with a view to identifying latent influences and root causes, particularly for more complex/high consequence events. However, many

2 Lag indicators - sometimes termed 'trail' indicators relates to past failures – accidents, ill health and near misses. They exemplify instances where a desired safety outcome has failed, or has not been achieved.

3 Lead indicators – relate to performance in managing precursors to harm. They are a form of active monitoring of defined key risk control criteria to determine their effectiveness

organisations find this deeper classification challenging, not necessarily because they are lacking expertise, but because realisation of this objective is inherently challenging, particularly where the task is performed by plural individuals. Levels of agreement between root cause classifiers are routinely found to range from modest to low. The intuitive solution of adding more detail to classification systems, in many instances, seems to have the effect of amplifying rather than attenuating the degree of disagreement (see, for example, Barnett and Weyman, 2016).

'Incident classification systems risk generating more heat than light; obscuring as much as they reveal - their design requires careful consideration' (Anderson and Weyman, 1998).

While valuable lessons can be learned from the appropriate and effective investigation of major indents (see Part 1), their rarity is problematic as a source of effective feedback on the quality of risk management performance within a given work organisation. This is because the relative paucity of data precludes reliable statistical testing, e.g. of change over time or between one site and another. Equally, there is a need to be mindful that the absence of an inherently rare chance-related event may owe more to good fortune than prowess in risk control.

The scarcity of major incidents tends to divert the focus on lag data to occupational safety events. This is not wholly inappropriate, however, prowess in managing occupational safety is not necessarily a good proxy for the status of control of major hazards. The often cited claim of a linkage between the two (see, for example, Heinrich, 1959) is based upon correlational, rather than causal evidence, i.e. a good record in occupational safety may be indicative of a high reliability organisation (see Annex A) but, in and of itself, constitutes insufficient grounds for concluding that an organisation has achieved that status.

Despite benefiting from strong intuitive appeal, occupational incident data tends to be problematic when attempting to monitor trends and detect emergent vulnerabilities. As noted above, fatal and major rates, in almost all organisations, are too low to support formal statistical testing. Insufficient data can result in the detection of both false positives (spurious indications of improvement) and false negatives (undetected improvement). Similarly, it is not possible to determine whether changes reflect random variability or some substantive difference, e.g. should a drop from five to three cases within a given category be interpreted as a cause for celebration, or merely the product of natural fluctuation and good-fortune?

In the domain of lag data, only minor injury and medical room entry data tends to be sufficiently prolific to support reliable statistical testing (particularly over relatively short accounting periods - e.g. quarterly or annual), or when attempting to compare one productive unit with another, and similar. However, its principal limitation relates to its high susceptibility to reporting bias (both amplification and attenuation effects are possible). Recognised influences include: management style; presence of safety performance targets; contractor selection criteria and injury compensation arrangements.

Near miss reporting, while a potentially valuable source of intelligence, is subject to essentially equivalent amplification / attenuation effects. It is also prone to producing a skewed profile of incidents by type, due the presence of systematic biases, i.e. greater propensity to report systems- rather than personnel- failures; under-reporting of events associated with personal / work team culpability; tendency to avoid getting peers into trouble ('telling on', 'grassing' etc.), and higher propensity to report events involving members of out-groups[4], e.g. contractors or agency personnel.

While a positive, receptive safety climate can ameliorate the degree of under-reporting of minor incidents and near misses, it is prudent to assume that the phenomena will always be present to some degree.

4 People outside one's own group, especially as considered to be inferior or alien; a group perceived as other than one's own.

Box 1

Summary of the limits of incident (lag) data

Linkage to risk - Relationship between risk behaviour and negative outcomes tends to be weak and highly chance related. A high proportion of the time, individuals and their organisations will be lucky. Particularly in complex systems, minor failures may routinely go unnoticed or have benign consequences; and, most will never achieve the necessary alignment to produce a significant failure.

Identifying trends – Accident data is sparse. A by-product of advances in risk control is that rates, particularly of major incidents, fatal and serious accidents, are typically low. Routinely, too little data is available to identify trends, or support reliable statistical testing. This can be challenging at corporate level, but is acutely problematic when attempting to measure change at the level of the work site or unit.

Identifying root causes - Lag data tends to be classified in terms of manifest consequences. This can mask deeper causality, particularly when presented in summary statistics. While there is routinely scope to improve classification systems, at best, the output will be limited to who, what, where and how much issues – with little insight into why; the latter being key to decision making over future intervention to achieve improvement.

Feedback on investment – The (short-medium term) non-linear relationship between risk and incidents renders lag data problematic as feedback on the effectiveness of investment in risk controls / improvement initiatives. Investment in risk control relates to reducing the potential for harm. To compare like with like, it is necessary to devise metrics of success in reducing that potential.

Reporting biases – The only sources of lag data that are sufficiently prolific to support reliable statistical testing (minor injury and near miss data) exhibit high susceptibility to reporting bias. Rates can become attenuated, amplified and skewed.

Restricted scope - Lag data relates to recognised failures. The detection of deeper, rarer, possibly previously undetected pathogens and weaknesses in risk control requires additional systems for data capture, and consideration of pathways to failure, particularly where these relate to complex systems and where the consequences of failure may be high magnitude, even catastrophic, e.g. a large scale uncontrolled release of chemical, structural collapse, or explosion.

At the most fundamental level, the utility of lag data is limited by the relationship between risk and incidents. For most practical purposes, this is most appropriately regarded as non-linear – certainly over typical business accounting periods (quarterly, annual, etc.).

To suggest that employers, shareholders, regulators and other stakeholders should disregard accident and ill health outcome data is both untenable and undesirable. Rather, the point at issue rests with the partiality and (in)sufficiency of lag data alone, as a source of feedback on corporate prowess in managing hazards and risks.

Growing recognition of the dislocation between risk (potential for harm) and outcomes (manifest consequences), underpinned by the regulatory emphasis on risk assessment, has stimulated significant interest in the scope for developing effective lead indicators, i.e. tools and techniques for data capture, with the capacity to identify vulnerabilities (‘ticking bombs’) in socio-technical systems.

A key distinction between lag and lead indicators relates to the relationship of each to risk and the potential for harm. The chance relatedness of incident data means that using these as a measure of effective hazard management is not comparing like with like, i.e. a case of comparing ‘apples’ with ‘oranges’. There is potentially a much closer match between risk management practice and (appropriately selected) lead indicators. Where the latter relates to measuring and monitoring the effectiveness of the former, it becomes possible to reliably compare inputs against outputs.

Common experience, however, is that despite the concept of lead indicators having entered the safety management discourse, many organisations appear to lack a clear conception of their nature and / or role; most acutely their potential to be applied in an active manner, to enhance learning and inform decision making over intervention to address vulnerabilities. Embracing the concept also rests upon the presence of a degree of corporate culture maturity that is receptive to, and prepared to engage with, the implications of 'bad news'.

16.1.2 Contemporary perspectives on lead indicators

Echoing features of the quality revolution of the 1980s (see Beck, 1992 and Power, 2004), the appeal of lead indicators is that they embody the potential to supplement and address recognised shortfalls in incident and near miss data, by providing early warning of problems before they become manifest.

Contemporary perspectives reflect a strong orientation around audit, focused on recognised sources of vulnerability, e.g. compliance with rules and procedures, status and availability of machinery and equipment. The intuitive value of such output is that it provides (most commonly) quantifiable data on current performance for a defined group of employees / process / work-site, etc., that can be compared against a benchmark, or some other comparator, e.g. referenced to a defined standard / improvement objective, or to provide early warning dips in performance that require intervention.

'In essence, contemporary perspectives reflect a logical extension of quality management practice. In contrast to earlier times, few manufacturers today limit their assessment of how well they have performed to the number of reject items piled up at the end of the assembly line - and the associated worry over the number of duds that were missed…' Power, 2004.

Box 2

Lead indicators:

allow organisations to detect improvements in health and safety performance;

can be configured to measure success (rather than focusing on failure);

provide regular, monitored, timely, feedback to stakeholders;

embody the capacity to predict future performance;

can be used to stimulate employee engagement in problem solving around safety;

make transparent what needs to be done to achieve improvement; and,

track the impact – effectiveness - and return of improvement investment.

Resilient organisations typically have a suite of lead indicators and effective systems for distilling results to inform senior management decision making and strategy over improvement / consolidation. Such organisations can be characterised as 'data hungry'. They actively seek-out evidence on weaknesses and potential vulnerabilities, with a view to their resolution, rather than a default orientation of reacting to events as they unfold.

The following discussion of lead indicators offers critical comment on a number of widely applied tools and techniques within contemporary safety management practice.

Lead indicators essentially fall into two families:

16.1.2.1 Measures of how effectively precursors to known sources of harm or failure are being controlled

For example, rates of risk assessment completion/review; training; auditing of infrastructure and equipment status/availability; rates of employee engagement/involvement; behavioural audits, and similar.

Under most circumstances, these should be based on some assessment of the physical properties of the issue being assessed. Where behavioural elements are relevant, measures should focus on behaviour, in preference to attitudes or opinions[5]. The perspective on behaviour should also be broad and aim to address fundamental elements, and not be limited to the observation of real-time, overt behaviour at the point it is exhibited. More is to be gained from a primary emphasis on the antecedents of behaviour, i.e. a focus on the trail of evidence that is the product of past behaviour. For example, a defeated interlock may reflect laxity in supervision, possibly extending to tacit acceptance of the practice by managers; similarly, the presence of non-standard tools and equipment at the worksite, or the adoption of improvised solutions.

5 Attitudes are a poor predictor of behaviour. Behaviour is a more reliable predictor of attitude.

Where possible audits should be of objective elements, using measures that produce reliable, reproducible results. A fundamental and necessary feature is that audit procedures and tools should be designed such that they produce equivalent results when used by multiple assessors (see Section 2.3.2. and Annex C). They should also be conducted with sufficient regularity to provide 'live' monitoring feedback.

Commonly encountered lead indicators:

Point of work audits – designed to produce quantifiable indication of the effectiveness of controls of recognised vulnerabilities, with scope to constitute or be linked to KPIs. Where the arising output is fed back to risk managers and actively used by them to inform decision making relating to the status of risk control, they can constitute a valuable component of oversight and scrutiny (see Part 1, section 2.5.10).

Typically, they are designed to relate to:

- Background monitoring of established systems and practices over extended periods, e.g. rates of risk assessment completion; training/certification; infrastructure and equipment status/availability; rates of employee engagement/involvement, and similar.
- Bespoke measures, which may (but not necessarily) be of short duration, e.g. linked to specific improvement initiatives and interventions, such as housekeeping standards and hazard spotting campaigns.
- Behaviour assessment and audit – widely applied in various forms, tend to be based upon snap-shot observations (of varying frequency) of active[6] employee (generally aggregated across plural employees) behaviour and / or the antecedents of behaviour (the presence of out-of-date lifting equipment at the worksite; blocked access route and similar - see Annex C).

Box 3

Point-of-work audits

Desirable features include:

- Reflecting the principle of a hierarchy of control, a primary emphasis on structural, engineered systems and job design components. Behavioural assessment should address antecedent components as well as observable behaviour.
- Where possible audits should be of objective elements, using measures that produce reliable, reproducible results. They should be conducted with sufficient regularity to provide live monitoring feedback.

Limitations:

- High potential for low inter-auditor (observer) agreement raises questions over the reliability of data.
- Scope tends to be limited to immediately observable elements, such that they are a better fit with occupational safety than major hazards risk control.

Why conduct audits?

To provide monitoring feedback on:

- the status and / or prevalence of recognised vectors of harm;
- the effectiveness of extant risk control measures;
- the presence and / or status of machinery, equipment and work conditions;
- compliance with rules, procedures and good practice, and
- the effectiveness of behaviour change interventions for defined processes or groups of employees, e.g. to provide early warning of dips in performance that would benefit from managerial action.

6 In contrast to behavioural antecedents – i.e. evidence of past behaviour.

Audit output is relevant to:

Site managers - The arising data is of value for monitoring the status of risk controls on their site as a whole, and its component functions/personnel by type. Good quality data identifies issues, functions and locations where action needs to be taken. It also identifies where controls are effective, and ineffective. Knowing this can bring efficiencies in resource allocation over intervention, by avoiding wastage on groups and issues that are already performing well.

Senior managers / Board level - The arising data is of value for broadly equivalent reasons to those outlined above, but with the advantage that data of sufficient quantity can be used to support the identification of trends and contrasts, as well as identifying priorities for future improvement, but importantly, also provides feedback on the effectiveness of established risk control measures and topic-based interventions.

16.1.2.2 Employee surveys

These aim to tap employee orientations towards and perspectives on the prevailing health and safety climate; work related stress, and related topics (see Annex C).

Box 4

Safety Culture or Climate?

- Much has been written regarding the distinction between the linked concepts of safety climate and safety culture. The terms are often used interchangeably - but not always. It may be useful to conceive of climate as relating to the context, or architecture[7] in which employees operate.
- There is strong evidence that climate plays an important role in shaping 'shop-floor' safety behaviour and culture.
- Climate variables are potentially malleable, i.e. they are amenable to management intervention in ways that impact on employee orientation, behaviour and culture.

While the data produced is inherently subjective, tapping employee impressions and beliefs, substantively accurate or otherwise, is valuable insofar as these impact upon behaviour.

Being subjective, although quantifiable, the output is more reliable in relative than in absolute terms, e.g. to compare relative differences between, say one employee demographic (grade/role/work unit etc.) and another, or as a measure of relative change over time within the same organisations. This is because, for these types of comparisons, any measurement error can be considered essentially common.[8] Comparisons of survey results between organisations are not recommended (despite their popularity) and are best treated with caution, due to the high potential for local amplification or attenuation effects.

An array of commercially produced measures are available. Most take the form of a set of attitude statements, against which a sample of the employees are asked to indicate their degree of agreement. The statements map onto a set of themed measurement scales (typically between 8 and 10; with around 4 – 8 questions on each).

7 Architecture extending beyond the built environment to include the design and availability of equipment and resources employees have to work with, the rules and procedures they operate to, systems of reward, organisational structure, management style, and more.

8 Where measurement error is essentially equivalent between groups of respondents, or can be judged to be stable over time measurement can be treated as common and of little consequence, in relative terms. However, it should be kept in mind that staff survey results can reflect broader influences on employee attitudes, e.g. grievances arising from industrial disputes, threats of redundancy programmes and similar can be vented through ostensibly unrelated channels.

Box 5

Safety Climate survey measures - desirable features

- Commercially available measures should have an auditable account of their development. Key criteria relate to:
  - Face validity – do independent specialists judge the scales to measure what they claim to measure?
  - Reliability – evidence that each scale (e.g. management commitment, compliance with rules) exceeds minimum standards of internal consistency; and do they produce equivalent results if repeated (authors should report Alpha coefficients >0.70 in each case).

    These criteria are important to verify as a number of commercially available scales have been found wanting in these respects - with the associated risk that the results they produce may be spurious.
- The facility for recording demographic details of respondents that relate to structural (rather than just personal) details e.g. grade, role, function, location.
- Questions that have a common reference subject i.e. questions that relate to the behaviour of the respondent or the behaviour of others; but not a mix of the two. – A number of commercially available measures exhibit a mix of 'I/your' (referring to respondent behaviour) and 'they / people who work here' (the behaviour of peers). Questions that ask about personal behaviour in relation to risk are undesirable due to the high potential for self-serving attribution bias, i.e. people's tendency to portray their own behaviour in a favourable light. Better measures use the behaviour of peers ('they') as the subject reference.

There is notable variability between the different measures in terms of the elements that the claim to measure. However, the most widely encountered scales are characterizable as:

- management commitment to health and safety;
- supervisor commitment;
- norms surrounding compliance with rules and procedures;
- risk taking behaviour, and
- incident reporting.

Note: Most organisations use commercially available off-the-shelf safety climate measures. An inherent limitation of using generic question sets is that they may fail to capture employee perspectives on important variables within the organisation.

Recognition of this has led to a small number of organisations / sectors developing their own bespoke measures.

Why conduct employee surveys?

When appropriately interrogated, safety climate survey output can provide insight into a range of recognised precursors to failure. Where weaknesses are apparent, this insight can usefully inform and direct thinking over priorities for improvement, not just by topic but also by employee demographic. Effective application can support profiling and comparison of different demographics e.g. work-sites / functions / staff grades / parallel workforces. As with audits, arising insights can be used to inform senior management thinking over the merits of a segmented, bespoke approach to intervention, e.g. by site, or staff grade, avoiding the waste that can arise from a one-size-fits-all strategy.

Output is of relevance to the following:

- **Senior managers / Board level** - to provide feedback on prevailing health and safety norms (typically, relating to infrastructure, equipment, work organisations and management style as well as behavioural components), the profile of which can be interpreted through reference to published guidance on good practice in maintaining risk control.
- **Site managers** - site-specific data can be particularly useful in organisations with multiple sites, where a range of different health and safety cultures may be present.

16.1.2.3 Audits and climate surveys - Reflections on practice (see Annex C)

A key consideration relates to whether the intent is to use the results as a passive monitoring measure of change over time, or to actively use the output to inform decision-making over priorities for improvement and as a benchmark against which to assess change. Most organisations have objectives on each.

It is generally more appropriate to deploy audits at a higher frequency than climate surveys. A number of proponents of behavioural safety techniques, for example, recommend data gathering as often as once per shift, or multiple times per week. Under most circumstances the appropriate frequency for climate surveys would not be greater than once in any 12 month period.

Auditing techniques are better suited to monitoring the impact of improvement interventions (potentially referenced to KPIs) than climate surveys as, when appropriately configured, audit output has the potential to be more objective than climate survey data. However, where the output of audits is based upon aggregated observations, care is needed to ensure that the data produced is reliable, particularly where audits are conducted by multiple observers, i.e. to be considered reliable, auditors need to produce equivalent ratings[9].

A significant limitation of the safety culture/climate perspective is that the area remains underdeveloped, in terms of the related science of application and intervention (see Annexes C, D and E). Specifically, it is not the shortage of assessment tools that constitutes a primary barrier to the realisation of the potential of such approaches, but the scarcity of guidance on their application and the contribution of the evidence produced to organisational learning, strategic decision making and intervention to address identified weaknesses.

While performance measures possess the potential to provide intelligence on **who** is at risk and in **what** way, they are merely barometers, with the capacity to highlight and monitor ‘hot topics’ or ‘hot spots’ that would benefit from intervention and change. As such, they represent the initial stage in the change process, and produce no change in and of themselves.

Measuring employee attitudes, beliefs and behaviour is relatively unproblematic, as is recognising what needs to improve. Change rests with finding ways to technically and/or socially engineer solutions through intervention. Translating the output from audits and climate surveys into effective actionable interventions; to socially engineer positive cultural change, however, remains a very challenging objective and an under-developed area (see Section 5.0; Part 3 and Annex C, D, & E).

16.2 TECHNIQUES FOR PRIORITY ELICITATION

A limitation of safety climate measures is that they provide no indication of the relative priority/importance of the variables measured, i.e. although the output gives a positive or negative rating for, say, management commitment or compliance with rules, it offers no indication of which element respondents regard as the bigger risk to the organisation's future.

An array of techniques for capturing employee perspectives on priorities for risk management attention and improvement are encountered.

Functionally, these can be characterised through reference to three typologies:

1. techniques designed to achieve consensus (e.g. Delphi);
2. relative ranking of priorities (e.g. direct ranking; Q-sort; paired comparisons) and
3. subjective rating scales (high – low ratings, e.g. 1 to 5 scales).

The output from these exercises tends to be used to:

- prioritise threats, e.g. as part of the development of a risk register;
- set priorities for safety management investment, and
- set local priorities for improvement, e.g. at plant or work unit level.

The choice of technique depends upon the intent of the exercise, but important considerations relate to their respective strengths and weaknesses (Box 6).

9 Techniques are available to test inter-auditor agreement – see Duff et al, 1999.

Box 6

Widely applied priority ranking techniques

Subjective rating scales - typically taking the form of a statement against which respondents are asked to indicate their degree of agreement or magnitude of importance etc. They tend to be the most widely deployed technique, due to their intuitive simplicity, speed and ease to complete.
Attempts at combining the output from multiple scales, through addition, multiplication, e.g. probability (P) x magnitude of consequence (C), as is commonly applied in risk assessment, can produce misleading results (P5 x C1 and P1 x C5 produce a common value (5), but are materially different); attempts at weighting *risk* introducing further opacity and error.
Rating scales are also, prone to eliciting extreme (ceiling and floor) effects, i.e. respondents are prone to over use the highest or lowest value on the scale, with a strong disposition to select the highest rating when contemplating hazards that could produce catastrophic impacts. This is because people are prone to focus more on consequences than probability.

Consensus techniques - e.g. Delphi. Although widely applied to establish agreement over priorities amongst specialists and managers, a degree of caution should be exercised. Being designed to achieve consensus (routinely where this has already proved difficult, e.g. where an issue is contentious) such techniques are designed to engender social conformity. Typically, participants are asked to produce their own independent rating / ranking, followed by participation in a facilitator-led interaction (face to face or on—line) with other members in order to agree a group rating / ranking.
In situations where achieving consensus is a necessary barrier to achieve an agreed way forward they can be useful. However, in other situations the tendency to engender groupthink[10] (a shared world view) may mean that important safety critical considerations are underplayed or omitted, i.e. the process tends to suppress rather than encourage critical voices; which is in some tension with what is claimed to be a core characteristic of high reliability organisations (see Part 3).

Ranking techniques – Simple (direct) ranking: asking specialists or managers to place a set of alternative priorities in order of importance, a > b > c etc., at face value presents as simple and easy task. However, where people are asked to rank more than three or four entities (particularly where these are complex multi-faceted issues, as is often the case within the safety/risk arena) this can induce high cognitive load (i.e. participants find it difficult). Problematically, the reproducibility reliability[11] for larger item sets can be low, particularly around the mid-range (i.e. the probability of eliciting the same response twice may be low).

Consideration also needs to be given to whether the ranking task is performed alone, in groups, before any discussion of the constituent entities, or afterwards.

More sophisticated ranking techniques, such as R*epertory grid* (Kelly, 1955), *Q-sort* (Stephenson, 1935) and the method of *Paired comparisons* (Thurstone, 1927) address most of the weaknesses of direct ranking. The method of paired comparisons affords the unique advantage of providing an interval rather than an ordinal output, i.e. proportionately, how much more important one item is considered to be relative to its neighbours on a simple linear graphed representation.

Irrespective of the technique selected, the output can (and, under a wide range of circumstances, should) be significantly enhanced through gathering supplementary, qualitative evidence, aimed at eliciting the rationale of participants performing the ranking / rating task, i.e. while the ranking task can provide insight into the relative salience of the issues being considered, it is routinely also useful to gather information on their underpinning rational.

10 Groupthink - see Janis, 1972.

11 Reproducability reliability – the potential for an individual to produce the same rank order if they repeated the task

17 SETTING AN AGENDA FOR IMPROVEMENT

As in other sectors, the setting of priorities for control and improvement within the major hazards domain routinely reflects a mix of internal and externally imposed (e.g. regulator, stakeholder, structural or market-inspired) topics and issues[12]. Reflecting the principles of organisational learning, our focus is on the former. However, the following material on intervention design is equally applicable to the latter.

While establishing systems for intelligence gathering, via the development of a comprehensive set of appropriate lead and lag indicators, offers organisations the capacity to benchmark and monitor their risk management performance, any arising gain hinges upon what the organisation does (or does not do) with that learning.

It is critical to keep in mind that lead and lag indicator data only constitutes an active part of the risk management system when its output is used to inform decision making, i.e. where the information captured is put to purposive use, rather than passively monitoring performance.

As highlighted earlier within the text, functionally, lead and lag indicators are merely barometers. Their contribution to risk management rests with the:

(i) quality of data captured (suitability of measures),

(ii) quality of analysis (appropriate treatment of data), and

(iii) accuracy/appropriateness of interpretation by leaders.

Common experience is that each of the above is prone to be problematic and there is scope for enhancement within contemporary practice.

17.1 ESTABLISHING A RESILIENT CASE FOR INTERVENTION

The strength of lead and lag indicators lies in providing insight into **what**, **where, who** and **how much**. However, they afford little insight into issues of **why** and **what needs to change,** that are of core relevance to inform the thinking of intervention architects. This embodies challenges for the safety/risk management function in terms of strategy, with respect to:

(i) how best to go about gathering insight into **why** issues (e.g. engagement with employees, review of published research);

(ii) technically – identifying and designing an effective intervention(s)(reviewing published research findings; seeking advice from specialists) – also see Part 3, and

(iii) effective use of the evidence derived from (i) and (ii) to successfully convince others (senior managers / budget holders within the organisation) of the veracity of the proposed approach(s).

Deriving insight into **why** issues through interaction with managers and employees and / or their representatives affords an opportunity for workforce involvement and, in most contexts, should be relatively straightforward to achieve provided that it is conducted in a manner that encourages free exchange in the presence of sufficient mutual trust.

Having derived this insight, there needs to be the capacity (typically within the human resources / safety / risk management function) to distil the amassed evidence from lead and lag indicators, as well as **why** insights, into a format that is accessible to decision makers / fund managers in order to support a convincing case for intervention.

Having identified priorities for change, the configuration of effective interventions rests upon the capacity to review relevant human factors and management and behavioural science evidence essentially to determine **'what works',** and transform this into a deliverable format that is a good fit with prevailing, resources logistics and relationships within the organisation.

A notable challenge to discovering **what works** in this area relates to determining the robustness and reliability of the underpinning published evidence. The breadth of material can be daunting, and spans a range from

[12] A notably feature of the early 21st century is the emphasis on themed approach to health and safety regulation / improvement by the Health and Safety Executive.

rigorous robust scientific evidence (typically published in peer-reviewed journals), to unsubstantiated and potentially spurious claims within the grey-literature and some web-based sources. Material published in peer-reviewed journals is potentially more reliable, but tends to be less accessible, both in terms of obtaining copies and with respect to the concepts and terminology used - although the former is increasingly less problematic with strong drives towards open-access publication.

Guidance based upon reviews produced by bodies such as the HSE, the National Institute for Care Excellence and other government departments / agencies and third sector bodies can be useful aids to navigation in this area. However, the interpretation and application of material from some sources to the work context may require a degree of extrapolation, as the largest contribution by volume comes from outside the health and safety at work domain, from social policy and, in particular, public health contexts.

18 CONSIDERATIONS WHEN DESIGNING BEHAVIOUR CHANGE INTERVENTIONS – THE CHALLENGE OF SOCIAL ENGINEERING IN THE WORKPLACE

Beyond the traditional risk control domains of exclusion, substitution and engineering control, intervention options relate to the design of work and embody the need to engage with a potentially complex array of socio-technical and psycho-social variables; notably, technology interfaces, leadership style, systems of reward, climate and culture.

While physical solutions to behavioural issues, such as exclusion, interlocks and guarding, reflect strong alignment with engineering perspectives, it is apparent that many organisations find the task of addressing socio-technical, cultural and psychosocial issues significantly more challenging, not least because the subject matter usually lies at the periphery of many safety professionals' comfort zone. A more fundamental challenge is that the science relating to 'solutions' is relatively immature such that it is far from comprehensively mapped.

The contemplation of intervention options requires engagement with the foreseeable outcomes arising from alternative psychology theories of change. It relates to the process of options appraisal and the consideration of alternative futures and foreseeable outcomes (see Part 3). Done well, this involves reference to published findings on evaluation evidence to determine **what works** and suitable consideration of the fit with the intended intervention context.

18.1 THEORIES OF BEHAVIOUR CHANGE

The concept of 'theory of change' relates to the mechanism by which inputs impact on the behaviour of target groups and the predicted magnitude of arising effects. This needs to be rooted in the relevant underpinning science (i.e. how strong is the evidence that stimulus X will produce response Y), principally psychological and sociological insights on human motivation. Some basic principles are discussed below.

Robust published evidence will tend to have some theoretical basis, i.e. to account for the underpinning logic between inputs and outputs / effects. This is not to suggest a need to become deeply embroiled in the technicalities of social and behavioural science, merely that the selection of alternatives requires a critical perspective informed by a working appreciation of basic principles.

18.1.1 To educate or to motivate?

Errors and risk-taking can be the product of insufficient or incomplete knowledge - in essence, unintended acts - alternatively they can be the product of well-intended / appropriately motivated acts that, simply, resulted in unintended consequences.

While plugging knowledge gaps in employees' mental models of their world (Box 7), via training and education, can enhance their perception and understanding of hazards and risks, where individuals are motivated to do otherwise, new knowledge is clearly not sufficient in itself to guarantee the desired change in behaviour.

Education and training play a key role, but organisations are prone to place an over-reliance on health and safety education initiatives. As on other issues, a critical perspective is desirable, to avoid rushing to the conclusion that the undesired behaviour is the product of ignorance and that education represents effective redress.

Discovering ways to motivate individuals to behave in ways other than they would naturally has long been a panacea close to the heart of employers, and has been a central topic of inquiry within organisational psychology and industrial sociology since foundation work in the early 20th century.

Box 7

Mental models and cognitive strategies

The concept of a mental model relates to how human beings make sense of their world, with respect to relevant entities and how they interact. Particularly when faced with complexity, human beings are prone to conceptualise features of their world using simpler rules of thumb, based upon what they believe to be the most salient elements.

It is important to keep in mind that even where knowledge is substantially complete, human beings are prone to adopt non-systematic strategies for conceptualising (heuristics) their world and the phenomena that arise within it, particularly when faced with complexity and / or time penalties, i.e. we tend to have hypotheses about how our world works, and appear pre-programmed to be receptive to patterns / solutions that (we believe) we are familiar with.

Most of the time our recourse to heuristic rules of thumb serves us well (they are essential characteristic of how we process information). However, they can also be a source of fallibility, particularly where influential groups share a common, but flawed or inappropriate mental model and apply a common heuristic(s). For example, managerial understanding in the case of the Nimrod disaster. (further examples are apparent in the Columbia, Thorp, Davis Besse, Hatfield and the Heathrow incidents discussed in Part 1).

Recourse to heuristics is not a trait that can be removed or unlearned, rather it is more appropriate to institutionally take account of the fact that human beings are prone to applying rules of thumb based on what they consider to be 'the most important variables' when faced with complexity – or where time or resources are short.

Discovering what people believe about how elements of their world operate (mental models) including the mental short-cuts (heuristic rules of thumb) they may use to allow them to conceptualise and mentally manipulate what they believe to be salient variables can be illuminating. It can thus be useful to test assumptions over how employees make sense of their world and how this impacts on their decision making and behaviour in regard to any arising safety implications.

18.1.2 Direct and indirect approaches to behaviour change

A key distinction between interventions are those aimed directly at individuals, that in essence attempt to modify behaviour through altering personal orientation to an otherwise unchanged world, and those that seek to change behaviour through alterations to the context (e.g. structure, job design, systems of reward, climate culture) in which individuals operate (figure 4).

In large degree reflecting the regulatory emphasis, in the UK, the dominant tradition within the workplace safety domain has been to focus on finding ways to address situational influences on behaviour (e.g. machinery guarding / interlocks; permit to work systems; an emphasis on workplace climate to influence cultural norms). This reflects the theoretical premise that changes to the environment in which people operate will nudge desired behaviour / sponsor positive behaviour change. It is also characterisable as an extension of the traditional engineering model of risk control to behavioural elements.

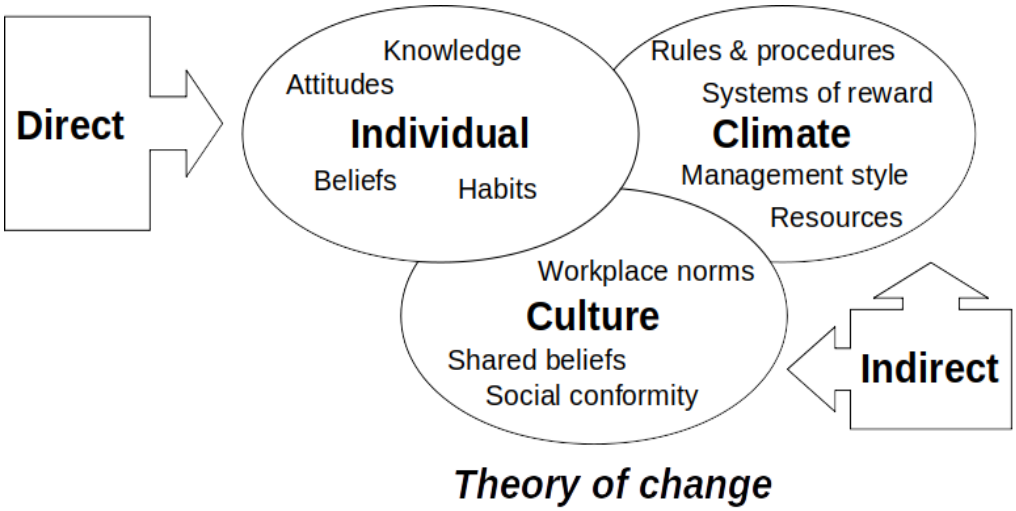


Figure 4: Direct and indirect pathways to behaviour change

This contrasts with non-workplace perspectives on behaviour change (e.g. public health and environment greening behaviour agendas) where the dominant emphasis has been on the individual as the focus for change, through finding ways to influence personal disposition in relation to risk; under most circumstances, reflecting the desire to motivate greater caution.

Note: Direct v indirect approaches - The underpinning theories of change are not just different, they are in tension with each other due to different assumptions over the basis for human behaviour, accident causation and responsibility for safety (see Annex C).

Recent years have witnessed a rise in the rate of individual focused approaches being applied in work organisations, e.g. mentoring senior managers; safety mindfulness training and stress management courses. While these can play a role, the pervading evidence is that where applied, in the absence of complementary action to address situational influences, impacts on behaviour tend to range from modest to weak (for a more detailed discussion see Annex D).

Deliberations over whether an individual or a situational focus is the more appropriate for a given behaviour change agenda can usefully be informed through consideration of the prevailing level of safety culture maturity and the related concept of hierarchy of (risk) control, i.e. a rule of thumb, applicable under a wide range of circumstances, would be to defer attention to individual elements until situational influences have been addressed.

A third perspective, that goes some way towards integrating situational and individual traditions has emerged over the last decade. Although primarily writing for a social policy audience, the concept of 'choice architecture', as articulated by Thaler and Sunstein in their influential text *Nudge* (Thaler and Sunstein, 2009), exhibits notable synergy with the concept or workplace climate. While more accurately described as a reinterpretation of established findings, rather than new science per se, these authors highlight how features within the physical, technical and social environment interact with recognised predispositions, biases and fallibilities that all human beings are prone to exhibit (see examples in Box 8).

Box 8

Examples of commonly encountered decision biases

- Under most circumstances people are averse to loss; but if faced with a certain loss are prone to become risk seeking in selecting a long odds option, e.g. the decision at Windscale to insert fire hoses to cool the reactor core despite the possibility of an explosion.

- Faced with a choice between a tried and tested solution and a new solution, people tend to select the familiar option - even where the presenting evidence that it will prove effective may be slight.

- When faced with a problem people are prone to explore hunches, rather than adopt a systematic approach, particularly where there is a belief that the issue has been encountered previously. Routinely this strategy is effective, but can lead to important issues being overlooked / under considered – to produce failure.

- The tendency to over-interpret a handful of cases of a common type as evidence of trend.

- The tendency to focus on frequencies of events of a common type, rather than rates.

- The presence of social norms and group processes engendering conformity effects.

- A preference for immediate reward rather than gains in a more distant future.

- A disposition to choose a certain (possibly) smaller reward in the near future rather than the promise larger, but less certain, reward in the future.

- Aversion to guaranteed loss (e.g. stopping production due to safety shortfalls) – relative to a cognitively more distant low probability of failure.

A central premise (and one that is at risk of over-promising within Thaler and Sunstein's account), is that the secret to socially engineering behaviour change lies in finding ways to configure the environment and options within it in ways that take account of known human decision making strategies and fallibilities, such that the desired behaviour becomes the natural default.

Thaler and Sunstein (and other authors aligned with this perspective) almost certainly overplay the ease with which positive environments (choice architectures) can be engineered, and are at risk of underplaying the extent to which extant, possibly more pervasive nudges might motivate counter behaviour. Nonetheless, their integration of cognitive insights with situational influences under the banner of decision architecture benefits from strong intuitive appeal as a means of characterising the interaction between cognitive and situational influences on behaviour.

The balance of evidence is that effect sizes (magnitude of impact) for interventions and initiatives that focus on changing individual orientation alone, within an otherwise unaltered, possibly hostile, socio-technical environment, are likely to be smaller than a more embracing approach which extends to modification of the world in which employees operate.

18.2 NOT JUST 'WHAT' AND 'HOW' - BUT 'HOW MUCH'?

A challenge common to any change agenda is identifying / developing suitable measures of impact. To be convincing, these need to be specific and mappable onto tangible, objective outcomes that arise directly from the intervention activity, i.e. in contrast to a reliance on highly chance related lag data, the focus should be on lead indicators of a type that produce a directly comparable (1:1) relationship between inputs and outputs.

It is important to keep in mind that theory of change considerations extend beyond selecting an appropriate psychology model of influence, to include evidence relating to the magnitude of change, for a defined input type and / or resource allocation. The latter is critical where the amount of change required relates to a defined quantifiable goal, e.g. a 5% year-on–year reduction in lost-time accidents, as this proportion requires the calculation (estimate - based on published evidence) of the number of individuals who would need to participate in order to be confident that the required number of individuals would change their behaviour as a result of the intervention (see Box 9).

Box 9

Magnitude of change considerations

Use of published behavioural science evidence on relative impact is important when choosing an intervention.

For example, realisation of KPI's of a 5% rise in rates of near-miss reporting, or a 10% increase in employee involvement in risk assessment, requires consideration of published evidence on foreseeable metrics of impact associated with a given intervention type/design.

For an organisation of 1000 employees this means a need to change the behaviour of 50 individuals, in the case of near miss reporting, and 100 individuals would need to become more involved in risk assessment.

Let us assume that from our review of published evidence on *'what works',* we identify two possible interventions. The near miss reporting intervention has been shown to be effective in changing the behaviour of ~4% of employee exposed to it. Similarly, the increased engagement in risk assessment has also been shown to change the behaviour of ~4% of employees.

This is important, because it allows us to calculate for the respective rates of change how many employees would need to be exposed to the respective interventions to achieve the respective targets of changing the behaviour of 50 and 100 individuals

This means that 650 individuals would need to exposed to the near-miss reporting intervention in order to be confident that 50 will change their behaviour in the desired way and, given that there are only 1,000 employees in the organisation, (an unattainable) 1300 to the risk assessment intervention.

Performing this type of calculation can inform decisions over whether an intervention idea should be pursed or abandoned. For the above examples, our choice of *near-miss intervention* presents as potentially viable, whereas the *involvement in risk assessment intervention* indicates that either an alternative technique that can be predicted to deliver higher rates of impact should be sought, or the improvement target should be revised.

Notice – when considering evidence on *what works* in intervention selection, it is essential that to go beyond what <u>can</u> work to take account of evidence on metrics of predicted impact, i.e. <u>how much?</u>

18.3 SUCCESSFUL INTERVENTION DESIGN – REQUIRES MORE THAN SILVER-BULLETS

It is important to keep in mind that Interventions can fail due to:

- Conceptual deficiencies - ill-conceived / inappropriate theory of change (Section 5.1.2 and Annex C, D & E).
- Propagation deficiencies - the scale of activity was insufficient to generate the metrics of change required to achieve defined goals, such as key performance objectives (see Box 9).

However, as highlighted in section 21, they can also fail, or be significantly blunted, by counter influences, e.g.:

- incident or near-miss reporting inhibited due to an underlying culture of blame;
- logistical barriers, e.g. insufficient capacity within the safety function for timely response to hazard reports;
- compliance with rules undermined by shortage of resources;
- line managers preoccupied realising more pressing objectives, and
- cultural components, such as micro-political rivalries, competing agendas and more.

For the above, and similar, reasons it is important to consider the logic of how an intervention will operate, i.e. what are the structures, mechanisms, processes and relationships that need to be in place to support its delivery? (For modelled examples see Part 3.)

Note: By analogy, in intervention design terms it is perhaps useful to think that the ***theory of change*** relates to the quest for a silver bullet(s) (informed by published evidence on *what works*); and the ***intervention logic***. as the mechanism for firing the bullet

18.4 INTERVENTION LOGIC MODELLING

In addition to grappling with the science underpinning theories of change, intervention designers need to consider how they will deliver their change initiatives, i.e. logistically, what elements need to be in place in order to deliver the intervention.

Potentially relevant elements include (but are not necessarily limited to):

- resources;
- defining staff roles and responsibilities, and
- recognising and mitigating barriers (e.g. structural, logistical, relational / tribal, counter motivating influences).

Routinely, this involves discovering ways to influence not just the behaviour of target group(s) that the behaviour change intervention is aimed at, but also the behaviour of those responsible for facilitating the intervention (potentially extending to staff who might constitute an obstacle to the roll-out), e.g. health and safety professionals, line managers, and supervisors (see Box 10 and Part 3).

Note: Compared with theory of change elements, to date, the social science evidence base has made a very modest contribution to the related science of delivery and making *it* happen.

Reflecting the central feature of a mature safety culture, effective delivery design requires an inward facing, self-critical, evidence informed perspective, in which the principles of risk assessment (the risk of intervention failure) are applied, i.e. focused on what could go wrong, rather than a best-case scenario.

Box 10

Systems dynamics modelling of intervention logic

A key strength of the system dynamics modelling technique detailed in Part 3 rests with its potential for:

- virtual trialling of alternative intervention designs - to inform options appraisal decisions;
- offering the facility for intervention architects to hone their chosen design, through testing the logic of envisaged pathways to change, including detecting unforeseen barriers, perverse motivations and other unwanted effects that might threaten the realisation of intervention objectives.

Effective intervention tends to be a cyclical and iterative activity, rather than a linear process. Therefore, careful thought should be given to designing-in feedback loops (qualitative and / or quantitative) to test that assumptions about how change will occur present as valid (i.e. theory of change - also see Part 3) and that defined intermediate delivery objectives, (e.g. how much change by when) are being met. Where issues that threaten the success of the intervention are detected, the intervention may need to be revised and refocused; possibly even, abandoned (see Box 11).

Many, if not most, interventions exhibit weakness in this area. They tend to be under-managed, and under evidenced with respect to the achievement of intermediate objectives. Leaving evaluation to the end of the process (which may be months or years after its inception) risks failing to become aware that it is not having the desired effect until it is too late to redress the situation. It is important to avoid discovering, at the end of your 12-month intervention that it stopped being effective in month two because, for example, line managers would not release their staff to take part. Such eventualities are not only wasteful of resources, with potential negative implications for the safety of individuals and integrity of systems, but can also inflict reputational damage upon safety professionals and the safety function.

For this reason, it is important to devise and map a set of sufficient (qualitative and quantitative) measures that provide feedback on progress, related to a set of defined KPIs.

Thus, an evidence informed approach to intervention purposely gathers data referenced to a set of defined intermediate delivery objectives / milestones.

Doing this is important to provide early-warning in the event that interventions that fail to germinate, drift off course, get overtaken by events, or otherwise flounder etc., such that they absorb resources to no useful purpose (see Box 12).

Box 11

Performance managed interventions (also see Part 3)

Most health and safety interventions are under-evidenced, particularly in the area of feedback on roll-out / delivery effectiveness.

As with incident data, a reliance upon headline impacts (e.g. rates of behaviour change) alone constitutes a high risk strategy, if the architects are unsighted regarding precursors to failure.

Designing feedback loops, e.g. qualitative evidence from participating stakeholders, with the capacity to support early recognition of barriers and other problems increases the opportunity to take ameliorative action.

Effective intervention is more commonly an iterative cyclical process than a linear process
.

Potential points of failure in the roll-out/delivery process are multiple, not least because almost all large scale interventions bring with them the need for some degree of organisational change, e.g. new procedures, new responsibilities, changes in relationships with others, the cessation of established (possibly highly culturally valued) working practices, and similar.

Box 12

Common reasons why interventions fail

The range of reasons why workplace health and safety interventions can fail is extensive, but includes:

- insufficient resource,
- structural barriers,
- (lack of) cultural readiness for change, possibly extending to active managerial / employee resistance,
- fundamental flaws in understanding of systems / the organisation of work,
- insufficient understanding of social relationships and
- incomplete models of exposure to harm

(Whysall et al, 2006, Nazaruk, 2010)

Note: Organisational change - it is prudent to assume that attempts at significant organisational change are likely to be subject to inertia, possibly extending to overt resistance from affected staff, at least in the initial period following attempts at their introduction.

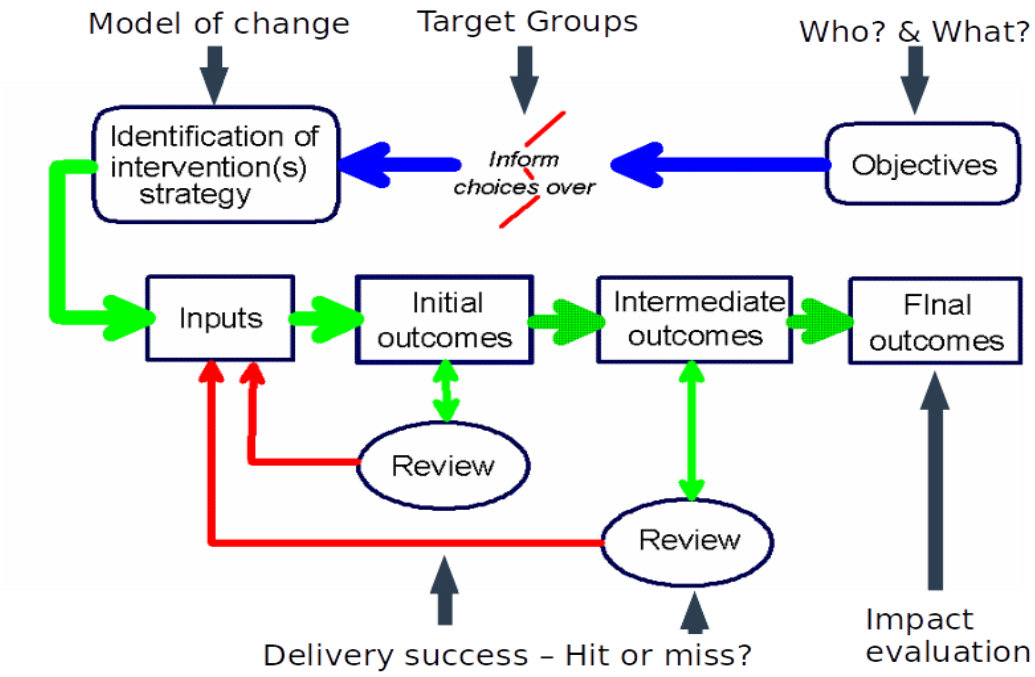


Figure 5: The intervention cycle

Effective performance managed interventions routinely involve the gathering of a mix of quantitative and qualitative evidence to capture progress towards defined milestones, with active use of this feedback to

refocus or reconfigure the intervention where necessary (refer to figure 5). Thus, evaluation should to be an integral component of the delivery cycle, rather than a summative adjunct to the process.

> **Note:** Notice that the intervention cycle depicted in figure 5 commences with consideration of the required magnitude of the change objectives, i.e. how many individuals does the intervention need to make contact with AND critically, based on published evidence, what proportion of this denominator can we predict will make lasting changes to their behaviour as a result – see Box 9.

The relative paucity of published evidence and guidance on successful intervention roll-out means that organisations are, to a significant degree, left to find their own way and learn their own lessons. Arguably, this increases the need for effective delivery monitoring. However, common experience is that most organisations exhibit significant weakness in this area. All too often, the approach to intervention is characterisable as one of 'hit and hope', rather than evidence informed.

Attempting to conduct an intervention, in the absence of a well-configured plan for monitoring delivery performance and progress towards defined objectives, not only risks interventions stalling, drifting off course, or even having counterproductive results, it leaves their architects (typically human resources and occupational health and safety professionals) vulnerable to detractors, to the extent that this may threaten future resource allocations.

Where possible, monitoring objectives should be defined in terms of outcomes - typically, frequency of a given behaviour, or other behaviour-related (antecedent), i.e. auditable end-points - that map onto the planned pathway to delivering risk reduction measures. For example, borrowing from the HSE's management standard for workplace stress (https://www.hse.gov.uk/stress/standards/), the delivery pathway might relate to the proportion of employees who have completed the baseline stress audit questionnaire; the proportion of line managers who have engaged with staff over the causes of job-stress; the proportion of departments that have implemented job-design changes; their impact on staff job-stress ratings, etc. Similarly, with respect to initiatives designed to increase rates of employee involvement in reviewing risk assessments - the proportion of work units that have recruited employee representatives; the number of assessment reviews that employee representatives have been involved in, the nature of any changes to working practices as a result, etc.- while remaining mindful of the scope for eliciting spurious reporting.

As alluded to in the preceding paragraph, it is important to keep in mind that options for measurement extend beyond rates of behaviour change in the target group itself; other stakeholders typically play a role along the path to achieving change. Monitoring change in these permissioning actors/agencies can provide valuable feedback on intervention progress, ideally referenced to defined time-bounded milestones.

Conceptually, intervention performance monitoring measures are lead indicators, insofar as they relate to precursors to failure and provide feedback on success in achieving time bounded milestones. However, they do not need to be exclusively quantitative. Qualitative evidence can be particularly useful in this area, e.g. interviews, focus groups and workshops involving key delivery stakeholders. These can provide essential feedback, particularly with regard to identifying barriers and how they night be redressed. While monitoring evidence is a key part of the intervention delivery process, it is important that it is proportionate, and that sight is not lost of its primary purpose - to provide learning that enhances intervention resilience.

19 CONCLUSIONS TO PART 2

An evidence-based, prevention orientated approach to managing behavioural, cultural and socio-technical elements in complex systems has strong intuitive appeal as a more informed strategic approach to workplace risk management, with potential operational and business benefits. However, the challenge of realising the added-value for occupation safety and health professionals and their employers is significant and multidimensional.

The core challenge relates to maximising learning from past and current performance and using the derived intelligence to design effective initiatives and interventions, with the potential to redress identified weaknesses and, thereby, enhance resilience.

This means the adoption of good practice in gathering and interpreting the data captured from lag and lead indicators, i.e. the capacity to identify trends and root causes in incident data within the host organisation; learning from relevant events in other organisations, complemented by a suite of lead indicator indices, e.g. workforce safety climate surveys and behaviour-related audits. Having defined an agenda for change, this also means having the capacity to review published findings on ‘what works’, and apply these insights to the design and delivery of effective interventions.

When attempting to engage with issues of safety climate / culture that embody socio-technical elements where humans interact with engineered systems, human factors, and broader behavioural and social science insights are of central relevance.

The challenge, with respect to behaviour change intervention design and delivery for organisations and safety professionals, is twofold. On the one hand, it requires the capacity to adopt a critical perspective to navigating through what might be unfamiliar academic and practitioner publication accounts of 'what works'. On the other is the need to grapple with the logistics of successful intervention design and delivery; a topic on which relativity little has been written.

For safety professionals, the challenge extends beyond mastery of relevant technical elements. It is compounded by the need to convince others of, firstly, the need for intervention and, secondly, of the relative merits of alternative intervention options. Aside from technical shortfalls, many workplace interventions fail, simply because their protagonists are unsuccessful in gaining sufficient support at a senior level. The effective use of data and evidence embodies the potential to strengthen the case for support.

Failure in this area can constitute a source of significant frustration but, more insidiously, can lead to the safety function retreating to narrower, less fundamental safety agendas, with the associated risk of trivialisation and marginalising of the health and safety function. It is important that safety and risk-management professionals possess sufficient competence in evidence gathering, analysis synthesis and intervention design to convince others of the value of their contribution.

PART 3

SYSTEM DYNAMICS MODELLING

20 INTRODUCTION TO PART 3

Part 1 outlined the results of a study of twelve important events within a variety of process safety industries and identified the common organisational and cultural lessons that emerged. This concluded with the articulation of an extensive set of 'organisational expectations' which form good practice and, if met, might reduce the risk of significant unwanted events.

Part 2 looked in more detail at the underlying aspects of organisational learning and the design of associated direct and indirect behavioural change interventions. Many interventions fail because their proponents are unable to gather sufficient evidence and successfully articulate the reasons why they believe that they will indeed result in improvement. Crucially, the design of such interventions requires a holistic perspective and engaging with emerging psychosocial and behavioural issues. A lack of capability to do so can result in the attraction towards simple, piecemeal, technocratic or superficial quick fixes.

Part 3 argues that the problematic situation is compounded by the way in which process safety successes and failures are modelled. It outlines the case for alternative approaches that better facilitate the identification of the underlying issues mentioned in the previous chapters at a systemic level. Specifically, it suggests causal loop diagrams (CLDs) as a participatory tool that can be used to identify issues and crucially to design and explore interventions in a way that seeks to explicitly understand the interacting issues relating to the failure to meet organisational expectations. The final sections outline the theory of CLDs, how they can be useful in this context and how they can be created by those working in process safety. Case study applications are described, and the pros and cons evaluated.

One key strength of CLDs is their ability to make implicit assumptions about causal processes visible in such a way as they can be easily critiqued and improved. The models presented here are intended to give an insight into the process of creating CLDs and their potential uses. As such the reader is invited to reflect upon the pathways of cause and effect they represent and consider how they might improve them.

Reflecting on practice in light of the previously identified 'expectations' in Part 1 may naturally lead to the need for change within an organisation. This change exists in the context of complex, interactive processes and behavioural factors. An approach is required that avoids 'quick fixes', and which allows for systemic corrective actions and meaningful performance indicators to be developed. Through the following sections, Part 3 demonstrates CLDs as a more effective way of implementing change than traditional approaches.

21 HOW WE MODEL ORGANISATIONAL AND PROCESS SAFETY FAILURES

Models and tools for analysing the causality of events have developed considerably over the last fifty years. The theoretical developments can be summarised by separating the approaches into three distinct groups: **sequential**, **epidemiological** and **systemic** (Erik Hollnagel and Goteman 2004; Qureshi 2007).

The earliest simple, **sequential** models conceived of events as occurring through linear, sequential chains of cause-and-effect, often focusing on discrete effects, technical and human failures, and direct chronological influences. Examples include fault tree analysis and failure modes and effects analysis (FMEA). These approaches tend to work well for simple, mechanical systems. They may be described as 'systematic' in the sense that they are methodical, but they aren't 'systemic' in the sense required by systems theory as they do not attempt to model complex interactions that may exist within a system. A HAZOP is systematic. It rigorously decomposes a complex system into its component parts/nodes in order to study them in detail. However, it can overlook interactions between nodes. Deviating from design intent within a specific node may, for example, be tolerable, but this might have severe consequences for other dependent nodes. Such propagation through the system is often overlooked (Baybutt, 2015).

Epidemiological models looked more closely at the role of human behaviour, likening the causality of these failures to the spread of a disease. They place a greater focus on latent errors, removed in time and space from the final event. These latent errors can create a situation where the system is prone to failure. A tipping point or trigger event pushes the system over the edge. Normal accident theory (Perrow 1984), Swiss-cheese model (Reason 1997) and man-made disasters theory (B. A. Turner 1978; B. Turner and Pidgeon 1997) conform to this type. In most cases the application of these theories still takes a linear, sequential, event-driven view of causality.

The final, contemporary group are grounded in **systemic** theory and control. They attempt to combine the human, technical and organisational factors focusing more on the interactions of the system, the functions it performs and variations in its behaviour, rather than discrete events. Models developed from this view are less widely used in practice. They include acci-mapping (Rasmussen, 1997), functional resonance accident model (Hollnagel and Goteman, 2004, Hollnagel et al., 2008) and the systems theoretic accident model and process (Leveson et al., 2002, Leveson et al., 2003a, Leveson et al., 2003b, Leveson, 2004).

The way in which process safety failure events are conceptualised - whether formalised in failure investigation and risk management techniques or tacit in the heads of those within the organisation - shape the conclusions about the underlying causes of such unwanted events. A discrete, linear model of process failures will uncover discrete causes and lead to discrete, isolated fixes. This has been identified in practice as the phenomena of what-you-look-for-is-what-you-find and what-you-find-is-what-you-fix (Erik Hollnagel 2008; Lundberg, Rollenhagen, and Hollnagel 2009).

The approach used to proactively or reactively conceptualise and manage the risk of adverse events shapes the sorts of interventions and actions taken.

21.1 WHY DO WE NEED DIFFERENT APPROACHES?

The dominant sequential and epidemiological approaches (henceforth referred to as the 'current' methods), while powerful in some contexts and undeniably useful, have several known shortcomings. This section summarises these and argues for the complementary use of more systemic approaches.

The current methods are reductionist (Rasmussen 1997). Decomposing complex issues and systems into separate elements or a sequence of events, errors, malfunctions or failures in isolated components can lead to a view of significant unwanted events that exist at the system level as somehow being simple, easily remedied problems. The simplification can aid the initial understanding of the facts of the event, but these

isolated facts do not necessarily reflect the complexity of the causes in the real world. Human factors, for example, should not be treated as separate from the reliability of physical components; instead a model is required that looks at the interactions of these elements. Decomposition can result in losing the understanding of the global behaviour of the system (Le Coze, 2005). It has been postulated that safety and risk are emergent properties at the system level (Woods and Cook, 2002; Dekker, 2006). The concept of a component being safe or reliable, especially a human being, has little meaning out of the specific context within which it sits or is being discussed. A component may be safe in isolation or in a certain system, but unsafe in another (Leveson, 2004) therefore it must be considered in terms of its interactions and purpose.

The current methods are based on sequential chains of causality, ignoring feedback (Leveson, 2004). The use of sequential chains is a specific type of reductionist decomposition. It still plays an important role in organising data, but as with the reduction to components, it produces a simplistic view of causality, inefficient for modern complex systems (Hollnagel, 2002; Hollnagel and Goteman, 2004) that overlooks the theoretical advances, particularly in the complexity of human error (Reason, 1997, Reason, 1990). Leveson (2011) summarised some of the ways in which event chains could be problematic:

- They do not cover non-linear interactions distant in time and space.
- They do not cover situations where no component explicitly failed.
- They do not go far enough in time to capture slow migrations or drift.
- They do not adequately cope with human decision making and associated mistakes.

Sequential, event-chain based models are also challenging because they force the idea of an initiating root cause. The assignment of the root cause is often arbitrary as the stopping rules are subjective and it is always possible to find some deeper cause (Kletz, 1994, Leveson, 2004). The frame of reference or paradigm of those conducting the investigation can influence the identification of a root cause, with a tendency to stop when information becomes harder to find, when a familiar cause is identified, or when a cause with a known cure is found (Rasmussen et al., 1990). If the system drifts for structural reasons towards vulnerability and the boundary of safe operation, then the identification of a root cause may not solve the problem (Rasmussen, 1997, p190).

This influence of sequential chains has been called ‘root cause seduction’ (Carroll, 1995, Carroll, 1998). It makes the organisational learning process less effective by encouraging limited isolated fixes.

Sequential models are said to encourage ‘individual blame logic’ (Catino, 2008) countering the documented benefits of ‘just’ or ‘blame free’ operation as highlighted in safety culture expectation 9 (SC9) in Part 1 (Section 5).

The sequential reductionism of the currently used tools fail to model or even acknowledge the role of feedback despite it being something particularly important in complex industrial processes and organisational systems (Dien et al. (2004, p151). In the nine-steps for moving forward from error (Woods and Cook, 2002) it was suggested that it was possible to ‘tame complexity through new forms of feedback’, but this relies on understanding the feedback in the underlying structure of the system.

Current methods do not address complexity and coupling (Hollnagel, 2008). Figure shows an assessment by Hollnagel (2008) of the current tools in the context of a revised version of Perrow’s (1984) complexity/coupling matrix. The revised model, Figure 6a, renames the horizontal axis from complexity to manageability. Figure 6b then summarises the assessment of the tools and the types of systems they were designed for. Root cause analysis (RCA) and the human performance enhancement system, the accident evolution and barrier function (AEB) are identified as designed and suitable for loosely coupled, manageable systems in the bottom, left quadrant. The ‘Swiss cheese’ model is to the upper left quadrant, suitable for mildly coupled and manageable systems such as marine transport and railways.

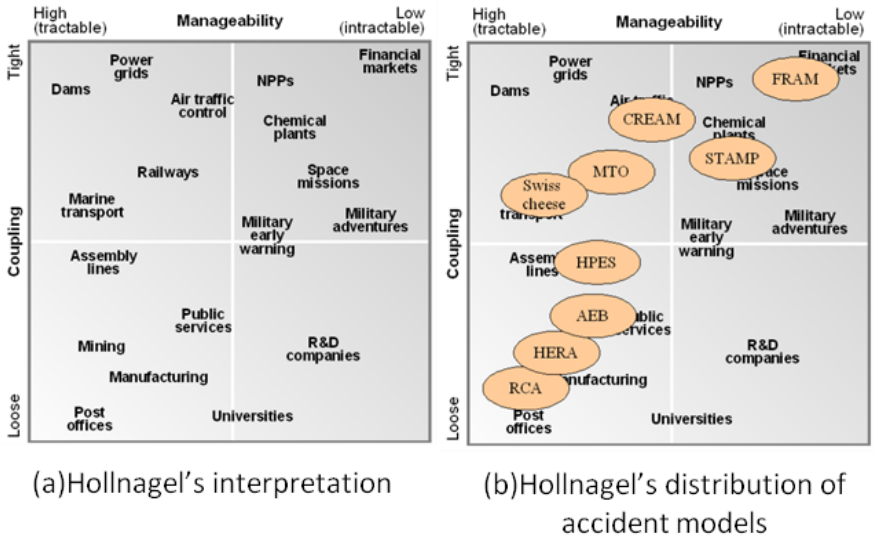


Figure 6a and 6b - Hollnagel's Distribution of Accident Models (Hollnagel, 2008)

In the upper right quadrant, suited to the complexity and coupling of nuclear power plants, are the newer tools of cognitive reliability error analysis method (CREAM), functional resonance analysis method (FRAM) and systems-theoretic accident model and processes (STAMP).

The current methods are non-contextual and focus on the local level (Reiman and Oedewald, 2007). They do not take into account wider factors, such as shifting values (Leveson, 2004). Similarly, the changing political and economic landscape can create a culture that rewards short term financial goals (Svedung and Rasmussen, 2002) which filters down to the operational level, influencing the drift towards vulnerability. Efforts to improve system safety based on models of local features are often negated by people adapting in unexpected ways (Rasmussen, 1997) as a result of 'more distant' influences.

The current methods only produce prescriptive reactions (Sterman, 2001, p11). That is to say they tend to result in the creation of new procedures or ways of working that are mandated to prevent the exact same event/issue from recurring. This is not always enough when dealing with complex systems (Doytchev and Hibberd, 2009). Prescriptive solutions make the system more rigid and constrain variability. While this can solve some problems, the ability to adapt can also solve others. The new paradigm encourages the development of systems that can adapt to unforeseen events within the given boundaries. Achieving this requires approaches that illuminate the underlying structures in the system.

The reason for these prescriptive actions stems from the current tools not going far enough to expose or explain the reasons for the observed behaviours (ESReDA Accident Investigation Working Group, 2009). Senge (1990) suggests that there are multiple levels of explanation in a system, all correct in their own way (see figure 7). Importantly though, each level of the hierarchy is a product of the level below. Patterns of behaviour result in the occurrence of discrete events (both desirable and undesirable), but these patterns of behaviour are in turn formed by the systemic structures. These structures could take the form of physical or digital process systems, or in an organisational sense they could be formally documented procedures, rules, guidelines or standards. These are intended to produce patterns of behaviour in people in order to produce certain outcomes or events. Focussing purely at the level of events (in isolation or in combination) means ignoring the longer-term patterns of behaviour that have created them. If the patterns of behaviour are overlooked it could lead to a conclusion that the events are unpredictable and therefore each simply needs to be reacted to once it has happened. Focussing on the patterns of behaviour which produce these events leads to the identification of trends, resulting in more understanding responsive approaches and the potential to identify leading indicators for a system drifting to a state of increased risk. Hence focussing on this level facilitates an approach based more on the anticipation of unwanted events. Most approaches exist at these two levels without giving due attention to what generated those patterns of behaviour in the first place.

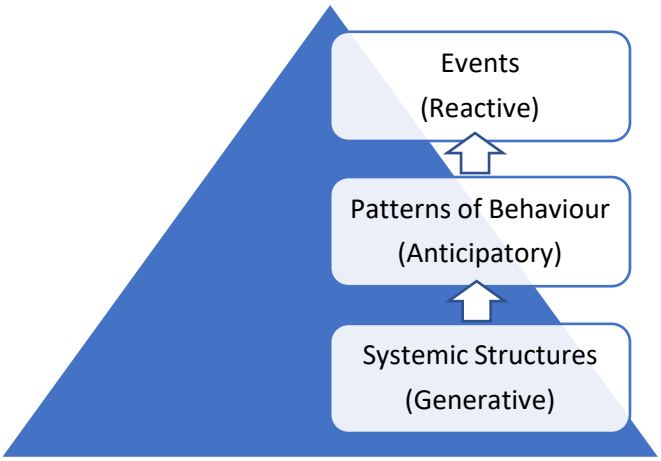


Figure 7 - Events emerge from behaviours that emerge from systemic structures (Senge, 1990 p52)

To summarise, there is a tendency to see things as a set of discrete events, a world-view reinforced by tools based on linear, reductionist models of cause and effect. This can lead to a reactive approach to problems that results in continual fire-fighting. These discrete events are just snapshots of a continuum of dynamic change forming patterns of behaviour over time. Understanding these patterns and trends allows a more anticipatory approach, planning for likely changes. But these patterns of behaviour are themselves produced by systemic structures. By understanding these generative structures, it is possible to design interventions that fundamentally alter them, and therefore change the patterns of behaviours and probability of unwanted discrete events.

Common tools and methods reinforce a way of thinking that makes it hard to analyse the role played by underlying systemic structures. CLDs provide a means to address some of these shortfalls in a way that is relatively easy to learn and apply.

22 CAUSAL LOOP DIAGRAMS

22.1 WHAT ARE CAUSAL LOOP DIAGRAMS?

CLDs provide a useful way of exposing, capturing and discussing the underlying complex structures of causality, facilitating the development of ways to change them or work with them to improve the safety and resilience of the system. They can be created in a similar interdisciplinary team-based way to conducting a HAZOP. They are different, in the sense that they are systemic, but are fundamentally complementary to one another's strengths and weaknesses as discussed in section 21.1.

CLDs have their origins in a modelling approach called system dynamics, created by Jay Forrester at Massachusetts Institute of Technology in the late 1950s (Forrester 1958, 1961). CLDs are visual representations of the influence between the variables involved in a particular system or problem situation.

Variables that influence one another are linked with arrows, labelled to indicate the nature of the relationship. In the language of CLDs there are just two different types of arrow.

Figure 8 shows two variables, A and B, along with the first type of arrow. The arrow indicates that A has some influence over B. The '+' label on the arrow signifies that a change in variable A will cause a similar change in variable B. That means if variable A increases it will cause an increase in variable B. Similarly, if variable A decreases it will cause a decrease in variable B.

The relationship need not be linear. A small decrease in A may cause a large decrease in B. In fact, this type of diagram does not indicate the quantitative nature of the relationship. In Figure 8 there is no arrow from B to A which suggests a change in B has no influence over the value of A.

The type of relationship from A to B shown in Figure 8 is referred to as a positive relationship, but it is important to note that the '+' does not mean variable B will always increase. It can go up or down depending on how A changes. It doesn't mean 'positive' in the sense that it is 'good' either. The relationship may be undesirable or produce unwanted outcomes.

Figure 8 - Positive Causal Relationship

Figure shows a simple example of this type of relationship. As the amount of sunshine increases it causes ice cream sales to increase. If the amount of sunshine decreased, it would cause ice cream sales to decrease.

Figure 9 - Example of a Positive Causal Relationship

In Figure the variables A and B are linked by an arrow from A to B labelled with a '-' sign. This indicates that an increase in variable A would cause a decrease in variable B. Similarly, were variable A to decrease it would cause variable B to increase. Again, the diagram does not tell us about the scale of the change caused and it is important to remember that both A and B can go up and down. The '-' symbol does not mean B always decreases, it just means B changes in the opposite or inverse direction to any change in A.

Figure 10 - Inverse Causal Relationship

Figure shows a simple example of this type of relationship. As traffic congestion increases it causes a decrease in air quality.

Figure 11 - Example of an inverse causal relationship

Multiple variables can be connected using these two types of causal connection to produce complex networks of influence. Crucially they can form **feedback loops**.

Figure is based on an example by John Sterman (2000). It shows a CLD comprised of three variables: the quantity of eggs, the population of chickens and the number of road crossings. There are three positive causal connections and one inverse causal connection. The combination of these three variables and four connections produces two feedback loops.

On the left-hand side, labelled with an R, is a **reinforcing feedback loop**.

An increase in eggs causes an increase in chickens and an increase in chickens causes an increase in eggs, reinforcing the initial change.

This loop could also be read in the opposite direction whereby a decrease in chickens would cause a decrease in eggs that would in turn reinforce the initial decrease in chickens. All things being equal, if some external force caused one of these variables to change then the change would be reinforced.

If one variable begins to decline the variables would decline to zero, if one variable were to increase, they would both increase exponentially (though of course in reality other factors would have an effect).

The combination of causal connections on the right-hand side causes a **balancing feedback loop** (labelled with a B).

The diagram shows that an increase in chickens causes an increase in road crossings, this in turn causes a decrease in chickens. Hence the initiating change in the chicken population is counteracted or balanced.

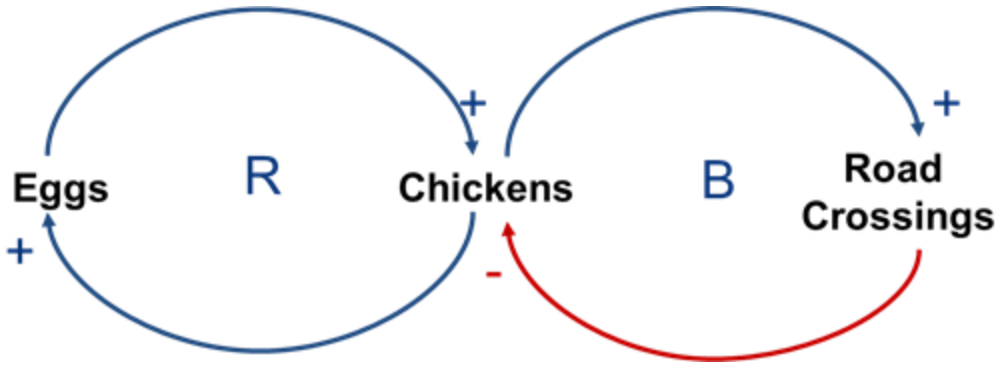


Figure 12 - Reinforcing and balancing feedback loops

There is one more important thing to know about CLDs. The time between a cause and the resulting effect can be very important. As such, it is useful to indicate on the diagrams where a **delay** is thought to exist. Normally, this is done by drawing two lines cutting across the arrow linking the variables.

For example, to make it clear that an increase in the number of chickens does not immediately result in an increase in the number of eggs, it takes a little while for the effect to occur, the two lines perpendicular to the arrow from chickens to eggs is added as shown in Figure . Similarly, there is a delay between a change in the number of eggs and the change in the number of chickens it causes.

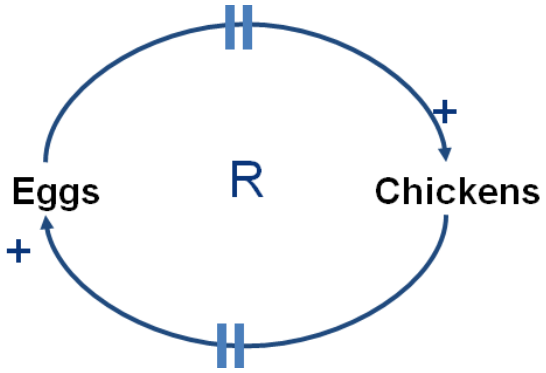


Figure 13 - Delays between cause and effect

Delays can be very important. Imagine trying to get a shower to the correct temperature when there is a delay between the changing the dial (the cause) and the water arriving at a different temperature (the effect). Increase the temperature dial, and if nothing happens immediately increase it some more... soon the water is too hot! Decrease the temperature dial quickly to compensate...soon the water is too cold! Even in a simple situation delays between cause and effect can cause oscillation around the desired outcome.

It is easy to overlook feedback loops or underestimate the effects they can have. There is a tendency to construct a clean narrative chain where a single cause produces a single effect like a row of dominos. Reality is often messier.

Complex behaviours can emerge from the interaction of a small number of variables. Consider, for example the structure of a double pendulum, comprised of a weight at the end of a jointed armature. The structure itself is simple, but the trajectory traced by the weight can be complex and seemingly unpredictable.

Feedback loops are all around us in natural systems and man-made ones. Explicitly identifying them can have many benefits.

22.2 How are causal loop diagrams useful?

While they do not provide a solution on their own, CLDs present several advantages that complement the previously mentioned challenges of traditional approaches.

CLDs illuminate underlying causal feedback structures. While common approaches largely focus on linear chains of cause and effect, CLDs are explicitly concerned with the formation of feedback loops between variables.

CLDs can be constructed collaboratively. While this is also true of many traditional tools it is nonetheless an important feature of CLDs. In a truly complex system, it is unlikely that any single actor or group will have a full and comprehensive understanding of the system in question, and even less likely they will individually have insight into all of the available data. Hence approaches such as HAZOPs are designed to be undertaken by diverse groups with multiple viewpoints. There is a large community of practice developing co-production, participatory methods for constructing CLDs, albeit beyond the domain of process safety.

CLDs visually represent otherwise tacit assumptions about causality. Again, while not necessarily different from some of the existing approaches, it is important to recognise that CLDs are constructed and

explored graphically using just two different types of arrow. Whether built as a group or developed in isolation by an individual and then shared with a group, they facilitate discussion and debate about the nature of causality within a system. This helps to address some criticism that current approaches are not conducive to effective organisational learning. Traditional methods can lead to conclusions about what needs to change, but are not always useful in communicating to others why those changes are necessary. CLDs provide so-called 'white box modelling' where the internal logic leading to the conclusions is clear.

CLDs can be quantified and simulated. Though this can be difficult and resource intensive, it is possible to use CLDs to run simulations of a system of interest. This can lead to the identification of feedback related effects that are otherwise difficult for humans to recognise. It also allows for potential intervention strategies to be tested before implementation in the real world.

CLDs allow for the identification of common systemic issues. Part 1 outlined the strikingly similar precursors and underlying factors that contributed to the events studied. As they seemingly reoccur time and time again in different industries each of these common factors, such as lack of contractor oversight or the development of an operation fragmented into silos, could be considered as a form of safety archetype - in other words, a typical factor in the causation of unwanted events. Similar archetypal entities have been shown to exist at lower levels of the hierarchy shown in Figure 7 in the form of frequently occurring generative systemic structures. These 'systems archetypes' are common structures, formed of feedback loops, that have been found to exist in many contexts as an underlying cause of failure. Despite their frequent occurrence, these systemic structures go largely overlooked.

These five features are key to CLD's ability to facilitate and promote the design of more effective interventions, corrective actions and other changes, as well as the identification of meaningful performance indicators.

The Fifth Discipline (Peter. M Senge, 1990) identifies several such system archetypes, for example the 'fixes that fail' archetype. Imagine our system of interest is facing a problem that can be measured quantitatively and is seen to vary up and down. Hence, we can treat the 'amount' of the problem faced as a variable in a CLD. A suggested fix to that problem also exists, and similarly it can be treated as a variable in a CLD. The more the problem occurs (or the worse it gets), the more its corresponding fix is used, as represented by the positive arrow in Figure 14. The fix causes the problem to reduce as represented by the negative arrow in Figure 14. This arrow also means that if the amount of fix is reduced the problem increases. Thus, a simple balancing loop is established.

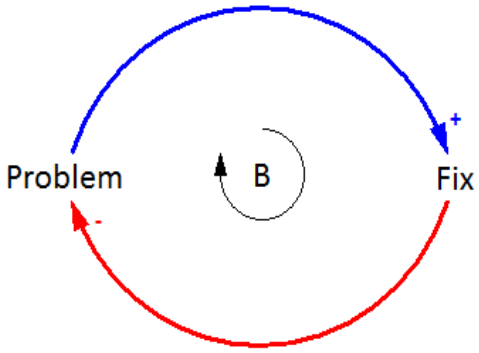


Figure 14 - A problem and a fix balancing loop

However, sometimes - and perhaps not immediately - the fix being implemented can cause unintended consequences. This might be unimportant, but it might create a whole new problem, or it could even cause the very problem we are trying to be fix to increase/get worse.

If it is the latter, then a reinforcing feedback loop is created as shown in Figure . This works to counteract the attempt to fix the problem. If the unintended consequences are severe it might even make the problem worse than before any fix was attempted. Hence, we have a fix that has failed. This can occur when we treat a chaotic or complex situation as if cause and effect only exists as a simple chain of events without feedback.

In such situations it might be necessary to modify the fix so that it doesn't produce the unintended consequences, implement something new to reduce the impact of the unintended consequences, or maybe try an entirely different fix.

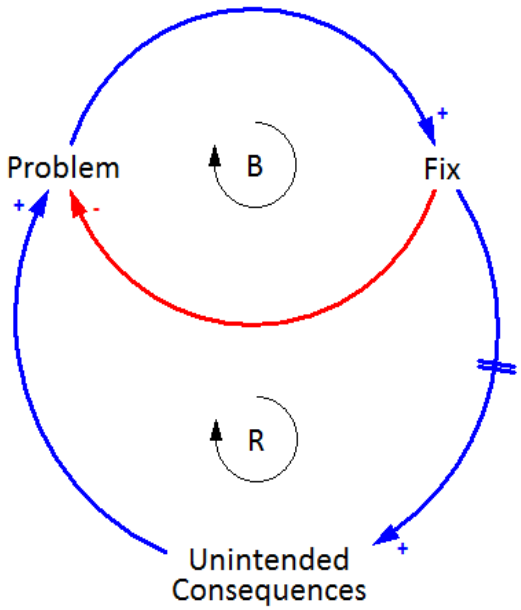


Figure 15 -The 'fixes that fail' archetype

Figure 16 shows an example of this archetype in practice. A company experiencing an unproductive workforce tries to fix the problem by increasing aspirational targets as an incentive. This works in the short term but trying to hit the targets has the unintended consequences of increasing sickness and stress within the workforce, ultimately decreasing productivity. An aggressive focus on targets may be at the expense of other important matters (as discussed in previous chapters and expanded upon in a subsequent section) and by following this the model could be expanded though the addition of variables. This archetypal structure is deliberately kept simple in order to highlight a particular key mechanism.

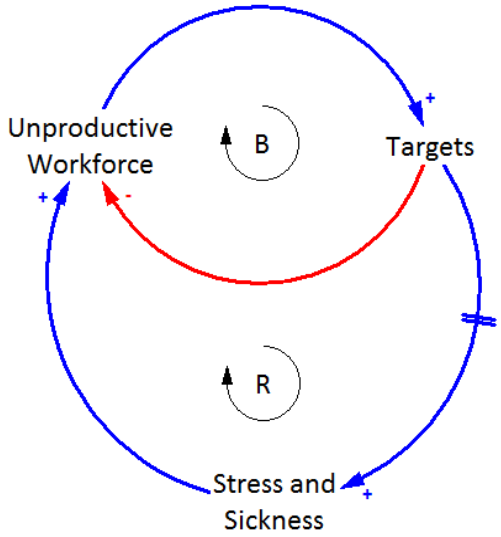


Figure 16 - An example of the 'Fixes that Fail' System Archetype

Employing CLDs to consider process safety facilitates the identification of such generic problematic structures of causality. Senge identified eight of these generative archetypes, using CLDs, in the context of organisational learning (P. M. Senge, 1994):

1. Limits to growth.

2. Shifting the burden.
3. Eroding goals.
4. Escalation.
5. Success to the successful.
6. Tragedy of the commons.
7. Fixes that fail.
8. Growth and under investment.

Senge's concept of archetypes has been extended to look at organisational safety archetypes (Marais, Saleh, and Leveson 2006). These archetypes fall into two categories: challenges of maintaining safety and, side effects and symptomatic responses:

Challenges of maintaining safety:

- Stagnant safety practices in the face of technological advances;
- Decreasing safety consciousness;
- Eroding safety goals, and
- Complacency.

Side effects and symptomatic responses:

- Unintended side-effects of safety fixes;
- Fixing symptoms rather than root causes, and
- The vicious cycle of bureaucracy.

Additional archetypal structures have been identified from the analysis of events described in Part 1, some of which are explored in the subsequent sections of this chapter. These generic structures offer a way to understand common structures that produce vulnerability and unwanted events, and a means to communicate this through the organisational learning process. The following sections looks at the way in which these models can be built using investigation teams, as is the case with the current tools.

Finally, once identified, **CLDs provide a means to design and test corrective actions to remove or counteract their outcomes**.

CLDs provide a means to collaboratively identify, construct, communicate and remedy potentially archetypal underlying structures of feedback that result in emergent unwanted events or conditions.

22.3 HOW ARE CAUSAL LOOP DIAGRAMS CREATED?

This section provides a process through which CLDs can be constructed. There are essentially two ways in which a CLD can be created:

1. by an individual/team with expertise in the modelling approach based on written documents (including transcribed interviews), and
2. co-created with those involved in the situation of interest with facilitation by an individual or team with expertise in the modelling approach – known as group model building (GMB).

These two approaches could be applied to historic situations, ongoing investigations or as routine processes. In all cases the general process is similar as extensively outlined in texts such as *Business dynamics* (Sterman, 2000) and *Strategic modelling and business dynamics* (Morecroft, 2007) among others. The generic process will be outlined via the following examples.

22.3.1 Method #1 - Constructing CLDs from historical texts

We can begin to construct a model by analysing existing documents. For example, the paragraph below is from the earlier 'reporting and learning' section in section 10 of this report:

> 'There should then be sufficient competent resource to ensure that the learning which emerges is distilled and communicated in an intelligible, prioritised and relevant way to those where it will be of value. If this is not achieved there is a danger that because material is not directly relevant, 'overload' of information may occur and recipients may not recognise and act on findings which are relevant to their activities.'

A chain of cause and effect can be inferred from this text, but the first step requires the identification of suitable variables that will form the building blocks of our model. '**Competent resources to distil learning'** is a quantifiable variable pertaining to the organisation in question. Some interpretation is required as to how best to name this variable as there needs to be an indication of what specific resources are being discussed. The sentence also states there is a point at which it is sufficient and by implication, a value at which these resources are insufficient. This variable has a causal influence on the **'relevance of learning material'**. This variable could implicitly include intelligibility of learning material, prioritisation of learning material, communication of learning material, or these could be included as separate variables in their own right. If we were to represent this relationship using the syntax of a CLD it would look like Figure 17. A blue arrow with a '+' symbol at the head shows how an increase in **Competent resources to distil learning** causes an increase in the **relevance of learning material**. This Figure equally shows that were the **competent resources to distil learning** to decrease, it would cause the **relevance of learning material** to also decrease.

Figure 17 - Competent resources and learning material fragment

The next sentence starts with 'if this is not achieved' implying a further causal relationship. The next variable might be '**overload of Information**' and from the sentence we can construct a causal relationship with the '**relevance of learning material'** using the CLD syntax (Figure 18). The red arrow with a '-' sign at the head attempts to show that as the '**relevance of learning material**' increases it causes the '**overload of information'** to decrease. Again, this could equally be read to represent the scenario where a decrease in the **'relevance of learning material'** causes an increase in the **'overload of information'.**

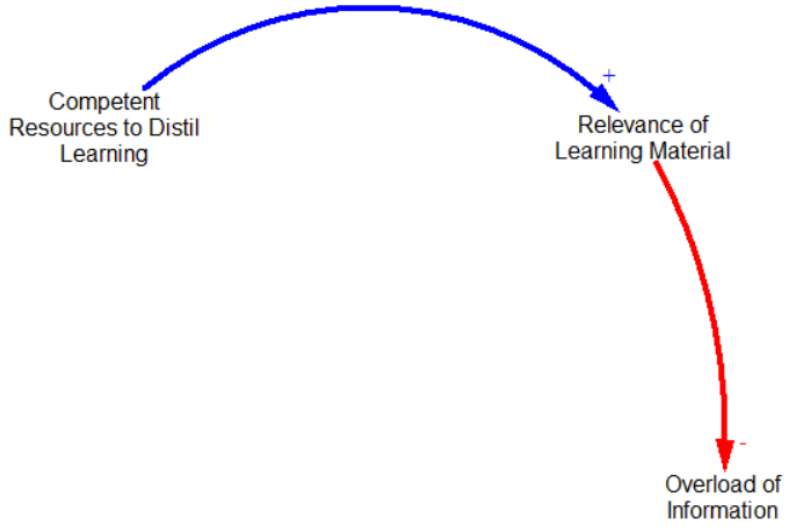


Figure 18 - Relevance of learning material and overload of information fragment

At this point it might be of value for those involved in the system under discussion to reflect on whether the model sufficiently captures the underlying system of causality or whether additional variables are required to clarify. There is a lot implied in the red arrow at present, and while this helps to keep the model simple, it might benefit from additional variables to explicitly show what is thought to be occurring. Alternatively, while 'relevance of learning material' emerges neatly from the text it might help the clarity of the model to flip the variable on its head and call it '**quantity of irrelevant learning material'**. The model would then look as shown in Figure 19, with the arrows flipped to match the variable change. This arguably becomes more intuitive while maintaining the essence of the extracted quote.

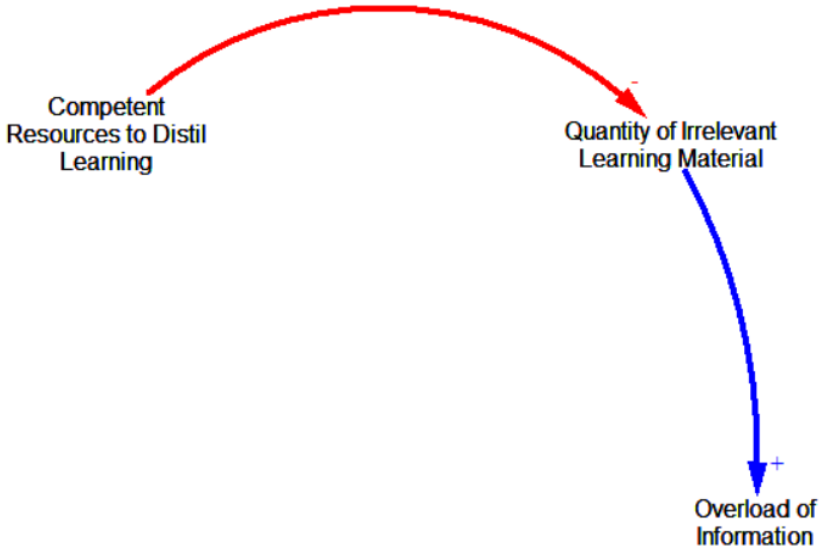


Figure 19 - Alternative variable naming

There is one final clause in the above paragraph relating to recognising and acting on the findings. For the sake of this example the variable name will be kept aligned with the original text, though as above some interpretation might result in a more intuitive model. The variable '**ability to recognise need to enact change**' is added to the model and the model builder reflects on how this is causally influenced by an '**overload of information**'. This gives rise to the third arrow shown in Figure 20.

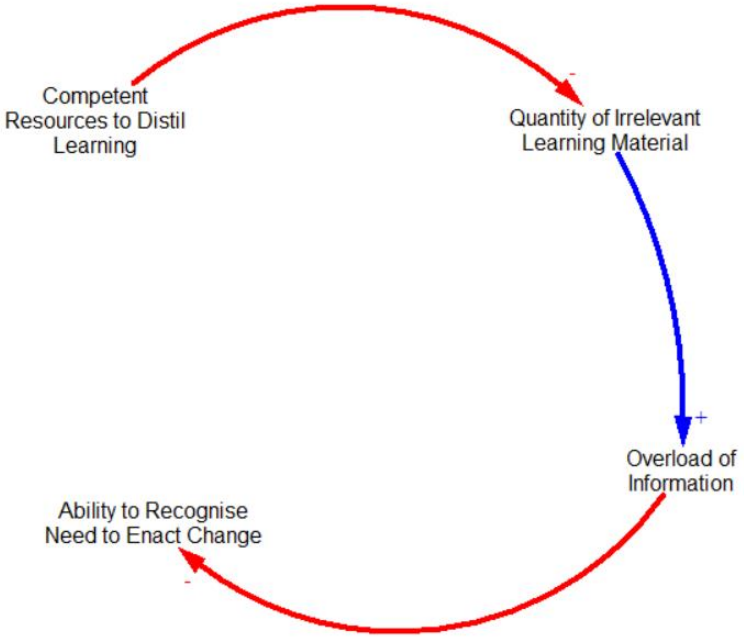


Figure 20 - Ability to enact change fragment

The visual layout of the model is starting to imply a feedback loop, but this is somewhat artificial. With the information available on the extracted paragraph these variables could have just as easily be set out in a straight line. There is nothing in the text to suggest the '**ability to recognise and need to enact change**' has any influence on the amount of '**competent resources to distil learning'**. It might take the addition of many more variables before any feedback loops begin to emerge. Though, of course, this could equally prompt a dialogue around whether or not there is a causal influence that would close this loop. Over time, would a reduction in an organisation's collective ability to recognise the need to enact change have any impact on its competent resources available to appropriately distil learning material?

22.3.2 Method #2 Group Model Building (GMB)

Historically, system dynamics models and CLDs have been applied in a consultant/client dynamic (Forrester, 2007) where a specialist consultant in system dynamics/CLDs would be employed by a client organisation to construct the model on their behalf. This can hinder successful intervention design as those not involved in constructing the models may not believe or trust them (Lane, 1992). Partially in response to this there has been increasing focus over the past 20 years on GMB, or in other words involving everyone directly in the modelling process rather than relying on an external specialist.

GMB has emerged as a methodology for not only gathering data from people, but capturing their experience and subjective interpretations of the causality present in the system (Vennix et al., 1992, Vennix, 1995, Vennix, 1999). It allows for the integration of a wider selection of stakeholders with different backgrounds and perspectives. Groups are more likely to question one another, and although there is a risk of 'group think' (see Part 1), GMB is more likely to be wider reaching than modelling performed by an individual. GMB also makes the participants discuss their otherwise implicit assumptions regarding causality (Vennix, 1999), and it has been shown that groups are better at filtering out false information compared to individuals (Shaw, 1932 cited in, Richardson et al., 1989).

Several different approaches to GMB have been developed within the field of systems dynamics, ranging in formality. Some advocate presenting a group with a prebuilt model and allowing them to discuss and refine it; others recommend collaboratively constructing models step-by-step (Richardson et al., 1989).

The first stage in the process, eliciting information, can be achieved using documented sources or knowledgeable people (who may be members of the model building group). This stage can cause problems for groups, who have a tendency to elicit less information than individuals (Richardson et al., 1989). A hybrid solution is therefore preferable whereby individuals are encouraged to work independently at times in this stage before feeding back to the group. This is referred to in GMB literature as an example of 'divergent

thinking' (Andersen and Richardson, 1997 p5). This is followed by a convergent thinking process in which the group collectively analyse the output of the divergent tasks to discuss assumptions, filter false information and group common suggestions.

A review of published GMB experiences found most implementations of this approach involved groups with 5 – 12 participants spending between 12 and 25 hours (Rouwette et al., 2002). There was also considerable variation over the size of the models (from 6 variables to over 1000 variables) and no consensus as to an optimum size.

According to the experience of Richardson et al. (1992), there are five key roles required for effective GMB:

1. The facilitator – elicits knowledge, constructs model;
2. The content coach – analyses the model, draws out assumptions, clarifies;
3. The process coach – manages the dynamics of the group;
4. The recorder – makes notes to expose the thought processes of the group, and
5. The gatekeeper – organises and manages the model building project.

The roles do not necessarily need to be conducted by five separate people. The facilitator needs to be a chairperson promoting the sharing of alternative views as well as a specialist in system dynamics/CLD construction. Arguably they should be more concerned with the process than the content (Vennix, 1999). As a result, they will often be the person controlling the software or drawing the models.

22.4 HOW CAN CAUSAL LOOP DIAGRAMS BE USED FOR PROCESS SAFETY?

This section outlines three example case studies of CLDs based on the previous sections. The first uses a combination of historical documents and GMB. The following case studies highlight some of the advantages of the CLD tool such as their ability to make visual and explicit otherwise tacit assumptions about causality, the collaborative processes through which they are created and their focus on the feedback loops formed between causal factors. They will also illustrate some causal structures that potentially underpin the common issues underlying process safety events described in the previous sections.

The application of CLDs is by no means limited to the approaches or issues described in these case studies. The case studies look at elements of oversight and scrutiny, incentives and indicators and, contractors and supply chain management. Other themes which may benefit from such an approach include initiative overload, over complexity and bureaucracy, management of major organisational change, staffing reductions in vital support functions, and insidious decline in capability.

22.4.1 Case Study #1 – Safety culture and oversight

Part 1 introduced important issues around the themes of safety culture, oversight and scrutiny, the business environment and communications that had seemingly contributed to many diverse events. This case study outlines the use of CLDs in the context of both understanding a specific event and the complexity and value of the emergent expectations reported earlier. The model described here is one of several constructed by 8 people in a one-day workshop. Six of those present had no prior experience with CLDs, two performed the role of facilitator and content coach.

The process began with the participants, having read the historical reports into the event, identifying the variables they believed to be influential in the degradation of safety at the facility in question and therefore the evolution of the incident.

Participants were instructed to not limit their suggestions to variables they knew were measured by the industry, or even those they knew how to theoretically measure. Participants were encouraged to work in a 'divergent mode', thinking as broadly and creatively as possible, noting as many potential variables as they could on post-it notes. These were then discussed collectively and developed into a refined set.

Table 12 gives an indication of this process by showing some of the original variables in the left-hand column and the final variables used after discussion in the middle column. The right-hand column provides some additional information. This selection of variables helped to define the initial boundary of the analysis.

Table 12 Original participant suggestions

Original participant suggestions	Modified	Notes
Workforce (i.e. size of, number of)	Workforce	The quantifiable total number of people employed by the organisation in question.
Resources (people)		
Sufficient resources (people and budget)		
Operator knowledge	SQEPs	The quantifiable subset of the workforce who are 'suitably qualified and experienced' (SQEP) for the task under investigation.
Right people		
Experienced staff		
Capability (skills/knowledge)		
Competence – training of operators		
Process change control	Compliance	It is important to notice that 'procedural adherence' was grouped as an initial suggestion under the heading of 'compliance' This is important because 'adherence to procedures as written' was used as a variable in one of the models.
Procedural adherence		
Reviewing operational procedures		
Qualification checks		
Conformance to procedures		
Safety case procedures compliance		
Safety information	Safety culture	'Safety', 'safety information' and 'safe operation' are not strictly encapsulated by the term 'safety culture' though they may be a product of it or contributor to it. It was felt that the degree of 'safety culture' was an important measurable stock and therefore quantitatively at least was a more tangible term than 'safe operation' etc.
Safety culture		
Safety		
Safe operation		

Following discussions between the workshop participants a set of 'policy variables' were identified. These are variables which affect the system of interest, but which arise from outside its control. For example, the business environment, and the relevant industry regulator were all perceived to control variables that would impact upon the system of interest. For example:

- Frequency of orders – The number of times in a given period that the organisation in question was contracted to produce a product.
- Commercial pressure – The impact of competitors on the organisation in question which in this instance was quantified on a dimensionless scale from 0 to 100.
- Regulatory oversight - This was conceived as the number of visits or inspections to the production facility owned by the organisation in question in a given period. This could be an external or internal regulatory function. Indeed, in the event in question, both played a role, but each has different requirements which may or may not be important.

The first two of the variables above in particular highlight that, despite being discussed here as illustrative of issues relating to oversight and scrutiny, these were far from the only or even the most significant factors in the actual causation of the event in question.

Additional variables emerged during the modelling process. Three separate models were constructed, though they shared a common set of variables. When combined they produced the rather complex model shown in Figure 21.

Figure 21 - A caveat: Despite the initial sense of confusion the following image might produce, it is in fact possible to extract key elements from this which the subsequent sections attempt to articulate. The reader need not dwell on this model or attempt to understand it at this stage, it is presented for completeness. To not present this model would be to imply an artificial degree of neatness which only arises at a later stage in the process. It is important to acknowledge that any extracted or simplified diagram is still in reality part of a much more complex whole. Simplifying before understanding the full extent of the complexity is to be avoided, hence the inclusion here.

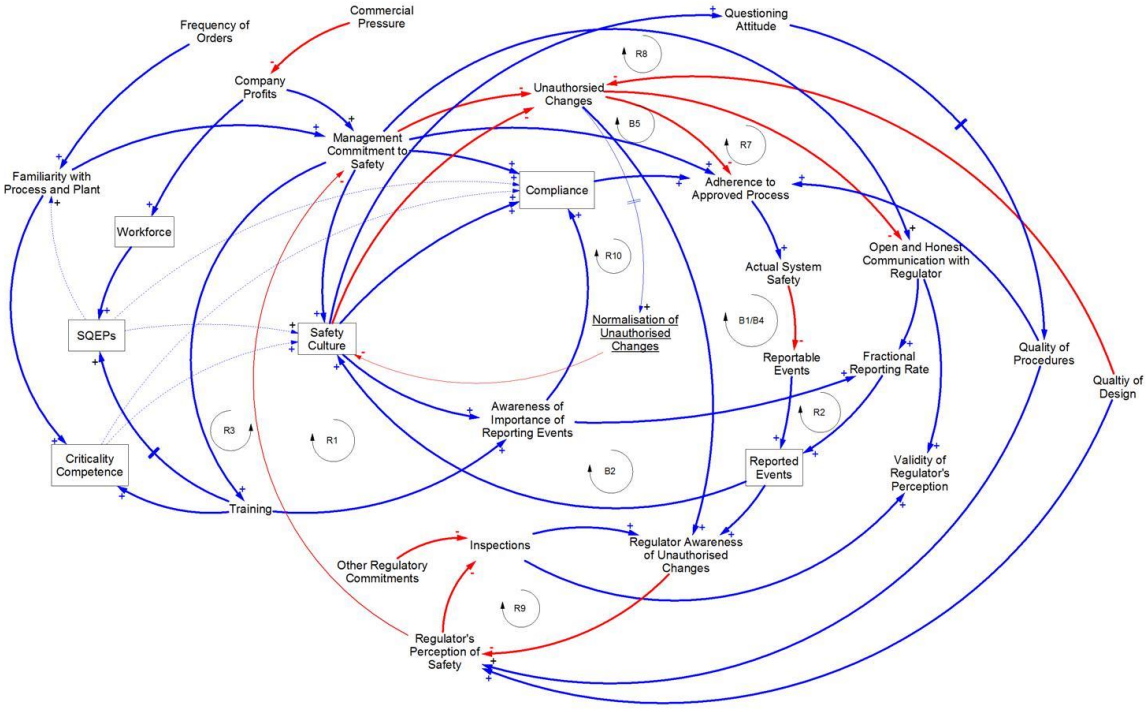


Figure 21 - Complete model from group model building workshop

This collective model was refined and used as the basis to extract a series of simpler models showing selections of feedback processes that were thought to be influential in the development of the event. One such extracted model aims to capture the following issue: **The regulator (which in principle could be a regulatory function internal to the operating company or an external government regulator) held a perception of the safety of the process system that may have been significantly influenced by the**

number of event reports coming from the organisation. Both parties' assumptions and mental models may not match the reality, as fewer event reports did not necessarily mean increased safety. The process, as those in the workshop felt the organisation in question and the regulatory function perceived it to be, is shown in Figure . In this Figure the arrows are numbered as this provides an opportunity to explore in more detail how to read or interpret a CLD.

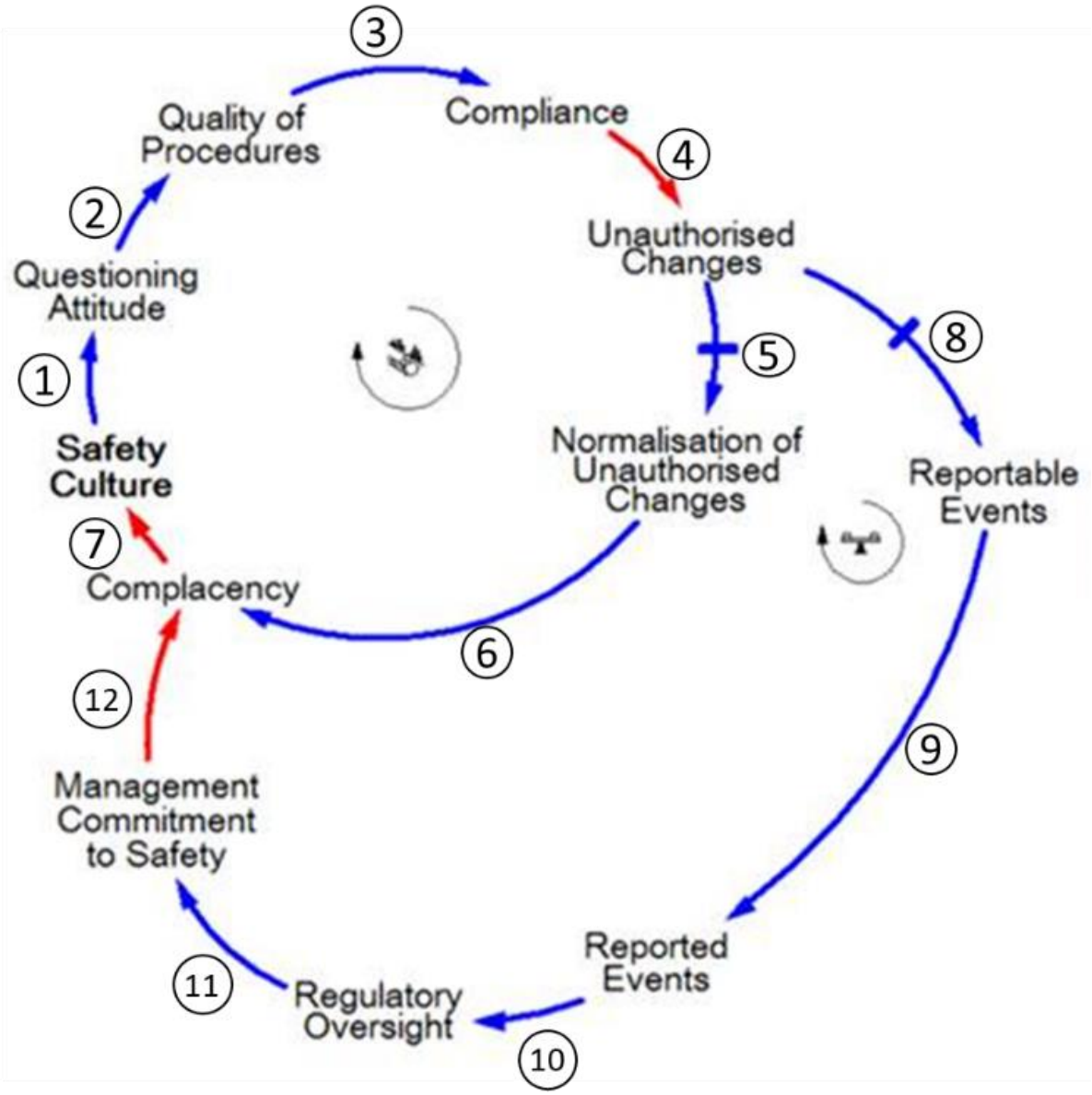


Figure 22 - Simplified 'mental model' CLD

The model features two feedback loops: a reinforcing loop at the top labelled with an image of a snowball rolling down a hill, and a balancing loop at the bottom labelled with an image of balanced scales/see-saw. A model like this can be 'read' in several different ways. An initial narrative can be formed by selecting a variable and tracing the consequences through the model. It does not matter which variable is chosen or how it is changed, the model is capable of representing any situation.

In Figure 22, numbers have been added to each arrow to help illustrate a potential narrative. It begins by seeing what would happen if '**safety culture**' within the organisation were to change. If it were to decrease, the model suggests through arrow (1) that it would cause the level of 'questioning attitude' within the organisation to also decrease. The model does not tell us the scale with which it would decrease (deteriorate).

This decrease in '**questioning attitude'** may cause the '**quality of procedures**' to decrease, presumably as a result of poor-quality procedures no longer being as frequently questioned and improved. The model does not tell us the time frame over which this change may happen. This connection between safety culture, questioning attitude and the quality of procedures relates to SC13 in Part 1, Section 5.

As the '**quality of procedures**' decreases, arrow (3) suggests this would result in '**compliance**' decreasing (linked to SC16).

Arrow (4) is the first inverse causal relationship encountered. As '**compliance**' decreases it would cause the number of '**unauthorised changes**' to increase (alongside other potential issues such as such as inappropriate operational waivers, SMS2 (Section 8), or other causal non-compliance factors). This is arguably tautological, and it would certainly be possible to simplify the model by including '**compliance**' or '**unauthorised changes**'. However, the group involved in constructing this model decided to include both to maintain clarity within the model.

Arrow (5) is the first causal link to explicitly include a delay, indicated by the two lines through the arrow. This suggests that as the number of '**unauthorised changes**' increases, it causes the '**normalisation of unauthorised changes**' to increase over a longer time frame than the other changes in the model. In other words, the more unauthorised changes that occur, the more the workforce considers such activity as a normal part of operations. As this increases it would cause '**complacency**' to also increase (arrow 6) which would in turn cause the level of '**safety culture**' to decrease (arrow 7).

Hence a reinforcing loop is formed whereby any decrease in safety culture results in a series of consequences that ultimately causes safety culture to decrease even further. Were safety culture to increase (improve) it would similarly reinforce this change, setting into action a series of changes through the feedback loop that would cause safety culture to further increase.

At this point it is worth briefly returning to the idea of a delay mark and what this may illustrate about the pros and cons of CLDs. Firstly, it is perfectly reasonable to make the case for delays on other arrows. Procedures can take a long time to change, so the influence of a questioning attitude on this may well be worthy of a delay mark. This highlights something often presented as a strength of such models. Figure 22 represents the output and beliefs of a particular group of people. Their assumptions and thoughts are explicitly visualised in the CLD facilitating such critiques as the placement of arrows and delay marks. Secondly, as a draw-back of the approach, the standard syntax of CLDs only allows for a delay or no delay to be indicated, there is no simple way of visually depicting a variable delay or delays of different lengths in the same model.

In describing the model above, the narrative began by imaging an initial change in safety culture but this need not be the initiating change. Some external factor not shown in Figure 22 could result in the quality of procedures improving, and the effects of this could be traced through the model as above. Or some external factor could cause complacency to increase and so on.

Starting again at '**safety culture**' we can trace the effects of the second feedback loop. If it were to decrease then the results would propagate through arrows (1) to (4) as above resulting in the number of '**unauthorised changes**' increasing. Arrow (8) implies that this rise in '**unauthorised changes**' would cause an increase in the number of '**reportable events**' as an unauthorised change is, in this regulatory set-up, reportable to the regulator. Naturally this would in turn result in an increase in the number of '**reported events**' (arrow 9). As the regulator received more of these event reports it would cause '**regulatory oversight**' to increase as shown by arrow (10). Again, this could be conceived as internal or external regulatory scrutiny, though each would have different reporting requirements and different legal consequences. Arrow (11) then suggests that this scrutiny from the regulator may in turn cause the '**management commitment to safety**' within the facility to increase. The increased '**management commitment to safety**' would act to drive down '**complacency**' which would in turn cause '**safety culture**' to improve (see L12 in section 4.1). Thus, this outer feedback loop counteracts the initial change. It is a balancing loop. It depicts the mechanism by which the regulator puts right declining standards within the organisations they oversee.

Figure shows the situation as it was perceived to exist by the regulator and the company being regulated. It was their shared mental model (see Box 7) and a situation from which they may well have drawn comfort. Should standards slip there was believed to be a process through which it would be put right.

However, the reality is closer to Figure with an additional variable, the '**fraction of events reported**'. As unauthorised changes and innovations to the approved processes become normalised, the fraction of events that get reported goes down. This sets up a second reinforcing loop. As presented, the models do not provide any insight into which of the two competing feedback loops will be most influential. It might be that the balancing loop is still capable of alerting the regulator to the declining safety. Alternatively, the second feedback loop could mean that the regulator is not alerted and the management themselves essentially become complacent based on an erroneous belief that the regulator would have intervened had standards slipped too far. There may be a feeling that the initial risk-laden non-compliance decision has 'paid off' without the potential negative consequences occurring and a sense of 'getting away with it' as it has gone unnoticed. With this, production can become an increasingly high priority to the detriment of process safety.

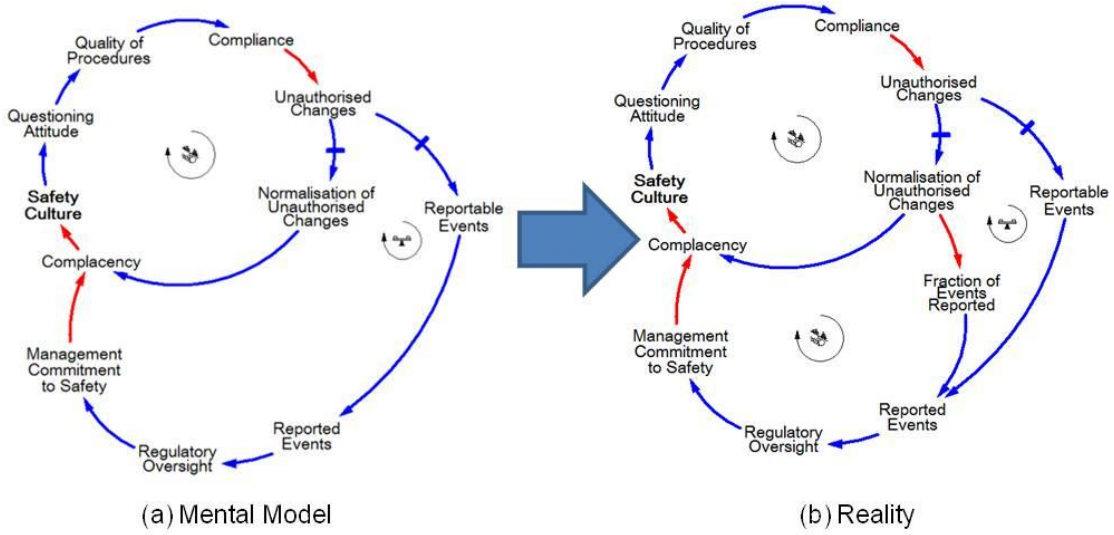


Figure 23a and 23b - Mental model versus reality

This reflects issues postulated within the 'incubation period' of man-made disasters (Turner and Pidgeon, 1997, p73) and provides a structural account of how the system (especially the relationship with the regulator) allowed or encouraged these changes. This also has similarities to the 'erosion of safety' archetype (Marais et al., 2006), the drift in safety consciousness identified in the Columbia accident (Dulac et al., 2005, Leveson et al., 2006), and even (in structure but not in meaning) the 'flirting with disaster' model identified from Salge and Milling's (2006) Chernobyl investigation.

This simple model also helps contextualise some of the expectations outlined in Part 1. For example, section 13.2.1 discusses the importance of 'auditing and more holistic scrutiny' rather than just relying on passive reporting methods:

> 'A further important role is to challenge the view that confidence in continued good performance is justified by past success. Thus those carrying out O&S should remain alert to evidence of 'organisational drift' and should ensure that business and corporate leaders are helped to maintain awareness of the 'reality' of how operations are being carried out and the associated organisation and culture. This should be made apparent even when there may be real or perceived pressure to conform to the accepted view.
>
> For some events studied, it was found that organisations had become insular and did not properly consider industry good practice and the findings from previous relevant events. This can indicate a weak safety culture. Those carrying out O&S should thus have the competence to identify and respond to deficiencies in safety culture and to ensure that learning opportunities are being taken.'

22.4.2 Case Study #2 – Incentives and indicators

The previous two Parts described the need for a combination of lagging and leading indicators, noting strengths and weaknesses. Data around significant events can, for example, be based on data sets too small to show any meaningful statistical trends. Data concerning smaller scale events or near-misses might be more plentiful, but is also more susceptible to reporting bias and perceptions over the apportion of blame (and may also have no causal relationship to the occurrence of significant events).

Method 1 was used to create the CLD shown in Figure 24. The model features 11 variables forming 7 feedback loops. The key variable, shown on the right-hand-side, is the '**risk of unwanted events**'. Naturally, the desire is to minimise this variable. The model depicts a scenario where two financial incentives are used to help achieve this. These are highlighted in black boxes. At the top right is a variable representing a '**financial reward for achieving good performance in period**'. In other words, this is something of economic worth (e.g. end of year bonus, a prize, raffle entry, charity donation, etc.) awarded if the organisation does not experience any (or below a threshold) unwanted events in the given period of data collection (e.g. financial year, calendar year, month, operating period, etc.).

The total amount given would, in this instance be influenced by the number of '**logged non-compliance events**' in the same period. These represent a lagging indicator as it is only possible to gather this data once an event has occurred. An increase in the '**logged non-compliance events**' causes the '**financial reward for achieving good performance in period**' to decrease. So, in this model it is a sliding scale. The fewer events recorded in a period, the higher the reward. It is of course important to acknowledge that the bonus is only based on reported events, not the actual number of events (which may or may not be different). As set out in this model, those administering the bonus, and presumably those in charge of the system, do not have sufficient oversight to know the true number of events. They rely entirely on what is reported to them. Rewards such as these need to be carefully formulated (see 4.2.5).

The intended effect of this bonus is shown by **reinforcing loop 2**. The offer of a bonus causes '**safe behaviours**' to increase which in turn causes the 'risk of unwanted events' to decrease and therefore the '**logged non-compliance events**' to also decrease. There is a question over whether such a crude bonus will have this affect on '**safe behaviours**' (hence the dashed line) and whether it will sufficiently counter any '**disincentives**'.

Linked to this is a potential unintended side-effect illustrated by **balancing loop B1**. An increase in the baseline '**financial reward for achieving good performance in period**' would cause a decrease in the '**incentive to report events**'. If an event occurs and it is reported then the associated bonus for avoiding such events will be reduced.

Expectation SC5 in Section 5 stated: 'Where possible, measurable criteria including proactive (leading) indicators should be in place to assess safety culture performance. These should be carefully formulated to reduce any unintended 'knock on' effects and to minimise misuse to meet targets. Where initiatives are taken to improve safety culture, these should be prioritised and coordinated to avoid initiative overload.'

To counter B1, a second financial incentive is introduced for more proactive engagement, i.e. a '**financial reward for logging events or concerns**' shown on the left of the Figure. Balancing loop B1 is therefore counteracted through **reinforcing loop R1**. The '**financial reward for logging events or concerns**' increases the '**incentive to report events**' which in turn causes the '**logged non-compliance events**' to increase should they occur. The two incentives would have to be carefully calibrated to achieve this.

'**Financial reward for logging events or concerns**' also incentivises '**risk register entries**' (a form of leading indicator). Through **reinforcing loop R3**, the more concerns raised the larger the financial reward. The logic behind this presumably being that it gives those with an oversight role richer information about the state of the system. This provides a challenge in calibrating the reward to counter balancing loop B1. An increase in '**risk register entries**' would cause an increase in '**meaningful corrective actions**' which in turn reduces the '**risk of unwanted events**'. This forms **balancing loop B2**, reducing risk through better information but again producing a counter point to the incentive as the safer the system the fewer events that will be logged. Again, this could be carefully calibrated with the other financial reward mechanism.

There are two more potential side-effects captured in this model. **Balancing loop B3** highlights a situation where the amount of data raised in the risk register as a result of the incentive becomes too much for the available resources to meaningfully handle. The '**ability to address each entry**' decreases as the number of entries rise. **Balancing loop B4** depicts a situation whereby an increase in the financial incentive causes the '**quality of risk register entries**' to decline. This can create a form of data 'noise' making it hard to distinguish or resource meaningful action.

This model highlights some of the benefits and uses of CLDs. As indicated in case study #1, the CLD has made some tacit assumptions about these causal processes visible in such a way as they can be easily critiqued and improved. It may very well be the case that someone reading this model would profoundly disagree with a causal connection or feedback mechanism depicted. The model makes it easy to identify such influences which may otherwise remain hidden from discussion. This also shows the benefit it can have on communicating the reasons for corrective action. Any changes to the system to address the side-effects shown could be justified with reference to the model. The model could be used to explain the need for change and the reason behind specific interventions.

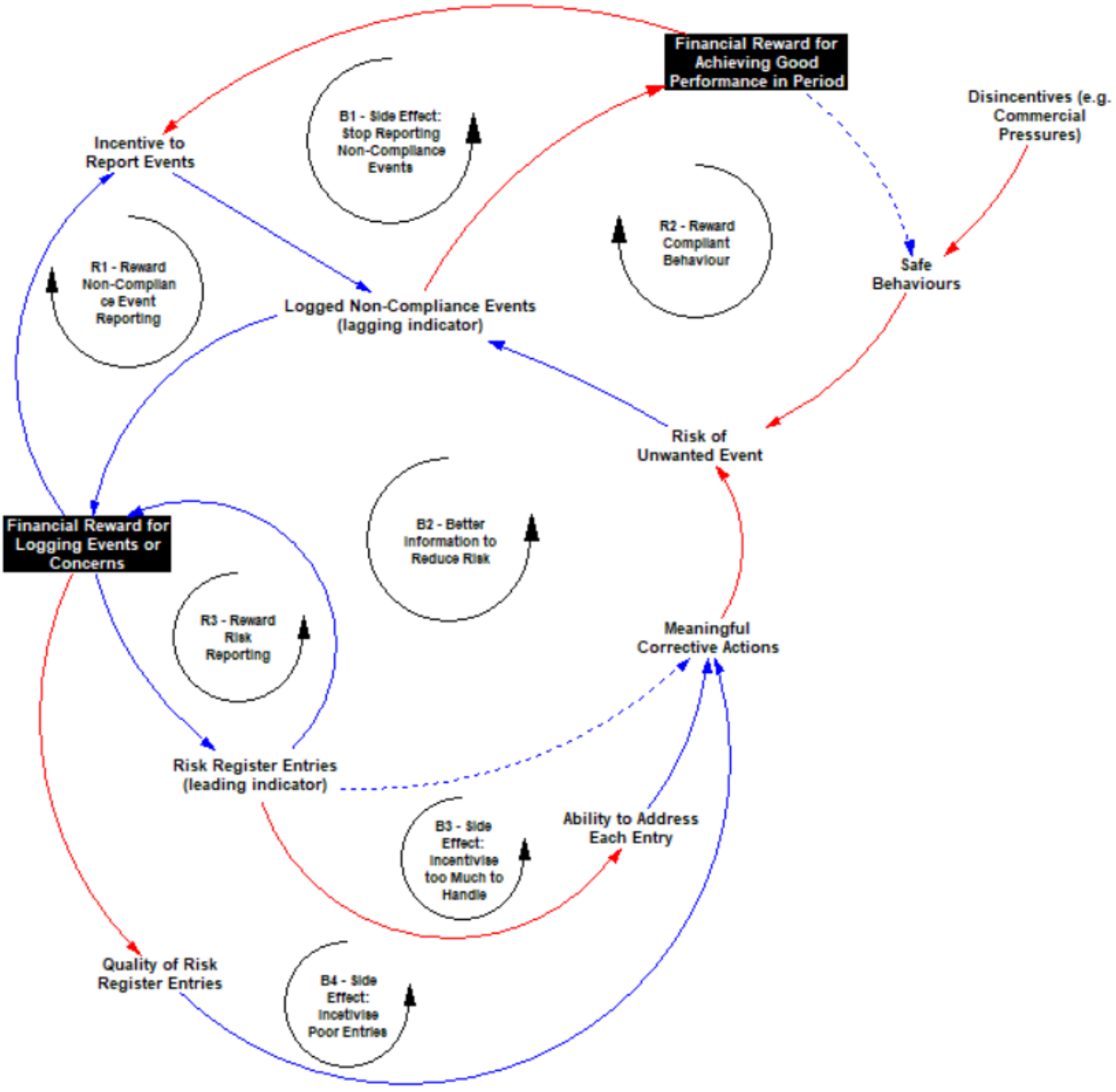


Figure 24 - Incentives and influences

22.4.3 Case Study #3 – Contractor and supply chain management

Part 1 outlined common causal factors relating to contractor and supply chain management (section 12). It highlighted the need for leadership of all parties to understand their obligations and align, where possible, client and contractor goals. The relationship between the parties should be structured in such a way as to avoid disincentives to meet those obligations. This could include the threat of financial penalties deterring parties from raising safety concerns in a timely manner. The client must maintain oversight, particularly to change processes, and sufficient capability as 'intelligent customer'. Clear communication channels and regular review points are recommended.

A small workshop was convened in order to explore these issues, and the interactions between them, in more detail. Three safety specialists from the rail and nuclear industries were taken through GMB exercise over the course of a few hours. As with the previous examples the initial output was complex and required some additional analysis to identify pertinent feedback mechanisms. For completeness the full model is presented in Figure , followed by an explanation of its creation and the post-analysis simplified conclusions.

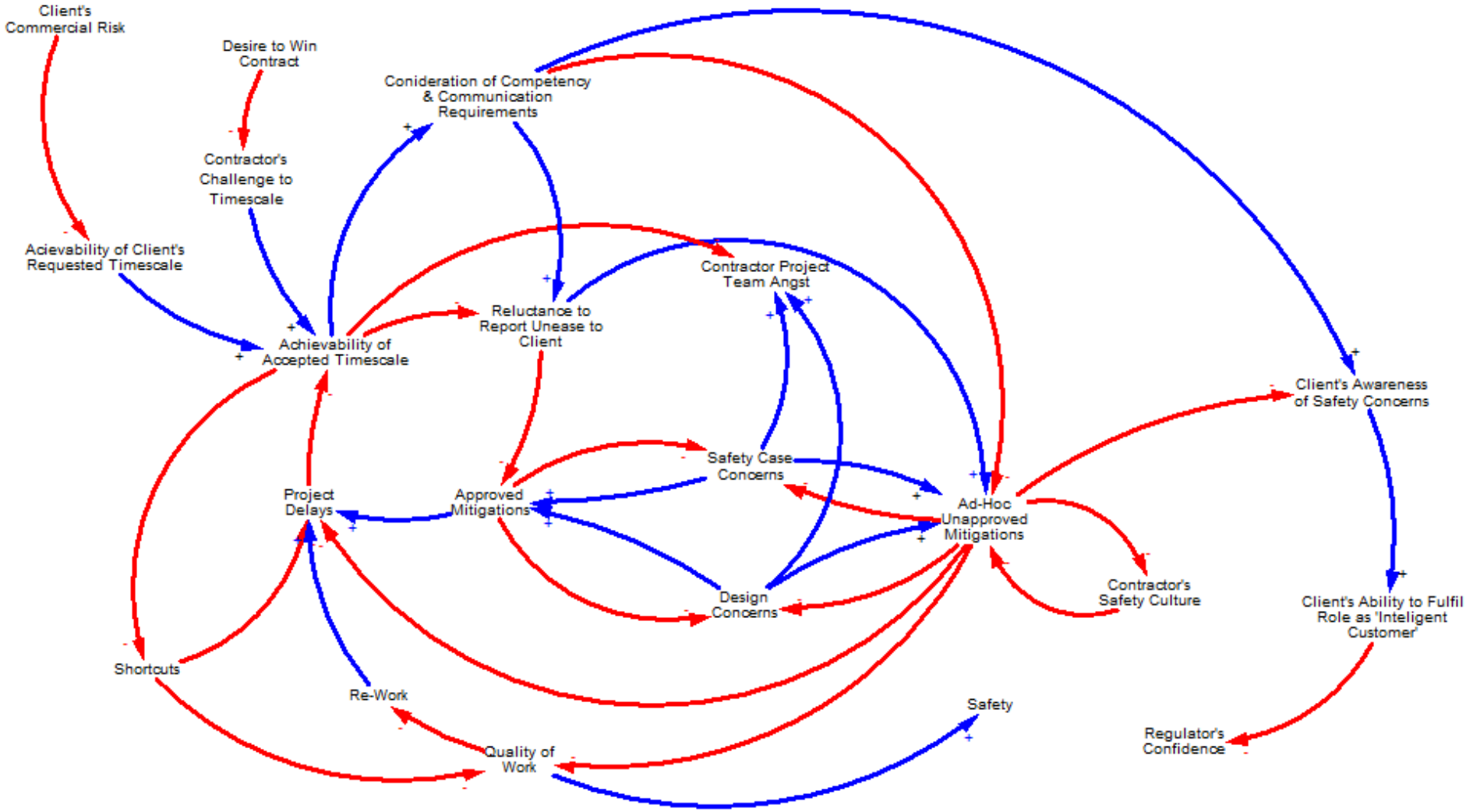
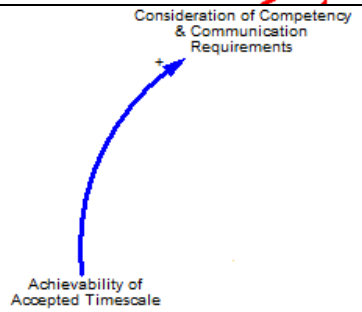


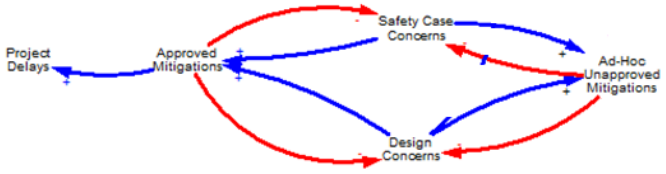
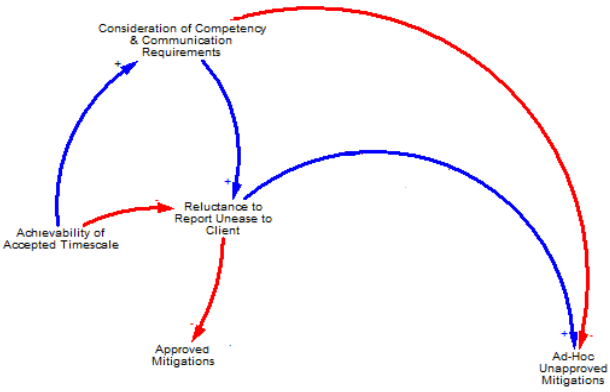
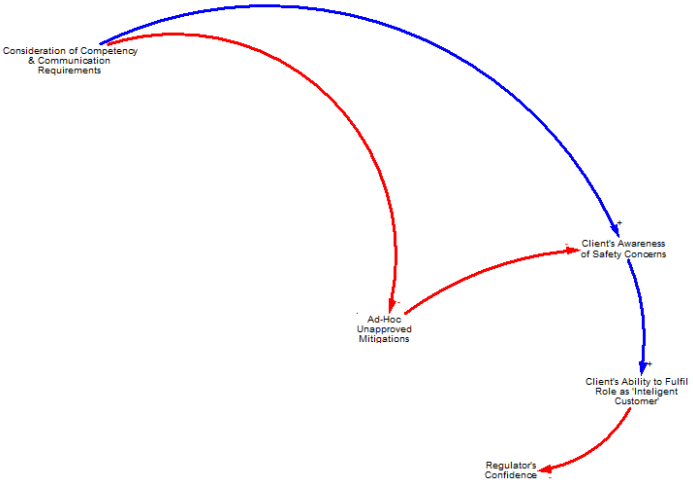
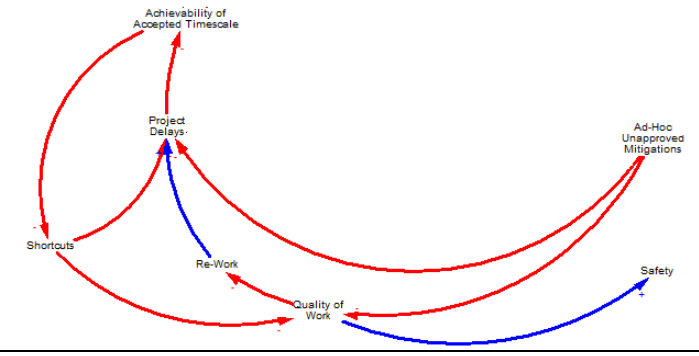
Figure 25 - Complete contractor and supply chain management CLD

As in case studies #1 and #2, participants began by identifying pertinent variables through a divergent process (essentially brainstorming on post-it notes) before combining, refining and converging on the final set of 21 used in the model above. A series of structured discussions were then held around the relationships between those variables. These discussions revealed fragments of cause and effect that when combined were able to form the complete model.

In order to provide insight into this process for the purpose of this report these discussions and the elements of the model that arose from them are summarised in (Table 13). The 'description' column paraphrases the statement made by one of the workshop participants, while the adjacent 'model representation' column shows how this statement is interpreted using the language and syntax of CLDs.

Table 13 – Model case study #3 creation

	Description	Model representation
1	Because of the client's commercial risks and pressures, they issue a request for tenders with unrealistically short timescales.	
2	Potential contractors do not challenge the timescales because they desire to win the contract.	
3	This can cause both parties to accept a project timescale with limited achievability.	
4	Upfront contract discussions and arrangements such as competence requirements, safety case/risk assessment and management of change requirements, reporting routes and project interfaces and progress reviews/oversight are not properly considered to minimise time as a result of short project timescales.	
5	Design and safety case concerns arise during the project (in a narrative sense these can be considered to be initially due to factors outside the current model). When identified, these lead to concern within the contractor's project team.	

6	The contractor minimises these (with or without the approval of the client) and deals with them either through an approved process which will add to project delays, or alternatively on an ad hoc basis in order to avoid or minimise delays.	
7	Whether or not the contractor seeks approval from the client is also affected by the initial consideration of communication requirements and the achievability of the accepted project timescale.	
8	The consideration of communication requirements and propensity towards ad-hoc, unplanned and unapproved modifications can impact the client's knowledge of safety issues they should be aware of. Their knowledge of these issues affects their ability to fulfil the role of 'intelligent customer' which can ultimately lead to changes in the relationship and trust between them and the regulator.	
9	The realisation of the key staff that short cuts/non-conservative decision making is being approved is likely to lead to a further deterioration in safety culture, reinforced by a view that management condones this.	
10	If the safety 'fixes' do not lead to delays or more serious impacts during the contract lifetime, there may still be longer term implications for the client.	

From the preliminary model in Figure 24 it is possible to identify **two key leverage points** which have significant impacts on the dynamics of the system and the observed behaviours, and could therefore be used to inform corrective actions.

Firstly, the '**achievability of the accepted timescales**' can be controlled at the inception of the project, and if a timescale with low achievability is accepted, it can set in motion a series of behaviours that could ultimately have negative impacts. A mechanism to ensure the timescale is achievable and realistic would reduce the probability of the subsequent actions and emergent behaviours.

Secondly, the management system needs to ensure that communication requirements are adequate and understood along with the mechanisms for approving changes/deviations from the original plan. This reinforces the importance of several elements discussed previously, and shows that if the specified requirements are in place, they should provide suitable leverage points which can be used to monitor and then reduce potential vulnerabilities.

23 CONCLUSIONS TO PART 3

Part 3 explored the ways in which process and other safety-related events are commonly understood through sequential and epidemiological models and methods. While powerful for capturing and structuring knowledge, they are not without their limitations. Principally they reduce causation to sequences of discrete events, overlooking the powerful effects that feedback can have to speed up or resist change. New 'systems-theoretic' models have been developed that provide ways to address some of these issues by looking at more complex representations of the relationships between causal factors. CLDs were highlighted as providing the basis for one such method.

The three case studies illustrated some of the processes for creating CLDs while also representing some of the common underlying structures of causality that contribute to the themes and failure to meet expectations described in the previous Parts.

CLDs are not without their own challenges. One common criticism is that, in not shying away from complexity, the initial models can be daunting and require some degree of sense-making and refinement. US Supreme Court Judge Oliver Wendell Holmes Jr. (1841-1935) once said 'The only simplicity for which I would give a straw is that which is on the other side of the complex – not that which never has divined it' (*Holmes-Pollock letters: The correspondence of Mr. Justice Holmes and Sir Frederick Pollock, 1874-1932,* 2nd ed., 1961, p. 109). There is a danger that simple explanations are sought before the complexity has been fully described and analysed. CLDs provide a potential way to explore this complexity.

CLDs also present several strengths in addition to balancing issues relating to traditional tools. The approach provides a means for constructing hypothetical structural models of the complex underlying mechanisms of causality. The CLDs produced can illuminate the underlying assumptions of the event investigators in terms of causes and effects by way of the visual nature. CLDs can facilitate an understanding of the complex interactions within the system and facilitate the development of corrective actions more informed by the interactions within the system, allowing for the structures of causality within the real world to be modified and avoiding the seduction of addressing single, isolated root causes. There is a need to incorporate behavioural issues and ensure the right things are being measured so as to avoid perverse behaviours. CLDs provide a means to achieve this. CLDs can lead to the identification of common mechanisms (archetypes) which frequently influence unwanted behaviours, which can then be proactively addressed. They can be used to benchmark and learn from others who have encountered similar causal mechanisms. While not discussed here, it is also possible to prepare the models for simulation allowing for a greater understanding of the dynamics of the system and the ability to explore alternative scenarios and test potential corrective actions.

24 CONCLUSIONS AND RECOMMENDATIONS

24.1 CONCLUSIONS

The prevention of major events in many industries relies upon the effectiveness of an overall system based on engineered protection, effective SMSs and required human behaviours, and the interaction between these. Recognising vulnerabilities can be challenging because problems which can arise in this complex, interactive environment may not be easy to identify. This Report has outlined the scope for developing new 'tools' and thinking which it is believed offers advances in addressing this problem and thus reducing the risk of major events.

The analysis of major incidents reported in Part 1 revealed a high degree of common causality, that could be characterised in terms of 10 themes. The interpretation of these themes, referenced to established human factors / safety management insights, enabled the generation of a set of expectations of good practice for mitigating the vulnerabilities identified in the major incident analysis. A potentially useful contribution of the report is, therefore, considered to be offering the facility for organisations to benchmark their current status against 'good practice guidelines' as defined by the set of expectations.

The authors believe that the set of expectations could potentially be distilled into a set of probing questions to produce a tool for formal assessment of the extent to which operational 'reality' reflects expectations of good practice, i.e. an 'audit tool' that would complement existing approaches for identifying deficiencies in engineering and management systems.

The expectations and associated discussion might also provide a basis to strengthen the understanding of decision makers in these sometimes neglected areas and could be further developed to provide a framework which would enable these important event precursors to be identified more effectively in event investigations.

Recognising vulnerabilities and what needs to change to mitigate them is key to informing decision-making over what, where, and how to intervene. In attempting to address the organisational and cultural issues identified, it is essential that human factors and broader behavioural and social science insights are understood and addressed. This requires an evidence-based approach to their management, as discussed in Part 2.

With respect to intervention, three fundamental issues are addressed in the report. The first relates to the measurement of safety performance and, in particular, the relative merits of alternative sources of data and evidence. The second to the relative merits of alternative techniques for priority elicitation, and lastly, the challenge of designing effective behaviour change interventions.

The latter requires the capacity to apply a critical perspective to the social science evidence on 'what works' (theory of change) and translating this into deliverable activity in a given organisation. Notable challenges surround the fact that the subject matter tends to be unfamiliar to many engineers and managers, compounded by the fact that guidance on the science of successful intervention delivery remains limited, i.e. relatively little has been written on how to apply insights on behaviour change in the workplace.

Arising risks relate to: the selection of inappropriate / sub-optimal types of intervention floundering due to delivery failures, or worse, interventions that engender perverse motivations that degrade rather than enhance safety performance. There is a significant need for guidance for employers in this area, and for tools that support the intervention selection/design process.

The CLM technique described in Part 3 shows promise in this respect, as a means of testing proposed interventions at the design stage.

Part 3 outlines some of the limitations of traditional sequential and epidemiological models and methods used in incident analysis. It outlines the case for alternative approaches for detecting vulnerabilities of the type identified in Parts 1 and 2. There is scope for causal loop modelling (CLM) in: forensic incident analysis; resilience testing of extant systems, and in proof testing the logic of proposed interventions at the design stage. The utility of this technique as a potentially valuable participatory 'tool' is illustrated in three case studies identified by the discussion in Part 1.

Causal loop diagrams (CLDs) provide a means for constructing structural models of the complex underlying mechanisms of causality and can illuminate the assumptions involved and enable the development of corrective actions more informed by the interactions within the system. The output can also inform decisions over the selection of safety performance indicators. Reflecting alignment with modelling techniques advanced by others, e.g. Leveson, Hollnagel and Rasmussen, their principal strength is considered to be the capacity to increase the transparency of interactions between variables in complex systems.

The potential of CLDs is reflected in the recommendations in 24.2. In particular, there is proposed follow-on work to further familiarise potential users with the use of the technique by providing further examples based on both key identified expectations and taking account some of the behavioural learning identified in Part 2.

24.2 RECOMMENDATIONS

24.2.1 Research

- Extend the 'library' of events studied to verify and potentially enhance insights into organisational and cultural precursors and to further refine the developed risk management expectations.
- Based upon foundation work described in this report, develop an event (incident and near-hit) investigation framework for senior managers and safety professionals, that complements established approaches by helping organisations detect the contribution of incubating organisational and cultural precursors to event causation.
- Develop 'penetrating' questions to facilitate the investigation of the extent to which expectations are being met in practice and thus to produce an assessment tool for use by employers and safety professionals to assess the resilience of (i) established systems (ii) proposed changes to systems.
- Develop behaviour–change intervention selection and design guidance, for employers and safety professionals; potentially extending to the development of an expert-system incorporating the novel feature of causal-loop modelling, with a view to, ultimately, producing a tool for organisations.
- Further develop and refine the CLM technique to provide illumination in three areas:
    - (i) incident investigation;
    - (ii) testing the resilience of established systems, and
    - (iii) prototyping planned interventions.

24.2.2 Knowledge transfer

- Develop training (courses/workshops) for senior managers and safety professionals in detecting and addressing system vulnerabilities, including learning from incidents, testing the resilience of established systems and evidence-based approaches to intervention design.
- Produce a more succinct abridged version of this report aimed at senior managers and leaders. This could be augmented by specific training/mentoring sessions, tailored to the needs and interests of leaders and their organisations.

ANNEX A
HIGH RELIABILITY ORGANISATIONS

The concept of HROs, widely attributed to Perrow (1984), has been said to characterise businesses that successfully manage and sustain their resilience to failure despite operating in complex, hazardous conditions, where the consequences of errors could be profound or catastrophic. While a defining characteristic is held to be that HROs exhibit 'nearly accident free performance' (LaPorte, 1996), this is not to suggest that they are vulnerability-free, rather the claim is that they demonstrate prowess in maintaining hazard control and detecting and reacting to vulnerabilities, to mitigate their potential.

> '…people who had examined these organisations [HRO's] were struck by their unique structural features. We saw something else: These organisations also think and act differently' (Weick and Sutcliffe, 2001).

Features relating to HRO practices have been divided into two categories: those relevant to the anticipation of failure, and those relevant to the containment of hard-to-avoid failures (Weick and Sutcliffe, 2015). These mindful organisations are said to anticipate failure through corporate adoption and cultural internalisation of the overlapping principles of preoccupation with failure, reluctance to simplify, and sensitivity to operations.

Preoccupation with failure: This involves regular reflective 'self'-critical testing of the reliability and resilience of established safety systems - to actively probe for weaknesses and degradation, as well as effectively monitoring changeable and emergent contingencies that may give rise to new hazards, i.e. the capacity to detect early warning signs of the potential for failure. Practices that can provide the desired degree of insight include the following (also see Part 1):

- Avoiding the temptation to assume that the absence incidents means that safety is being effectively managed;
- Responding to near miss events with the same degree of vigour as actual failures;
- Removing barriers to incident reporting and offering multiple reporting routes for employees.
- Pro-actively seeking-out 'bad news';
- Regularly asking 'what might go wrong' questions, at all levels within the organisation, and
- Considering and addressing the scope for undesirable knock-on effects arising from systems and interventions. Regular constructive conversations with managers and employees about incidents, errors and associated learning.

Reluctance to simplify: An example of this is that while aggregating data and information can be useful for identifying trends across an organisation, a disadvantage is that this can have the effect of masking local issues. Practices that help organisations and management to keep in tune with operational reality include the following:

- Collecting and analysing qualitative, as well as quantitative data;
- Basing insight and decisions upon multiple complementary data sources;
- Using active listening skills to understand the nuances of others' perspectives;
- Eliciting and being prepared to meaningfully engage with all stakeholders;
- Ensuring transparency of the decision-making process so that subordinate staff and other stakeholders can understand and recognise the underpinning logic' and
- Giving a meaningful voice to dissenters as well as champions.

Note: With respect to analytical capacity – the presence of a healthy degree of slack and redundancy (rather than paring to a minimum), to provide a pool of resources is viewed as advantageous to enhance resilience. 'Organisational slack in terms of time and human resources [and capacities] is important for organisations coping with the challenges of the 21st century.' (Lawson & Samson, 2001).

Sensitivity to operations: This involves the recognition of the need for architects of safety systems, rules / procedures and change management to be cognisant of operational conditions and practices. Relevant features include the following:

- Regular director/management shop-floor walkarounds;
- Approachable leadership;
- Regular formal and informal safety conversations with staff, and
- Regular review of operating procedures, safety rules, and risk assessments.

Commitment to resilience: the organisation's capacity to adjust its functioning prior to, during and following a failure, in order to contain its consequences is important in this context. Relevant practices include the following:

- Training staff to possess conceptual systems-based skills, as well as specialist skills;
- Periodically exposing staff to work and experiences outside their specialism;
- The capacity to learn during the incident, as well as after, and
- Avoiding overdoing lean-management to the point where it may compromise capacity and options when emergencies do arise.

'The signature of an HRO is not that it is error-free, but that errors don't disable it' (Weick & Sutcliffe, 2001).

Deference to expertise: Responding to unanticipated failures requires fluid decision making structures that do not assume that relevant expertise is proportionate to rank. Relevant practices that enable this can include the following:

- Having an up-to-date competency map profiling internal capabilities and knowledge that can rapidly mobilized in the event of an emergency, and
- Operational staff input into rules, procedures and risk assessments.

Note: Critics see value in deference to expertise (whether professional / technical or front-line insight) but point to the micro-political and hierarchical challenges of making it happen.

Reflections on the HRO concept

Essentially, Weick's model reflects an idealised organisation, i.e. it is probably most appropriately regarded as aspirational.

Weick offers a potentially useful check-list against which an organisation might assess its status relative to any array of what are claimed to represent HRO characteristics. However, the reality that complex organisations are routinely in a constant state of structural flux and socio-technical evolution suggests the conclusion that these are principles rather than a defined end point. For example, as Hopkins (2007) concludes, attempts at determining achievement of HRO status in any material / quantifiable sense would constitute an over-interpretation of Weick's model.

ANNEX B
SAFETY CUTURE MATURITY

A notable feature of most, if not all, workplace accidents is that constituent components have routinely occurred previously. Rarely are each of the component elements that lead to an incident new or unique events. It is only when they achieve the necessary alignment that an accident or near-miss occurs. This is a common feature of relatively minor, routine accidents involving individuals as well as major disasters. Effective risk management relates to corporate resilience over the capacity to detect and block (or mitigate) pathways to failure.

Organisational learning, specifically the capacity to gain insight into how effectively hazards and risks are being controlled, is key to producing resilience to failure. Critically, this requires the capacity to gather evidence that goes beyond accident and ill-health statistics and to develop a suite of measures that relate to how effectively the organisation is managing recognised precursors that can lead to failure.

In many organisations, claims of a plateauing of improvement in safety performance, arising from engineered safety solutions, has sponsored an increased focus on decision making, behavioural and cultural elements - in particular aspects relating to reducing human-error and volitional risk-taking. The post-war tradition in the UK, and most of western Europe, has been to focus on situational drivers of employee behaviour, rather than individual differences e.g. personality traits. While some may argue that this owes much to the convenient alignment between the (UK) safety regulator emphasis on employer responsibilities and the systems focus within the human factors paradigm, the capacity for situational influences to transcend dispositional influences on employee safety behaviour is widely evidenced.

The recognition that human beings do not operate in isolation, and that social conformity influences, and shared ‘world views’, can have a pervasive influence on how individuals behave, is central to the concept of safety culture. However, employees’ behaviour in relation to risk is, transparently, not merely the product of normative effects attributable to peer influence.

The work environment can embody an array of other, potentially more pervasive, behaviour and performance shaping features. Some of these are structural, e.g. the demarcation of departmental responsibilities and accounting units. Others relate to how work is organised; the design features of machinery and equipment; systems of reward, as well as 'softer' elements such as management priorities and style. These and associated features are perhaps best characterised as relating to organisational safety climate. They are scene setting variables - ‘the choice architecture’, which intersects with and impacts on workplace safety culture.

‘Safety culture’ is not a noun, it is an adjective, i.e. a safety culture is not something that organisations possess or lack. All organisations have a safety culture (which may well extend to plural sub-cultures), such that they occupy a position on the continuum between positive and negative. The notion of safety culture maturity relates to attempts to characterise where an organisation is on this continuum, referenced to contemporary perspectives on good practice (e.g. Institution of Occupational Safety and Health (IOSH), 2015).

Note: Conceptually safety culture maturity reflects the broader, established principle of a hierarchy of risk control. A central tenet is that selected interventions need to be of good fit with the prevailing level of cultural maturity.

The capacity to characterise and take account of the level of safety culture maturity is important when developing safety improvement plans. In particular, it is critical to proceed at an appropriate pace and to progress in incremental steps that build on firm foundations that reflect the hierarchy of control, e.g. a focus on behavioural elements, where fundamental aspects relating to levels of management commitment, resources, or engineered control measures are found wanting. For these reasons, characterising an organisation’s safety culture maturity is widely held to represent a cornerstone in the change process towards reduced risk taking.

Where interventions are of poor fit with the prevailing level of maturity, their impact is likely to be blunted to the point where they represent a poor return on investment.

A range of indicators of safety culture maturity have been advanced. While embodying detailed differences, all share the perspective that an organisation (or sub-division of an organisation) can be assessed with reference to a continuum. The capacity to do this is important, both as a benchmark against which to assess change over time and, most pertinently, because it informs decisions over the types of intervention that are of best fit with prevailing workplace norms, values, attitudes and practices. At a fundamental level, assessment signposts what needs to change to progress to higher levels of maturity.

The assessment of safety culture maturity is potentially complicated by the scope for an organisation to exhibit multiple cultures, i.e. it is rare to find a large complex organisation that can reasonably be characterised as possessing a single homogeneous culture. For example, different sub-cultures may be present both between and within sites, reflecting differences in management / supervisory style, local norms / historical precedents, systems of work, industrial relations and more. Determining the extent of homogeneity / variability is an important issue, as it informs thinking over the relative merits of universal (whole organisation) or local bespoke (segmented) solutions.

A number of models of safety culture maturity have been produced. In the UK the HSE endorsed the Keil Centre model. This was intentionally designed to mesh with the key regulatory risk management guidance: *Managing for health and safety* (HSG65), *Reducing error and influencing behaviour* (HSG48), and the foundation Advisory Committee on the Safety of Nuclear Installations (ACSNI) publication *Organising for safety* (HSC, 1993). Table A.1 provides a staged sequential series of vignettes that reflects an elaboration of the HSE-Keil Centre model, developed by Weyman and Lunt (unpublished), that takes the form of a set of heuristics designed to characterise different levels of cultural maturity.

With a view to enhancing transparency through supplementary elaboration of the HSE-Keil Centre model, Weyman and Lunt (2016) developed the version depicted in table A.1. Each facet of maturity is referenced to a linear five-point rating, each anchor being represented by a vignette designed to characterise current practice within the organisation / function being assessed. No empirical basis for the scaled vignettes is claimed, they are simply offered as what the author's hope readers will view as a logical, but by no means definitive extension of the original, reflecting equivalent principles aimed at providing employers with a more tangible means of assessing their organisation's level of maturity.

Table A.1 - Suggested elaboration of HSE safety culture maturity criteria

Cultural maturity (Keil Centre)	**Behavioural antecedents**	**Cultural level**				
		Emerging	**Managing**	**Involving**	**Cooperating**	**Continuous improvement**
Board management commitment / visibility (inclusive of leadership)	Is safety seen as important for business, moral and/or legal reasons? Do senior management have a reactive or proactive approach? How do senior management demonstrate commitment? How responsive is management to health and safety (H&S) issues? To what extent do senior management walk the talk? Board champion? Flexible leadership/resonant leadership Visibility in meetings	Safety is not seen or managed as a key business risk. No discussion of H&S at board meetings. No board member with H&S responsibility. No public commitment to H&S improvement. Non systematic approach - H&S priorities primarily reactive to incidents	Safety is managed as a business risk in so far as avoiding legal costs. Limited discussion of H&S at board meetings A board member with H&S responsibility identified. A public commitment to H&S improvement has been made. H&S priorities are primarily compliance driven. Command and control leadership style.	Safety is managing a business risk in terms of avoiding legal costs and protecting reputation. H&S is an agenda item at all board meetings. A board member with H&S responsibility plays an active visible role in promoting H&S. Corporate commitment to H&S improvement has been widely publicised. H&S prioritisation is driven by lagging indicators. Visionary leadership style used.	H&S is managed as a legal, business and moral risk. H&S is the first item on the agenda item at all Board meetings. A board member with H&S responsibility provides active visible leadership in promoting H&S. Corporate commitment to H&S improvement and improvement goals / KPIs has been widely publicised. Recognition of the limitation of trail data for setting H&S priorities. Receptive to new ideas and innovative techniques in H&S / risk management.	H&S is managed from the perspective that it brings business opportunity (i.e. that the workforce is an asset) and as part of a portfolio of broader risks (e.g. inclusive of quality, security etc.). H&S is the first agenda item at board meetings A board member with H&S responsibility provides active visible leadership in in H&S. Corporate commitment to H&S improvement and improvement goals / KPIs has been widely publicised. Receptive to new ideas and innovative techniques in H&S / risk management.

					Visionary and participatory leadership.	Recognises the benefits of drawing upon KPI and related evidence to inform strategic thinking over H&S priorities. Flexible leadership approach.
Site leadership	Tailoring board requirements to site needs? Level of visible proactive leadership on safety.	No visible involvement in safety activity. No representation of site views to the board. Board views delivered as H&S command and control. Little insight into workforce motivations.	Modest - infrequent visible involvement in safety activity e.g. attendance at safety meetings. Sporadic/ad hoc representation of site views to the board and of board views to site. Evidence of being responsive to H&S risks / issues raised, but inconsistent. Some appreciation of workforce motivations.	Recognition of H&S leadership role. Regular visible involvement in safety activity e.g. attendance at safety meetings. Reliable advocates of site perspective to the board, and of board requirements to the site. Evidence of responding to H&S risks / issues raised, in a consistent and timely fashion. Effective insight into workforce motivations.	Regular visible involvement in safety activity e.g. attendance at safety meetings. Evidence of active leadership role in H&S, e.g. public workforce engagement; pro-active contribution to development of safety improvements; active engagement with and participation in H&S initiatives / interventions. Able to tailor board requirements to site needs. Recognition of H&S leadership role. Evidence of responding to H&S risks / issues in a	Regular visible involvement in safety activity e.g. attendance at safety meetings. Evidence of active leadership role in H&S, e.g. public workforce engagement; pro-active contribution to development of safety improvements; active engagement with and participation in H&S initiatives / interventions. Recognition of H&S leadership role. Receptive to new ideas and innovative techniques in H&S / risk management. Evidence of responding to H&S

					consistent and timely fashion. Recognises the importance of a receptive and fair management style. Good insight into workforce motivations - and taking account of this e.g. in setting / managing performance objectives.	risks / issues in a consistent and timely fashion. Adopts a receptive and fair management style. Good insight into workforce motivations - and taking account of this e.g. in setting / performance objectives. Has an effective site - specific set of lead indicators in place; monitors the performance and actively uses the output maintain / enhance risk control.
Communication	Two or one way,? Clear/Easy to comprehend? Regular/repeated? Timely? Multi-channel, multi-media? Reporting options. Feedback mechanisms.	Dedicated formal systems for communicating safety information with staff. No point-of-work safety briefings / tool-box talks. No staff suggestion scheme. No formal system for eliciting staff views –	There is an intention to introduce a dedicated formal system for communicating safety information with staff. There is an intention to introduce a point-of-work safety briefings / tool-box talks. There is an intention to introduce a staff	Dedicated formal systems for communicating safety information with staff are in place. Communication is managed so that it is timely and repeated. Point-of-work safety briefings / tool-box talks are in place.	Dedicated formal systems for communicating safety information with staff are in place. Communication is managed so that it is timely and repeated. Multiple channels are used. Point-of-work safety briefings / tool-box	Dedicated formal systems for communicating safety information with staff are in place and used regularly. Communication is managed so that it is timely, repeated and updated. Multiple channels are used.

		e.g. staff survey; safety climate survey. The above – re-contractors / tenants.	H&S suggestion scheme. There is an intention to introduce a formal system for eliciting staff views – e.g. staff survey; safety climate survey. The above – re-contractors / tenants	A staff H&S suggestion scheme is in place. Formal systems / structures for eliciting staff views – e.g. staff survey; safety climate survey are in place. The above – re-contractors / tenants. Attempts are made to make the communication engaging (e.g. tailored, interactive).	talks are conducted regularly. Staff H&S suggestion scheme is in place - with evidence of use by staff. Systems are in place to inform staff of H&S issues raised / reported; feedback on arising management action relating to accidents, near miss and confidential reports. Managers provide feedback on staff suggestions. Formal systems / structures for eliciting staff views – e.g. staff survey; safety climate survey have been formally adopted as a recurrent feature. The above – re-contractors / tenants.	Point-of-work safety briefings are conducted regularly. Staff H&S suggestion scheme is in place - with evidence of use by staff - producing high quality material that can be used by senior management decision making over risk control. Systems to inform staff of H&S issues raised / reported; feedback on arising action relating to accidents, near miss and confidential reports - the are KPI's associated with response times. Managers provide feedback on staff suggestions. Response time is a KPI. Formal systems / structures for eliciting staff views – e.g. staff survey; safety climate surveys have been formally adopted as a recurrent feature. The output from such

						is used at a senior level to inform decision making over performance and priorities for intervention. A safety committee system is in place, with employee representation at senior management policy meetings. Involvement of staff representatives in devising safe systems of work = custom and practice. Staff representatives have a formal role in incident investigations and make an active and meaningful contribution. Safety representatives play an active role in the design and roll-out of safety improvement initiatives and interventions. **Training & competence:** Clear definition of competencies and

						certification exist for all job roles. All new staff undergo induction training. Refresher training is provided for all job roles - to defined time-lines. Employee safety representatives receive advanced H&S training, e.g. incident investigation. A diverse range of regular interactive face-to-face and online training is offered, encompassing H&S, technical and 'soft' skill that includes contractors includes relevant supply chain personnel. Safety record is the principal criterion in the contractor selection process. The above – re-contractors / tenants / supply chain.

Productivity vs. safety	Productivity first, safety first, or both? Context dependent (e.g. safety first following accident)? Mixed messages over priorities?	Productivity is always prioritised over safety. Safety does not feature in operational decision making.	Production frequently takes priority over safety. Safety rarely features in operational decision making.	Production sometimes takes priority over safety. Safety features in operational decision making - sometimes.	Production and safety have equal priority. Safety routinely considered in operational decision making.	Safety always prioritised over productivity during decision making. Safety is seamlessly embedded into operational decision making.
Safety resources	Appropriate? Usable? Maintained? Available? Accessible? Instruction on use? Sufficient?	Widespread reports of equipment shortages. Widespread reports of safety system failure. Widespread reports of staff shortages.	There are some reports of equipment shortages. There are some reports of safety system failure. There are some reports of staff shortages.	Reports of equipment shortages – and evidence of delay in their resolution. Reports of safety system failure are apparent – and evidence of delay in their resolution. Reports of staff shortages. Available resources inappropriate, or in poor condition.	Reports of equipment shortages are infrequent – and there is evidence of timely resolution. Reports of safety system failure are infrequent – and there is evidence of timely resolution. Reports of staff shortages are infrequent – and there is evidence of timely resolution. Resources are appropriate but not necessarily easy to access.	Reports of equipment shortages are rare – and there are KPIs for timely resolution. Reports of safety system failure are rare – and there are KPIs for timely resolution. Reports of staff shortages are rare – and there are KPIs for timely resolution. Resources are appropriate and accessible.
Participation//involvement (inclusive of industrial relations)	Told, sold, consulted, feedback on use, delegated?	No safety committee system. No staff representative involvement in	There is an intention to introduce a safety committee system. There is an intention to introduce a formal	A safety committee system is in place. There is a formal system for involving staff representatives	A safety committee system is in place, with employee representation at senior management meetings where	Safety committee system is in place, with employee representatives at senior management meetings where

	Inclusiveness (e.g. of supply chain, tenants)? Staff representation.	devising risk assessment / job planning / safe systems of work. • The above – re-contractors / tenants.	staff representative involvement in devising risk assessment / job planning / safe systems of work. The above – re-contractors / tenants. Explanations are provided on a 'because we have to' basis.	in devising risk assessment / job planning / safe systems of work. Staff representatives have a formal role in incident investigations. The above – re-contractors / tenants. Explanations / directives are justified (a 'why') is provided.	safety policy decisions are discussed. Involvement of staff representatives in devising risk assessment / job planning / safe systems of work represents custom and practice. Staff representatives have a formal role in incident investigations. Staff consulted prior to introduction of changes.	safety policy decisions are made. Involvement of staff representatives in devising risk assessment / job planning / safe systems of work = custom and practice. Staff representatives have a formal role in incident investigations and make an active and meaningful contribution. Safety representatives play an active role in the design and roll-out of safety improvement initiatives and interventions. Decisions delegated to staff where appropriate.
Training and competence (inclusive of contractors)	Relevant competency requirements defined for all jobs? Inductions/training occur before people start job for first time?	No clear definition of competencies and certification by job role. No induction training. No refresher training.	Clear definition of competencies and certification exist for some, e.g. safety critical, job roles. All new staff undergo induction training.	Clear definition of competencies and certification exist for all job roles. All new staff undergo induction training.	Clear definition of competencies and certification exist for all job roles. All new staff undergo induction training. Refresher training is provided for all job	Clear definition of competencies and certification exist for all job roles. All new staff undergo induction training.

	Relevant and sufficient? Competent/credible providers? Transferable? Technical and soft skills? Inclusion of contractors? Contractor vetting?	No provision for monitoring the above regarding contractors. Safety record is not considered in the contractor selection process.	Refresher training is provided for some, e.g. safety critical, but not all job roles. There are systems for monitoring the above regarding contractors, e.g. safety critical, but not all job roles. Safety record is a criterion in the contractor selection process.	Refresher training is provided for most job roles. A competent / credible training provider is used. Employee safety representatives receive dedicated H&S training paid for by the employer. There are systems for monitoring the above regarding contractors for all job roles. Safety record is an important criterion in the contractor selection process.	roles - referenced to defined timelines. A competent / credible training provider is used. Employee safety reps receive advanced H&S training, e.g. incident investigation, paid for by the employer - with good levels of take-up. A diverse range of regular interactive face-to-face and online training is offered that includes contractors / relevant supply chain personnel. Measures are taken to ensure transferability to the workplace. There are systems for monitoring the above regarding contractors. Safety record is a primary criterion in contractor selection.	Refresher training is provided - to defined timelines. A competent, credible training provider is used. Employee safety representatives receive advanced H&S training, e.g. incident investigation. A diverse range of regular interactive face-to-face and online training is offered, encompassing H&S, technical and 'soft' skills that includes contractors, and relevant supply chain personnel. Measures are taken to ensure transferability to the workplace. Safety record is the principal criterion in the contractor selection process. The above – re-contractors / tenants / supply chain.

						The workforce is empowered and judged competent to exercise their own discretion in dealing with novel or unusual situations.
Systems (HSG65)						
Policy	Inclusive of worker involvement? State the overall current risk management context of the business (comprehensively)? Consultation during development? Reflect H&S commitment	While a policy is present, there is no evidence of workforce consultation in its development.	Policy underwent some workforce consultation in its development but its wording and content does not provide any sense that worker involvement is valued.	Developed with input from the workforce, the policy conveys the importance of worker involvement.	The H&S policy is clearly linked to other policies related human resource (HR) / occupational health (OH) polices such as bullying, rehabilitation, negotiation and OH access.	The H&S policy is fully integrated with HR/OH, security, quality (i.e. in style, consideration of their interactions).
Safety management system	Consider future risks, the unknown? Responsiveness to changes (HRO)? Workforce inclusion and extent of consideration (i.e. logistic interfaces sub-industries, suppliers, tenants? Emergency planning?	No formal system of risk assessment. No risk register. No safety improvement plan / KPIs. No emergency plan. No recognised SMS, e.g. ISO 45001 in place.	A formal system of risk assessment is present. Consideration has been given to the introduction of a risk register. Consideration has been given to the introduction of an	A formal system of risk assessment is present with a defined time-line for review. Employee representatives are involved in developing some risk assessments / method statements / job planning and reviews.	A formal system of risk assessment is present with a defined time-line for review. Employee representatives are involved in developing most risk assessments / method statements / job planning and reviews.	A formal system of risk assessment is present with a defined time-line for review. Employee representatives are involved in developing all risk assessments / method statements / job planning and reviews.

	Balance between process and safety process. Consideration of impact upon the supply chain.	Unresponsive to H&S risks / issues raised.	improvement plan and KPIs. Consideration has been given to the introduction of emergency plan. Consideration has been given to the introduction of a recognised SMS e.g. ISO 45001. Evidence of being responsive to H&S risks / issues raised, but inconsistent.	A system for point-of-work / ad-hoc risk assessment is in place. Evidence of responding to H&S risks / issues raised, in a consistent and timely fashion. Risk management covers conventional and process safety but systematic consideration of emerging risks is not undertaken. Propensity to focus on conventional rather than process safety.	A system for point-of-work / ad-hoc risk assessment is in place - and there is evidence of its use by line managers / supervisors. A risk register has been introduced. A H&S improvement plan plus KPIs is in place – with KPIs for lag and lead indicators. An emergency plan is in place - with periodic testing. Evidence of responding to H&S risks / issues in a consistent and timely fashion. Risk management covers conventional and process safety. Systematic consideration of emerging risks is undertaken.	A system for point-of-work / ad-hoc risk assessment is in place - with evidence of routine use by line managers / supervisors. A risk register has been introduced - based on evidence derived from lead and lag indicators and expert judgement. A H&S improvement plan plus KPIs is in place – with KPIs for lag and lead indicators. An emergency plan is in place - with simulation exercises referenced to a defined time frame. A recognised SMS e.g. ISO 45001 is in place and fully functioning. H&S implications and impacts of supply chain elements are addressed. Evidence of responding to H&S risks / issues in a

						consistent and timely fashion. Risk management covers conventional and process safety. Systematic consideration of emerging risks is undertaken.
Hierarchy of controls	Hierarchy of controls appropriately applied.	Unreasonable reliance on personal protection and behavioural elements. Engineered control solutions are under-applied.	A heavy reliance on personal protection and behavioural elements. Evidence of introducing engineered control solutions.	Evidence of effective engineered control solutions. Reliance on personal protection and behavioural elements limited to controlling residual risk.	Evidence of widespread introduction of effective engineered control solutions. Reliance on personal protection and behavioural elements limited to the control of residual risk.	Evidence of widespread introduction of effective engineered control solutions. Reliance on personal protection and behavioural elements limited to the control of residual risk.
Integration/performance management	What are the formal incentives that drive behaviour - productivity at expense of safety? Extent of integration with other management systems.	H&S always seen as an addition to normal activity.	H&S usually seen as an adjunct to normal activity.	Safety viewed as an integral component of normal activity e.g. job-planning. H&S included in performance management.	Safety treated as an integral component of normal activity e.g. job-planning. H&S objectives set within performance appraisals.	Safety treated as an integral component of normal activity e.g. job-planning. Career progression contingent on H&S performance/attitude.
Job						

Physical working conditions and job design	Managed to mitigate impact of heat, weather, lighting, fatigue upon attention? Due consideration of person, environment fit? Comfortable?	Little / negligible attempt to monitor the impact of working conditions (physical or psychosocial) upon situational awareness, inclusive of stress.	Attempts are made to regulate the impact of working conditions upon situational awareness for physical but not psychosocial risks.	Physical and occasionally psychosocial aspects of working conditions are managed to optimise situational awareness.	Physical and psychosocial aspects of working conditions are systematically managed to optimise situational awareness.	Sufficient flexibility is built into resource allocation to permit their rapid realignment in line with changing conditions, demands and job requirements in keeping with HRO principles.
Rules and procedures	Understood? Relevant? Reviewed? Enforcement.	Little/no active enforcement. Do not reflect custom and practice. A high proportion are impracticable / unworkable. No clearly defined sanctions for infringement. No formal system for review. Review only occurs in reaction to incidents. No employee representative involvement in drafting.	A significant proportion of custom and practice reflects deviations from rules and procedures. A significant proportion of rules and procedures are not practicable or workable. Clearly defined sanctions for infringement. Evidence of active enforcement – inconsistent. Some employee representative involvement in drafting.	A small proportion of custom and practice reflects deviations from rules and procedures. The majority of rules and procedures have been reviewed to enhance practicability and workability. Employees demonstrate an awareness of clearly defined sanctions for infringement. Evidence of active consistent enforcement. Employee representatives actively involved in drafting / reviewing.	Deviations from rules and procedures are rarely encountered. A formal system for periodic review (with defined time scales) has been introduced. Employees demonstrate an awareness of clearly defined sanctions for infringement. Evidence of active consistent enforcement that employees perceive to be just and fair. Employee representatives actively involved in drafting / reviewing. Analysis of incidents has been integrated	Deviations from rules and procedures are very rarely encountered. A formal system for periodic review (with defined time scales) has been introduced with KPIs. Employees demonstrate an awareness of and buy-in to clearly defined sanctions for infringement. Evidence of active consistent enforcement that employees perceive to be just and fair. Employee representatives actively and meaningfully

			There is an intention to introduce a formal system for review. Reaction to incidents dominates the approach to review.	A formal system for periodic review has been introduced. Analysis of incidents integrated into the review process.	into the review process. The scope for elimination / substitution to avoid reliance on compliance is actively explored / adopted.	involved in drafting / reviewing. Analysis of incidents and employee suggestions has been integrated into the review process. The scope for elimination / substitution to avoid reliance on compliance is actively explored / adopted and examples of such solutions can be identified.
Supervision	Bottleneck? Supported? People management skills? Role model. Receptive to being challenged.	Primary emphasis on productivity. No, or under-defined safety responsibilities. Little, or no effective policing of compliance with safety rules.	Primary emphasis on productivity. H&S responsibilities defined – but relate to a general obligation – i.e. non-specific. Limited / selective policing of compliance with safety rules. Low ownership of personal responsibility for H&S.	Potential for productivity and safety tensions recognised and taken account of. H&S responsibilities specific, clearly and unambiguously defined. A strong emphasis on consistent policing of compliance with safety rules. Show interest in H&S initiatives and interventions.	Potential for productivity and safety tensions recognised and taken account of. H&S responsibilities specific, clearly and unambiguously defined - and accepted. A strong emphasis on consistent policing of compliance with safety rules. Confident in raising H&S issues with senior managers.	Potential for productivity and safety tensions recognised and taken account of. H&S responsibilities specific, clearly and unambiguously defined - and accepted. A strong emphasis on consistent policing of compliance with safety rules. Confident and pro-active in raising H&S issues with senior

			Little or no support in managing competing demands.	Some support for managing complex demands.	Willingness to participate in H&S initiatives and interventions. Receptive to the introduction of new ways of working on H&S grounds. Reliably supported to manage complex demands.	managers formally and informally. Receptive to new ideas and innovative techniques in H&S / risk management. Willingness to take a lead role in H&S initiatives and interventions. Spontaneously contributes to identifying new ways of working on H&S grounds. Reliably supported to manage complex demands.
Team working / peer influence/support	Challenging occurs? Positive or negative peer influence/team norms? Team dialogue on safety? Supportive (no bullying)? Buddy system, 'fresh pairs of eyes'.	Risk taking is a widely encountered feature of custom and practice. Very little enthusiasm for working with managers to improve H&S. Negligible ownership of personal responsibility for H&S. Individuals do not necessarily	Risk taking remains a significant feature of custom and practice. Little enthusiasm for working with managers to improve H&S. Low ownership of personal responsibility for H&S.	Risk taking remains custom and practice in a limited range of areas / activities. Significant % of employees willing to work with managers to improve H&S. Low rates of engagement with H&S improvement interventions.	Risk taking is not the norm and is rarely encountered. Some active positive social policing of H&S behaviour of peers. Most are willing to work with managers to improve H&S. The majority of staff recognise their personal	Risk taking is not the norm and is rarely encountered. Significant active positive social policing of H&S behaviour of peers. Almost all are willing to work with managers to improve H&S. Almost all staff recognise their personal

		appreciate/understand whether conditions are unsafe.	H&S interventions viewed with scepticism / cynicism.	Individuals confident to STOP when they feel unsafe.	responsibility for H&S. Evidence of use of H&S suggestion and near-miss reporting systems. Fair rates of engagement with H&S improvement interventions. Individuals always STOP working whenever they feel unsafe.	responsibility for H&S. Evidence of use of H&S suggestion and near-miss reporting systems. Receptive to new ideas and innovative techniques in H&S / risk management. High rates of engagement with H&S improvement intervention. Individuals always STOP working whenever they feel unsafe. Learning from this is systematically collected.
Individual / human factors						
Approach	Process / impact evaluation. Intervention logic. Appropriateness within the hierarchy of controls. Fidelity checks. Inclusion of supply chain.	Does not reflect hierarchy of control - e.g. focus on behavioural elements in the presence of notable infrastructure / safety systems / systems of work weaknesses. Significant scope for enhancement of	General approach reflects principles of hierarchy of control – but significant scope remains for engineered solutions. Choice of topics for intervention reactive to events / based on lag indicators / regulators priorities.	Evidence of widespread introduction of effective engineered control solutions. Choice of topics for intervention reactive to events / based on lag indicators plus lead indicators e.g. safety climate;	Scope for further enhancement of infrastructure / safety systems / systems of work, e.g. via engineered controls is limited. Choice of topics for intervention reactive to events / based on lag indicators plus	Approach reflects hierarchy of control. Scope for further enhancement of infrastructure / safety systems / systems of work, e.g. via engineered controls is very limited. Choice of topics for intervention informed

		infrastructure / safety systems / systems of work. Choice of topics for intervention is random / ad-hoc, rather than informed by contextual evidence. Theory of change for behavioural focused interventions is absent / weak / restricted scope e.g. individuals only - no context / inappropriate. Evidence relating to impact not recorded /absent and no baseline. No intervention logic monitoring / process management evidence gathered – 'hit and hope'.	Theory of change for behavioural-focused interventions is absent / weak. Evidence relating to impact not recorded /absent and no baseline. No intervention logic monitoring / process management evidence gathered'– 'hit and hope'.	behavioural audit data, etc. Linkage between lead and / or lag indicators and intervention choices weak / confused / absent. Choice of behavioural focused interventions reflects 'what works' guidance. Baseline data gathered but evidence relating to impact is absent / weak. No intervention logic monitoring / process management evidence gathered – 'hit and hope'. Appropriate lead KPIs and measurement tools that map onto intervention activity identified.	lead indicators e.g. safety climate; behavioural audit data, etc. Effective linkage between lead / lag and supporting evidence e.g. employee engagement and indicators and intervention choices. Effective integration of contextual data evidence on 'what works' to inform intervention topics and design. Baseline data gathered with appropriate evidence relating to impact gathered. Process management principles / evidence used to monitor progress towards objectives and soundness of intervention logic. Appropriate lead KPIs and measurement tools that map onto intervention activity	by contextual evidence - lead and lag indicators; climate assessment / staff attitude survey / employee engagement activity etc. Theory of change for interventions reflects guidance on what works. The scope of intervention activity addresses situational and well as individual determinants. Evidence relating to impact is recorded referenced to reliable quantifiable benchmark measures – with KPIs. Process management principles / evidence is used to monitor progress towards objectives and soundness of intervention logic - referenced to suitable KPIs, e.g. rates of behaviour change.

					identified and operationalised.	Appropriate lead KPIs and measurement tools that map onto intervention activity identified and operationalised. Checks are made to ensure the intervention is implemented as intended. Supply chain are included.
Content / behaviour Change techniques / intervention logic: Coverage individual behavioural drivers (based on capability, opportunity, motivation and behaviour model (COM-B)) (motivation, intention to behaviour, and maintenance of behaviour change). (Note: capability already addressed by training / competency).	Extent to which motivator strategies covers automatic and reflective decision making. Extent to which the approach encourages translation of motivation into behaviour. Extent to which the approach covers sustained behaviour change / maintenance strategies.	One-off awareness raising activities are considered sufficient for securing interest in safety. No attempt is made to appeal to personal motivations (the 'what's in it for me'). No attempt to target messages. No attempt is made to consider the transferability of any learning to the workplace. Behavioural observation techniques prematurely used	Attempts are made to appeal to personal motivations (e.g. by creating cognitive dissonance, encouraging cost-benefit appraisals). Motivation strategies may encourage some reflection but do not target automatic decision making (by raising situational awareness). Assumption prevails that motivation is enough for securing behaviour change. No attempt is made to consider the	Attempts are made to appeal to personal motivations (e.g. by creating cognitive dissonance, encourage implications of risk taking on family/work mates etc.). Strategies may encourage some reflection but do not target automatic decision making (by raising situational awareness). Inclusion of techniques that helps translate motivation into action (e.g. by demonstrating that	Attempts are made to appeal to personal motivations (e.g. by creating cognitive dissonance, encourage implications of risk taking on family / work mates etc.). Strategies may encourage some reflection but do not target automatic decision making (by raising situational awareness). Inclusion of techniques that helps translate motivation into action (e.g. by demonstrating that	Attempts are made to appeal to personal motivations (e.g. by creating cognitive dissonance, encourage implications of risk taking on family / work mates etc.). Strategies may encourage some reflection but do not target automatic decision making (by raising situational awareness). Inclusion of techniques that helps translate motivation into action (e.g. by demonstrating that

		(before consideration of whether the job context is sufficiently ready).	transferability of any learning to the workplace. Behavioural observation techniques prematurely used (before consideration of whether the job context is sufficiently ready).	controls work to counter response efficacy, by action planning, contingency planning, goal setting). Behavioural observation techniques prematurely used (before consideration of whether the job context is sufficiently ready).	controls work to counter response efficacy, by action planning, contingency planning, goal setting). Inclusion of techniques with the potential to tackle automatic decision making (nudge, mindful safety). Behavioural observation techniques prematurely used (before consideration of whether the job context is sufficiently ready).	controls work to counter response efficacy, by action planning, contingency planning, goal setting). Inclusion of techniques with the potential to tackle automatic decision making (nudges, mindful safety). Context suitable for behavioural observation-based techniques. A suite of techniques are used for maintaining change (e.g. behavioural observation, trouble shooting workshops, refreshing messages, appropriate reward and recognition). Knowledge management techniques used to elicit useful knowledge from new recruits, assure business continuity etc.).

Delivery/Plan/Do check Act						
Assessment (leading and lagging indicators covered by organisational learning)	Suite of lead and lag indicators. Representativeness / generalisability. Reporting/ Under-reporting. Quality / reliability / validity / sensitivity / responsiveness. Basis on a model. Scope for plotting covariance (e.g. with productivity data). Controls / ability to eliminate alternative explanations / counterfactual / biases. Scope for process evaluation (understanding of why the interventions work).					
Monitoring check (active)	**Active:** routine inspections, health surveillance.	No proactive monitoring undertaken.	Intention to introduce proactive monitoring.	Proactive monitoring undertaken.	Proactive monitoring undertaken. Attend to low level signals.	Proactive monitoring undertaken. Attend to low level signals.

						‘Bad news’ actively sought.
Monitoring check (reactive) (Inclusive of shared responsibility)	**Reactive:** incident Investigation. Are accidents / incidents / near misses always reported? Are investigations done by multi-functional teams including operators where appropriate? Do investigations identify underlying causes and system failures not only immediate causes? Do investigations look for root causes (performance influencing factors)? Quality of investigations controlled through management arrangements e.g. training, guidance and quality insurance?	Accidents are an accepted feature. No discernible interest in identifying root causes. Managers / investigators focus almost exclusively on behavioural elements. Primary orientation around accountability and blame.	Accidents are seen as preventable. Some interest in identifying root causes for fatal / major accidents. Managers believe the majority are caused by rule breaking / employee ignorance / wilfulness. Primary orientation around accountability and blame. People learn about the incidents mainly via ‘the grapevine’.	Accidents are seen as preventable. Active attempts to identify root causes for fatal / major accidents / near misses. There are in-house staff trained in basic incident investigation skills. Stakeholders recognise the need to consider elements beyond immediate causes and behavioural components. The perspective accountability and blame extends beyond the ‘perpetrator’ / injured person. Learning is formally shared with some of the organisation.	Accidents are seen as preventable. Active attempts to identify root causes for fatal / major accidents / near misses. There are in-house staff trained in advanced incident investigation skills / external specialists engaged for high profile / consequence incidents. Stakeholders see value in looking beyond immediate causes and behavioural components. The significant focus is on learning and future prevention, rather than determining responsibility. The perspective on responsibility / accountability extends beyond the	Accidents are seen as preventable. Active attempts to identify root causes for fatal / major accidents / near misses. There are in-house staff trained in advanced incident investigation skills / external specialists engaged for high profile / consequence incidents. Checks are built in to ensure impartial accident investigation and reporting. Stakeholders see value in looking beyond immediate causes and behavioural components. The primary focus is on learning and future prevention, rather than determining responsibility.

					'perpetrator' / injured person. Learning is systematically shared across the organisation.	The perspective on responsibility / accountability extends beyond the 'perpetrator' / injured person. Learning is systematically shared across the organisation and throughout the supply chain.
Near misses (Inclusive of trust and shared Responsibility)	**Reactive:** near misses. Reporting systems. Confidentiality. Trust.	No system for near miss recording. No system for confidential reporting. Employee trust is low. The above – re-contractors / tenants.	There is an intention to introduce a system for near miss reporting. There is an intention to introduce a system for confidential reporting. Employee trust in engaging with managers over H&S issues is low. The above – re-contractors / tenants.	A system for near miss reporting is in place. A system for confidential reporting is in place. Employees exhibit significant trust and willingness to engage with managers on H&S issues. The above – re-contractors / tenants.	System for near miss reporting in place - and high quality data is gathered, appropriately analysed and used to inform decision making on risk control. System for confidential reporting in place - is used by employees, and produces useful, actionable evidence. Employees exhibit high trust and willingness to engage with H&S issues. The above – re-contractors / tenants.	A system for near miss reporting is in place - and high quality data is gathered and is actively used to inform decision making on risk control at a senior level. Confidential reporting system in place and produces useful, evidence that is acted upon to enhance risk control. Employees exhibit high trust and actively engage with managers on H&S issues.

						The above – re-contractors / tenants.
Act: organisational learning (Inclusive of assessment and review)	Internal. External / benchmarking. Proactive / reactive. Reliable dissemination of learning.	No systematic attempt to identify patterns in incident data. No formal root cause analysis of incidents. No lead indicators.	Some steps have been taken to identify patterns in incident data. Root cause analysis has been applied to a small number of headline incidents. Some consideration has been given to identifying a suite of lead indicators.	There is senior stakeholder recognition of the limitations of lag indicators and added value of lead indicators. Significant steps have been taken to identify patterns and trends in incident data. The product of the above is fed back to senior management. Root cause analysis has been applied to a significant proportion of headline incidents. A suite of lead indicators has been identified. Quantifiable benchmarks have been established for a defined suite of complementary lagging and leading indicators.	Significant steps taken to identify patterns and trends in incident data - including the use qualitative methods. Root cause analysis applied to all major and fatal accidents. A suite of lead indicators has been identified. Quantifiable benchmarks established for lag and lead indicators - with effective reliable measures of performance towards defined goals. The product of the above has been fed back to senior management - in a form that can be used to inform the decision making process, e.g. setting priorities for intervention and improvement.	Comprehensive approach to identify patterns and trends in incident data, including the use of qualitative data. Root cause analysis is applied to all fatal and major accidents. A suite of lead indicators has been identified - with appropriate defined KPIs. Quantifiable benchmarks established for lag and lead indicators - with reliable measures of performance towards defined goals. The product of the above has been fed back to senior management - with evidence of having impacted on the decision making process, e.g. setting priorities for

					Senior stakeholders see value in and use output from lead indicator data as indicators of safety management performance / progress towards improvement. Output from lead and lag indicators is used by safety professionals to identify priorities for intervention. Learning is systematically shared across the organisation.	intervention and improvement. Senior stakeholders place value in and use output from lead and lag indicator data as indicators of safety management performance / progress towards objectives and use the output to inform decision making over priorities for improvement. Output from lead and lag indicators is used to identity the focus for intervention (topic / location / function / personnel demographic) and options over nature of intervention. The organisation proactively engages with other organisations to share learning (e.g. via industry platforms).
Quality of evidence		Internal. External / benchmarking.			3. Three or more biases can be ruled out: selection, attrition, performance and detection; or theme saturation.	

	Proactive / reactive. Reliable dissemination of learning.	2. No more than two biases can be ruled out. Partial theme saturation. 1. Highly biased: No more than one bias can be ruled out or no theme saturation. N/A (E.g. management information)**.**

ANNEX C
STRENGTHS AND WEAKNESSES OF INFLUENTIAL BEHAVIOUR CHANGE PERSPECTIVES

This annex provides a description of key features, historical background, underpinning assumptions and recognised strength / weaknesses of some of the most widely applied behaviour change perspectives and techniques in the UK:

- behavioural / behaviour-based safety;
- workplace safety culture / climate;
- choice architecture (nudging), and
- (health) psychology social-cognition models.

A high proportion of workplace safety and risk interventions are most appropriately characterised as atheoretical; the safety culture / climate tradition being a notable case in point, i.e. they reflect a pragmatic perspective, informed by established scientific insights, but lack a definitive theoretical basis. This is in marked contrast to other behaviour change domains, many of which tend to be dominated by theory-based models that lend themselves to formal testing (see Dolan, 2012).

A great deal has been written on these topics, and there is insufficient scope within this document to provide a detailed review of influential contemporary behaviour change models (see Darnton, 2008). The following account aims to offer a summary of some of the key considerations and a commentary on recognised strengths and weakness of the more commonly encountered perspectives.

C.1 BEHAVIOURAL SAFETY

Behavioural safety, behaviour-based safety and behaviours modification (B.Mod)[13] are umbrella terms used to refer to an array of intervention tools and techniques that, in varying degrees, reflect the principles of applied behaviour analysis / behaviour modification. Rooted in foundation work within psychology, principally involving animals, a core assumption is that behaviour can be changed through conditioning and reward. The unit of change is, generally, at a group level, e.g. employees who share a common demographic (typically this is geographical e.g. a defined work site).

They are essentially an auditing activity, the theory of change relating using the output as a benchmark against which targets for improvement are set. Change rests with setting targets for improvement that are claimed to be reinforced though the setting of normative goals which are claimed to motivate employees' goals or other forms of reward, e.g. badges, lottery tickets, charitable donations (see Annex D).

Although originally conceived, and predominantly used, as a technique for addressing occupational safety issues, there is also potential to apply the approach to monitoring human factors elements of systems safety

[13] Note: An observation is that a significant proportion of the schemes and techniques that are currently marketed under the auspices of behavioural safety and behaviour modification have strayed some distance beyond what might reasonably be justified on the basis of the underpinning science.

issues in complex environments. Behavioural audit findings can also be used to monitor safety performance in order to inform managerial thinking over the need / priorities for intervention, and relatedly, as feedback on the effectiveness of live interventions (see Section 15). Indeed, there are grounds for concluding that there is a stronger case for using behavioural audit output for safety performance monitoring than as an adjunct to reward schemes aimed at motivating behaviour change.[14]

The prevalence of behaviours needs to be assessed through regular, repeated observation / recording, using demonstrably reliable measures (quantifiable check-lists) that are bespoke to the site. Meeting these criteria is important because:

(i) the higher the frequency of observations the lower the potential for random error; some sources recommend twice or three times per week.

(ii) observation criteria need to be clearly defined and tailored to the respective work-site to minimise the scope classification error so that the results from one observation can be reliable compared with the next.

(iii) checks need to be made that observers are using the check list in an equivalent way – minimising the number of observers/recorders is desirable.

More sophisticated approaches tend to focus on the antecedents of behaviour (e.g. equipment left in an unsafe condition, evidence of interlock having been defeated, shortages of personnel, etc.) rather than behaviour per se, as this broadens the array of elements that can be considered. It also reduces the potential for undesirable observation effects, i.e. personnel altering their behaviour due to becoming aware that they are being observed. For this reason, schemes that are based on the direct observation of a sample of individual employees tend to be of questionable utility.

A focus on antecedents (past behaviour) brings the more fundamental and desirable advantage of broadening the perspective on causality beyond the overt behaviour of front-line staff, to deeper issues e.g. condition of machinery, hazards within the built environment, insufficient supervision.

A focus on presenting (visible-overt) behaviour components alone e.g. use of personal protective equipment (PPE), compliance with rules, with the implicit undertones of individual accountability and blame, risks a superficial perspective. It is this partial focus that lies at the heart of the significant trades union opposition to behavioural safety programmes, that risks sullying the reputation of the behaviour safety / behaviour modification as a whole.

Arguably, the primary value of the technique lies in the safety function / senior manager's use of the arising data to highlight weaknesses that need addressing. Some schemes use the findings as material to feed back to staff in safety briefings, or to stimulate discussion over ameliorative action, whilst others actively involve employee representatives in setting targets for improvement. Ultimately, it is important not to lose sight of the fact that behavioural audits are nothing more than that, in and of themselves they do nothing to influence the behaviour of personnel; it is the use to which the data is put and arising interventions that embody the potential for improvement.

When used in conjunction with rewards, care needs to be exercised to select a system of reward that is appropriate to reinforce the behaviour(s) of interest, and which does not engender perverse motivations (see Annex D). There is much debate over the durability of change arising from behavioural safety and behaviour modification programmes, particularly after the point at which rewards are removed. The underpinning theory would suggest behaviour will revert to the pre-intervention level. While, there are claims

[14] Note**:** While one-off snap shot audits are sometimes branded as behavioural safety, and these have their own utility, they do not reflect the scientific premise (theory of change) that underpins the behavioural safety tradition and are most appropriately regarded as a separate enterprise.

of sustained change to produce positive shifts in workplace norms, such that they become a feature of an enhanced safety culture, robust evidence to substantiate this is sparse.

C.2 SAFETY CULTURE AND CLIMATE

The phrase safety culture is widely attributed to the IAEA analysis of the Chernobyl incident (INSAG4). However, the concepts of culture and climate were well established within wider organisational theory and research at that point.

The concepts of climate and culture are perhaps a little vague and opaque. Academics have spent considerable time attempting to distinguish between them, the product of which has arguably been to create more 'heat' than 'light'. Pragmatically, a useful working distinction can be to characterise climate as relating to contextual elements within both the sector e.g. prevailing market conditions, regulatory arrangements, and historical norms, and, not unrelatedly, structural and technological elements, safety systems, resources and operational priorities and similar within a given organisation. In this definition, climate contrasts with culture, this being cast as the shared psychological orientation(s) of managers and employees working within the respective climate, e.g. as reflected in leadership style, employee beliefs, attitudes, norms and practices.

The theoretical basis for the safety climate / culture perspectives is quite different from both behavioural safety and mainstream psychology motivation models of behaviour change. The principal differences can be summarised as the following:

- A focus on situational rather than individual (trait and dispositional) influences on employee behaviour;
- The premise that change can (and should) be achieved though changes to situational (social, technical and structural) elements that lie beyond the individual, and
- The premise that the realisation of change is the product of collective, rather than individual action.

Foundation work set out to:

- Identify a set of universal variables common to all organisations that represent the primary influences on safety culture / climate, and
- Refine the identified headline influences to produce employee survey tools with the capacity to benchmark and monitor change over time.

However, beyond the identification of senior management commitment and compliance with rules, findings revealed limited commonality across the different studies. This gives rise to at least two conclusions:

- findings reflect the different perspectives of the respective researchers / authors i.e. the topics / questions they included their surveys were simply different, or
- different climate and culture variables are relevant in different organisations.

The intervening period has witnessed the emergence of a significant array of climate / culture tools, of varying quality.

Conducting a safety climate survey is not an intervention. Climate surveys are barometers. Their contribution rests upon the use of the results, being used to inform thinking over setting priorities for improvement.

C.2.1 Limitations and potential pitfalls

The finding that the set of headline influences is prone to vary between sectors and organisations is in some tension with the ambitions of purveyors of commercially available tools, as an arising implication is that a generic tool may miss important context specific issues. In recognition of this, some sectors and organisations have begun to develop their own sector-specific tools.

While the output from climate / culture assessment tools is subjective, this does not render it problematic in relative terms, e.g. comparing one function or department with another, or evaluating change over time. However, it is important to keep in mind that responses to staff surveys (of all types) can be tinged with broader satisfaction or dissatisfaction with work and associated relationships.

Many users under-capitalise on their climate surveys, because they fail to give sufficient consideration at the planning stage regarding how they wish to explore differences in profile across their organisation. Traditional contrasts of gender, age and ethnicity, for example, may be of relevance, but under many circumstances are less useful to know than structural components, e.g. job grade, functional role, department / function, work-site. However, it is also important to keep in mind that too fine a degree of granularity (too small a sample) may preclude statistical testing of relationships. Too detailed a focus also risks inhibiting respondents, due to the fear of being identified (e.g. how many part-time, female supervisors might there be at site x, in department y, of age z?).

Climate and culture survey tools provide an indication of the status (relative positivity / negativity) for each of the constituent scales. However, they offer no indication of their relative importance. Other techniques need to be applied to determine this (see part 3).

C.3 CHOICE ARCHITECTURE PERSPECTIVES (NUDGES)

All human beings are prone to exhibit an array of systematic biases in their decision making, e.g. unrealistic optimism (overestimation of personal ability / skill relative to others); aversion to loss (particularly where this relates to highly valued objectives in the near future), and selecting long-odds options when faced with an otherwise certain loss. They are also prone to over-applying mental short cuts (heuristic rules of thumb), based on past success and / or as a reaction to complexity.

A key insight is that the manner in which options are presented can render the likelihood of individuals (and groups) exhibiting (non-rational) biases and recourse to heuristics is increased, i.e. situational elements interact with cognitive elements.

Recognition of the interaction between human decision-making traits / frailties and the configuration of choices that they face is not new science. However, the concept of ‘choice architecture’ is, and is intuitively useful in highlighting the role of context on human sense-making and decision-making, together with the implication that relevant influences are potentially malleable and reconfigurable to produce better, more desirable, choices on the part of decision makers - in the current context managers and employees.

Although influential authors such as Thaler and Sunstein have focused on public policy contexts, and offer modest comment on workplace applications, the concepts that they articulate are of no less relevance.

Critically, the nudge perspective represents a divergence from the traditional education deficit (the presumption that undesirable behaviour is the product of ignorance) and (health) psychology behaviour change models (increasing worry over personal vulnerability motivates change – see below); but reflects alignment with the safety climate / culture and human factors perspectives. Arguably, what the choice architecture perspective potentially brings to the safety and risk management arena is an intuitive means of characterising the interaction between features of work (structural, technical and psycho-social) and how

these have the potential to interact with cognitive elements (knowledge / sense-making, mental models of casualty, etc.).

Echoing the safety culture / climate perspective, the focus is not on the individual as the unit for change, per se, but on finding ways to engineer the context in which individuals operate, that take account of how individuals (cognitively) operate. It is not a rejection of, or necessarily incompatible with, individual motivational perspectives (see C.4), rather it is a supplement that lays claim to addressing more fundamental influences on decision making.

Recognition of the role of context as an important driver of behaviour sponsors the conclusion that resolution lies in redesign / reconfiguration of the choice environment i.e. its architecture. Work organisations and, in particular, their senior managers, play a key role as choice architects. Examples of relevant features of choice architecture include: organisational structure and functional / tribal rivalries; systems of reward (and sanction); relative priorities and availability / status of systems and resources; as well as cultural elements such as norms; openness; trust and blame.

C.4 (HEALTH) PSYCHOLOGY MODELS OF BEHAVIOUR CHANGE

The discipline of psychology offers an array of theoretical models of behaviour change. These have been widely applied in public policy and workplace contexts, notably in the area of lifestyle-health agendas, e.g. with the purpose of motivating healthy diet, physical activity and smoking cessation. To a lesser degree, they have also been applied to motivating self-protective behaviour within the occupational safety domain.

The list of psychology behaviour change models below is not exhaustive; its purpose is to make the reader aware of the headline assumptions and limitations of intervention tools and techniques of this type that they may encounter (e.g. when reviewing published findings or when considering marketed tools and techniques that claim to be based upon them). It is perhaps instructive to note that in a review of intervention practice, the National Institute for Health and Care Excellence (NICE) (2007) concluded that, despite claims of being rooted in these models, linkages are often rather tenuous, i.e. there is a tendency for their designers to over-claim in this respect.

Value expectancy models - principally the *Theory of reasoned action* (Fishbein and Ajzen, 1976); the *Theory of planned behaviour* (Ajzen, 1985); the *Health belief model* (Becker, 1974) and *Protection motivation theory* (Rogers, 1975). These characterise behaviour as a product of individuals weighing up the relative costs and benefits (in at least quasi-rational terms). Interventions in this area most commonly take the form of publicity / education / awareness raising programmes designed to make employees feel (more) vulnerable, the assumption being that this will motivate greater caution - particularly where the magnitude of consequences is high.

While these models vary in the degree to which situational barriers to the desired behaviour are taken account of, at a fundamental level they attempt to change individual orientation to an otherwise unchanged world. This is a primary contrast with the nudge, safety climate and human factors perspectives.

The theory of planned behaviour, for example, has nothing to say about the array of potentially important external variables that constrain individual volitional behaviour, e.g. availability of resources, time pressure, quality of rules and procedures.

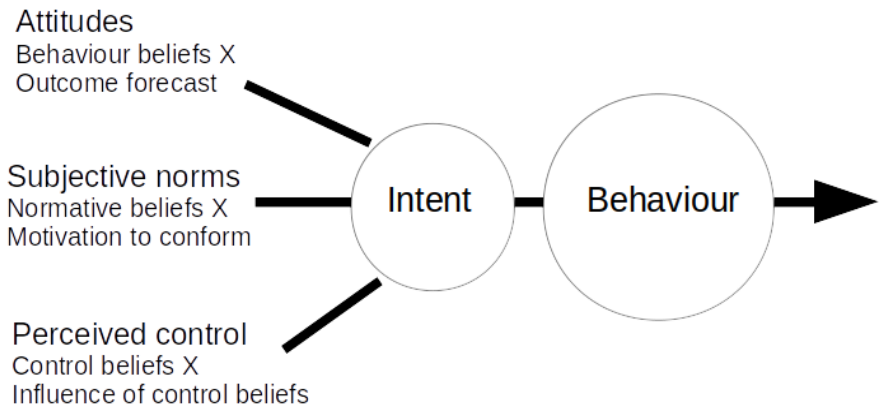


Figure 26: Theory of planned behaviour[15]

Stages of change models – characterise behaviour change as a linear series of cognitive stages that the individual passes through to achieve behaviour change, e.g. smoking cessation, wearing PPE. Interventions based on staged models hinge upon findings ways to support individuals as they travel along their pathway to change. The cognitive stages are typically cast as: pre-contemplation – contemplation – preparation – action, and sustained change. The *Trans theoretical model* (Prochaska and Di Clemente, 1986) and the *Health action process approach* (Schwarzer, 2008) are the most widely encountered. Weinstein's (1988) *Precaution-adoption process* is a functionally equivalent five stage model (becomes aware of the hazard – believes in susceptibility of others – acknowledges personal susceptibility – decides to take personal precaution – takes precaution). The stages of change approach benefits from a high intuitive appeal, which may go some way towards explaining the frequency of its application.

Echoing the safety culture maturity concept, success is held to be rooted in matching the approach to intervention (with each individual) with the stage that they are currently at (see DeJoy, 2010).

Both value expectancy and stages of change models assume that people are rational decision-makers motivated by utility maximisation (highest value / personal benefit). However, the evidence on cognitive biases (see Box 8, and Annex D) highlights that people are prone to make non-rational decisions. These (health) psychology models also tend to underplay the, often pervasive, role of situational influences on behaviour (e.g. systems of work and reward, cultural norms, and habituation effects). By analogy, consider the proportion of New Years' resolutions that flounder, despite good intentions.

More fundamentally still, they assume that the individual enjoys sufficient autonomy to be considered the master of their own destiny. In many workplace situations this is not the case, or at least the scope for such tends to be constrained to varying degrees, by external events and contingencies.

To date, neither of these types of change model have received widespread application in the health and safety domain, beyond elements relating to motivating lifestyle (health) change. However, occupational safety examples can be encountered, with respect to motivating self-protective behaviour. Despite claims to the contrary, the overwhelming evidence is that the magnitude and durability of impact ranges from modest to weak, tending to be further eroded with the passage of time (NICE, 2007).

[15] Source: http://johnnyholland.org/2011/01/24/the-a-b-c-of-behaviour/intent-behaviour/

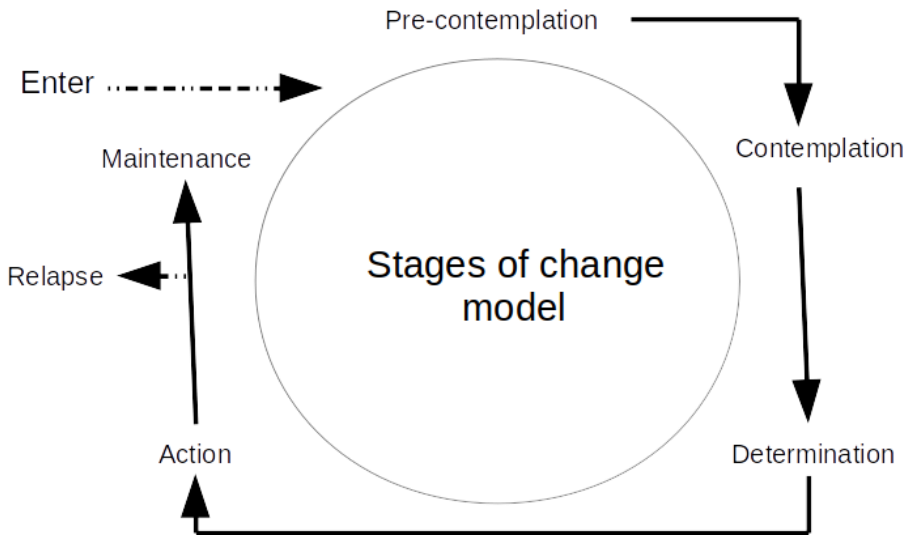


Figure 27: The stages of change conceptual model[16]

These, and similar models, share a theory of change rooted in the premise that increasing people's awareness of risk and attempting to make them feel vulnerable to the negative consequences of undesired outcomes will motivate attitude change that will lead to a positive change in behaviour. Established social and cultural norms (observation and imitation of the behaviour of others) are typically characterised as barriers to change.

Primary criticisms of the health behaviour change models surround claims that they:

- overplay rationality and autonomy (choice);
- overplay the degree to which attitude change translates to behaviour change;
- are too focused on individual orientations, underplaying structural barriers to change, and
- similarly, underplay social and cultural (particularly normative) counter influences.

16 Source: http://johnnyholland.org/2011/01/24/the-a-b-c-of-behaviour/intent-behaviour/

ANNEX D
TRAINING AND COMMUNICATION INTERVENTIONS

Training and communication interventions functionally relate to skills acquisition (expertise), awareness raising and plugging knowledge gaps in employee mental models of causality.

Skills acquisition - at a basal level relates to sufficiency of expertise to perform a defined role. Under most circumstances this is likely to prove sufficient. However, it can also be important that employees possess an effective conceptual appreciation and understanding of their contribution to the wider productive process. This can be acutely important where the consequences of their actions have implications for the safety of others and the integrity of systems, as well as the capacity to recognise the implications of anomalies that they may encounter, either during the course of their work or incidentally.

The latter can be important from the perspective of organisational resilience. For this reason, as highlighted by Weick (1991), there may be merit in training that extends beyond basic sufficiency to perform a defined role. In practical terms, job / task appraisal might usefully include consideration of the extent to which there may be value in providing operatives with a more conceptual appreciation of how the system operates and threats to its integrity and arising safety implications, i.e. a transformation from what have been characterised as 'programmed' to 'concept' operatives. The effectiveness and completeness of near-miss reporting, for example, in part rests upon the capacity to recognise what constitutes a near miss and its implications.

Characterising individuals / roles as those that can be performed by concept or programmed operators can offer a useful distinct characterisation. Employees' mental models can be important (see Box 7). The concept of a mental model (Craik, 1943) relates to how individuals make sense of their world, specifically their conception of which variables are salient in a given context and how they interact. This includes issues relating to how systems operate, including functionality and causality. Of central interest for psychologists and human factors specialists is discovering how employees believe systems they interact with operate in order to discover the extent to which these may be incomplete, partial or otherwise inaccurate. For example, when faced with complex systems, understandings will tend to be more impressionistic, with staff disposed to fall back on intuitions and heuristic rules of thumb (refer to Annex C).

Awareness raising - while embodying elements of skill acquisition, awareness raising routinely reflect the ambition to motivate some level of change in employee behaviour. Potential pitfalls surround the tendency towards over-optimism on the part of senior managers that raising awareness will be sufficient, in and of itself, to motivate a change in employee orientation, particularly where it is assumed that the behaviour in question is the product of knowledge deficit. Awareness raising has a role, but examples of instances where volitional risk taking occurs in the presence of substantially complete knowledge are routinely encountered in work organisations.

Mental models - discovering and mapping employees' mental models of how systems function, and the related safety implications, is frequently revealing, and represents an important foundation step in the process of plugging knowledge gaps. The mental models approach to training and education in risk relates to knowledge transfer, rather than motivational elements, per se. Rather, it is based on the recognition that conceptual deficiencies may lead to even the most highly-motivated and engaged employees missing important things, misinterpreting the information they are presented with, or behaving in ways that may present to others as non-rational. A simple example, drawn from the occupational safety domain, is of electricians aware of the risk posed by asbestos donning a dust mask in the erroneous belief that this will offer sufficient respiratory protection.

Organisations and their managers are more prone to telling employees what we believe they **need** to know, based on the premise that this is known (by educators), rather than charactering employees' extant

knowledge (and misunderstandings) in the first instance and tailoring communication content to plug detected gaps and shortfalls.

Failure to do this risks redundancy in communication content (telling people things they already know), omission of material relating to important gaps and misunderstandings and relatedly, where a one-size fits all approach is adopted, leads to lost opportunities to tailor content to the needs to different segments of the workforce.

Intervention logic considerations

Assuming that the configuration of message content is optimised through good practice in its development, e.g. taking account of insights from the mental models perspective and broader insights on effective communication (see, for example Covello, 2004), the pathway from message transmission to behaviour change is perhaps usefully construed as passing through an array of filters:

- **Penetration** - even when well targeted, the communication is unlikely to reach all relevant individuals. Careful planning and an evidence-informed perspective on transmission pathways is needed.
- **Dispositional effects** - some groups of employees may be (culturally) more receptive than others.
- **Locus of control** - there may be differences between groups of employees over their latitude to act on the content.
- **Relevance** - the message content must be relevant and appropriately focused and of a good fit with the physical and social context in which the receiver works.

Where the objective of the communication intervention is to alter individuals' orientation to an otherwise unaltered environment (see Annex C), under a wide array of circumstances, rates of sustained behaviour change can be predicted to be modest. The science surrounding foreseeable metrics of impact is far from exacting. For illustrative purposes, Figure 28 offers a heuristic of the potential rate of attrition relating to the proportion of individuals who receive the message and that are likely to make sustained changes to their behaviour. In the absence of complementary activity that addresses more fundamental issues, it is prudent to assume that, under a wide array of circumstances, this will be low.

A salient reflective question, therefore, when reconsidering the merits of a communication intervention is: ‘will the foreseeable proportion of individuals who change their behaviour as a result make a sufficient difference to render the intervention worthwhile?’

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Target group receiving the message

Message raises awareness

Message content contains new & previously unknown material

Message engenders more positive beliefs

Message fosters more positive attitudes

Enhanced intention to change behaviour

Initial change in behaviour

Sustained behaviour change

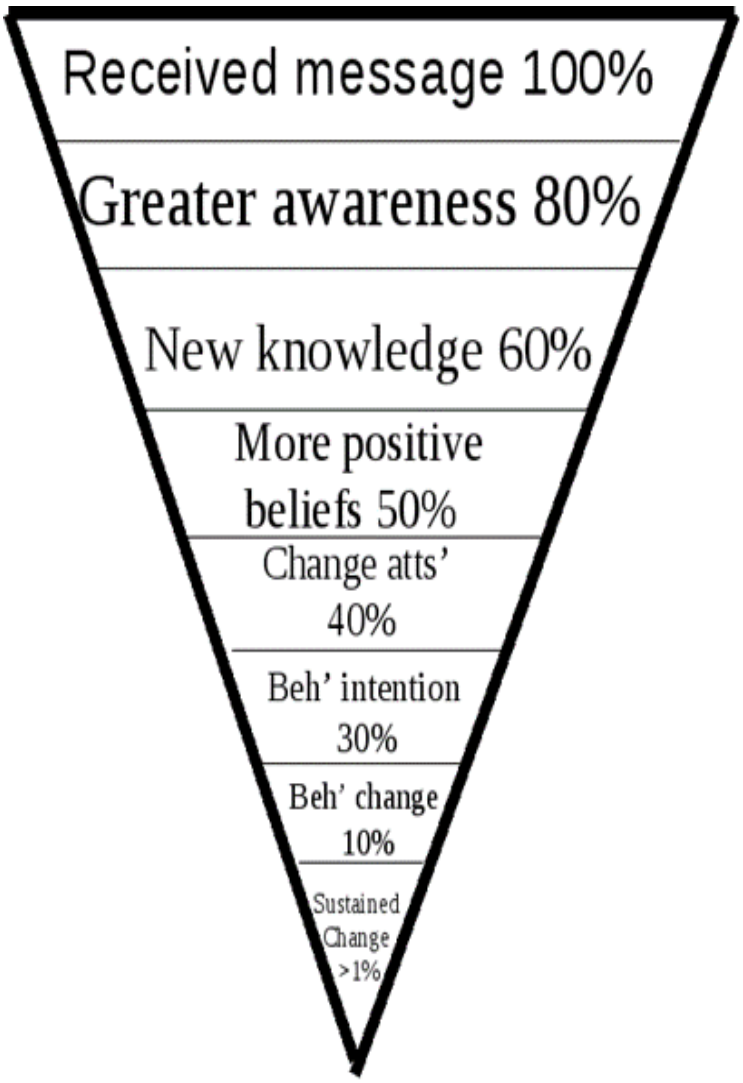

Figure 28: Communication impacts on behaviour - rate of attrition a heuristic model (Weyman et al 2012)

ANNEX E
INCENTIVES AND REWARD SCHEMES

E.1 INTRODUCTION
Annex E is broken down as following: General principles; desirable, and undesirable features (in Box 13).

E.2 GENERAL PRINCIPLES
Incentives are rewards and have been used with the aim of motivating employees and recognising effort since the earliest days of industrialisation. More routinely ascribed to productivity related performance, they are now widely applied within the safety domain, where proponents claim major gains in safety performance.

By contrast, detractors cast them in terms of bribery and superficiality, emphasising the propensity for ill-conceived rewards to engender perverse motivations, e.g. suppression of incident / near-miss reporting; inducements to save time by sponsoring safety rule infringement, etc.

Contemporary HSE guidance stresses the need to reward safe behaviour e.g. procedural compliance, and specific safe behaviours, but does not endorse rewarding non-events, e.g. accident free periods, reductions in number of lost time accidents (LTAs) etc. that are only weakly linked to individual motivation.

Much of the evidence relating to claims of positive impacts on safety behaviour emanates from non-peer reviewed practitioner publications and on-line sources, rather than peer reviewed accounts. The balance of evidence from peer reviewed sources gives rise to the conclusion that impacts tend to be short lived. However, there are grounds for concluding that appropriately configured incentives can play a useful role as component of a broader programme of activity aimed at raising the profile of the safety agenda.

For example:

- encouraging employees (and groups of employees) to follow health and safety procedures;
- rewarding employees who exhibit outstanding or desired levels of health and safety performance;
- rewarding employees who actively support / contribute to a creating a positive health and safety culture;
- encouraging participation in safety initiatives, e.g. climate surveys; safety committees, and
- rewarding measured improvements / goal achievement in (group) safety performance, e.g. based on behavioural audit data.

When designing reward schemes, a key consideration relates to the theory of change i.e. the mechanism by which the reward is assumed to impact on employee behaviour. Many schemes encountered are weak in this area. At the most fundamental level, the reward needs to be sufficiently attractive to employees to motivate some change in behaviour.

Financial incentives are perhaps the most intuitive reward, but other forms of effort / performance recognition can also be effective. Setting achievable goals for improvement can motivate even in the absence of tangible rewards. Rewards can also relate to third parties, e.g. charity donations. But in all cases at the planning stage, it is wise to find out what is attractive to the target employees in a given context, rather than basing this on best guesses. High value / highly valued rewards are more prone to engendering perverse motivations e.g. under-reporting of incidents, than low value rewards.

Rewards can be ascribed to whole sites, individual managers, management teams, supervisors and groups of front-line employees and individual workers. However, it is important to ensure that rewards further up the hierarchy do not engender perverse motivations on the part of managers and supervisors, and that rewards relate to good practice and not simply good fortune (see Part 3).

E.3 DESIRABLE AND UNDESIRABLE FEATURES

This section provides a summary of review findings relating to desirable and undesirable features of safety reward and incentive schemes (based on Reviews by Weyman [1999] and Marlow [2005h]).

E.3.1 Desirable

Individuals - rewards for individuals that are in direct proportion to personal effort work best in motivational terms (but may be more challenging to configure).

Teams - rewards that are ascribed to small teams can bring useful peer-policing gains, but tend to work better with cohesive teams with stable membership, i.e. they are unlikely to work well with teams of casual labour.

Lead indicators - a focus on positive (lead), rather than negative components (lag) of safety, counters undesirable under-reporting motivations engendered by the latter. Rewards that relate to objective change / improvement in reducing risk, e.g. standards of housekeeping in a defined area which a defined group of employees has designated responsibility or levels of compliance with PPE rules, for a defined (usually less than 10 individuals) work team, and similar. However, it is important that the assessment criteria are viewed by employees as fair and objective. There is scope for linking this type of scheme to antecedent-type behavioural audits.

Standards - rewards that relate to recognition of incremental improvement, or achievement of defined standards, are potentially less problematic than league tables (see E.3.2)*.*

Recognition - beyond point of work behavioural components, there is scope to recognise and reward employee continuations to the safety agenda through involvement, e.g. in safety committees or topic specific working groups, and through contribution to safety suggestion schemes, and similar.

Feedback - the provision of feedback to employees on progress towards defined objectives can be a positive feature and have a positive impact on motivation, but is dependent on the direction of travel, i.e. if performance is falling this can have a negative impact. Additionally, the feedback should be at a level of specificity that is meaningful to those who receive it. Broadly speaking the more locally referenced the better, i.e. feedback on 'your' team, shift, or function, possibly extending to 'your' site is likely to have a more positive impact than on corporate level data.

Safety and health - reward schemes are more commonly encountered with respect to safety performance, but can also be applied to aspects of occupational health, health monitoring and lifestyle health elements.

E.3.2 Undesirable

Large groups - rewards ascribed to large group of loosely coupled employees tend to have limited impact on motivating individual employees, i.e. there is a risk of free-rider effects.

Good fortune - rewards, the receipt of which owes more to happenstance than effort are not useful, particularly where they do not relate to specific behaviours, e.g. accident free week or month, etc.

Lag indicators - rewards relating to decreases in accident / sickness absence rate, if sufficiently attractive, will tend to suppress reporting. This has implications for employee wellbeing, but also for organisational learning and resilience. Almost all respected sources strongly caution against reward in relation to reduced incident rates.

Lotteries - rewards in the form of raffle tickets / lottery tickets and variations on this, even when referenced to high value prizes are poor in individual motivational terms. Receipt of a lottery ticket with a slim prospect of winning an electric toaster, or similar, is unlikely to give rise to significant behaviour change. One-off prizes can be appropriate, e.g. relating to ad-hoc activities, but will have a very brief

effect.

League tables - e.g. relating to achievement of improvement goals (or accident free periods) can promote competition, which can enhance motivation. But competitions of all types involve more losers than winners. If the same individual or groups win all or most of the time, others are prone to quickly lose interest. They can also sponsor disharmony over accusations of unfairness and cheating.

Box-ticking - rewards (and performance indicators) that relate to rates of completion of safety procedural components e.g. rates of delivery of tool box talks, completion of point-of-work / ad-hoc risk assessments should be carefully considered with respect to their potential to engender self-serving behaviours on the part of those responsible for their delivery. While such targets will likely be met, their contribution to safety improvement and resilience is questionable.

ANNEX F
OUTLINES OF EVENTS STUDIED

This Annex provides very brief descriptions of each of the events investigated and identifies in outline some of the key organisational and cultural factors which were present. These accounts do not present mitigating factors and the full range of factors involved, and readers are encouraged to read the referenced event investigation reports and the summaries contained within them, to obtain a fuller account of the events and the causal factors involved.

F.1 PORT OF RAMSGATE WALKWAY COLLAPSE

On 14 September 1994, part of a walkway at the Port of Ramsgate in the UK collapsed. Six passengers were killed and seven seriously injured. The walkway was in three sections:

a) from shore to a floating pontoon, which was supported on a portal frame;

b) across the pontoon, and

c) from the pontoon to a docked ferry.

The end of the section from shore to the pontoon failed because of an inadequate weld securing the end of a stub axle to the walkway. Investigation by the HSE showed that the design did not provide the support and articulation necessary. Estimates of loadings on the stub axles were inadequate and there was a failure to consider the effects of fatigue.

Among the findings of the investigation of the event (HSE, *Walkway collapse at Port Ramsgate: A report on the investigation*) were the following:

a) The project proceeded with very great haste (no contract papers were completed) and vital information was not provided to the designer and was not pursued.

b) Overall, there was an absence of suitable arrangements for project management and supporting systems - including QA, with the client failing to act as an intelligent and competent customer for the work.

c) In addition to other aspects of unsatisfactory leadership and a generally poor safety culture, warning signs of likely failure were not heeded and faults in input data and fabrication not identified. No maintenance procedures were requested or made available.

d) There was a lack of liaison (communication) between client, designer, fabricator and a 'classification society' whose primary role it was to certify the structure. There was also a failure to keep records of decisions etc. and the role of the classification society was not made clear to the parties involved.

e) Checks on calculations and assumptions were not satisfactorily carried out (lack of oversight).

f) A risk assessment was not performed.

F.2 HEATHROW EXPRESS NATM TUNNEL COLLAPSE DURING CONSTRUCTION

A serious event occurred in October 1994 when tunnels being constructed under the central terminal area at Heathrow Airport collapsed, exposing the workforce and the public to 'grave risk'. Workers were evacuated only minutes before the collapse. By great good fortune, nobody was injured, but extensive disruption ensued with major consequent costs. A new technique for tunnelling in London clay known as the 'new Austrian tunnelling method' (NATM) was being used for the construction. An HSE investigation found that the direct causes of the collapse were substandard construction of a section of the tunnel over a period of three months, the use of a process called grout jacking which damaged the same length of tunnel, together with inadequately associated repairs and the construction of a parallel tunnel in failing ground (HSE, *Collapse of NATM tunnels at Heathrow Airport. A report on the investigation by the HSE into the collapse of new Austrian tunnelling method (NATM) tunnels at the Central Terminal area of Heathrow Airport on 20/21 October 1994*).

The investigation found that the accident 'had all the hallmarks of an organisational accident'. The following inadequacies were among those identified:

a) failures in 'defensive' systems that did not deal adequately with hazard identification and control of risks;

b) poor design and planning;

c) a lack of quality during construction;

d) a lack of engineering control;

e) poor safety management;

f) unsatisfactory communication and reporting processes led to the views of the workforce not being sought and heard and,

g) weaknesses in competence in various roles.

In addition, HSE pointed to several major lessons that could be learnt from the shortcomings leading to the event, including:

a) the need for the risks of major accidents to be addressed;

b) the requirement for more rigorous understanding and assessment before adopting new or unfamiliar technologies;

c) the need to take into account organisational and human factors issues when designing management systems;

d) the need to balance production pressures by defensive precautionary systems and,

e) the importance of high levels of commitment to health and safety and effective communication with the workforce.

F.3 LONGFORD GAS PLANT EXPLOSION

On 25 September 1998, a major explosion at the Longford gas plant in Australia killed two men, injured eight others and cut off Melbourne's gas supply for two weeks. The plant took gas from platforms in the Bass Strait, together with hydrocarbons, liquids and water. It removed the water, most of the liquefiable components and the small amount of hydrogen sulphide which was present. Separation occurred through a series of heating, cooling and pressure changes. Occasionally, variations in the mixture coming ashore caused disturbances in operating conditions. This accident occurred when a significant variation, coupled with a failed automatic valve, led to a major build-up of condensate. As part of the process control, pumps shut down automatically, leading to reduced oil flow and operators were unable to restart them. As a result, a 14-tonne heat exchanger became extremely cold. Operators then reintroduced warm oil, leading to catastrophic brittle fracture, an explosion, and a fire.

The book by Hopkins provides very valuable insights into the event but since it was not an 'official' report, it has not been used as a source for the current study (Hopkins, *Lessons from Longford: The Esso gas plant explosion*). The event was investigated by a Royal Commission (Royal Commission, *The Esso Longford gas plant accident: Report of the Longford Royal Commission*). Many of the conclusions are also presented in the State Coroner's Report (State Coroner Victoria*, Inquest into the deaths of Peter Brubeck Wilson and John Francis Lowery and the fire at Longford gas plant number 1*). They concluded that organisational and cultural factors were important, including issues relating to:

a) weaknesses in risk assessment;

b) a lack of effectiveness of audit and oversight and leadership review of standards;

c) inadequate levels of competence;

d) insufficient monitoring and response to information about system status (e.g. tolerance of alarms);

e) communication issues, including during shift handover;

f) the impact of organisational change, with cuts in staff numbers and other changes which included the possible effect of moving engineering support staff away from the plant to a separate location some distance away;

g) shortcomings in the SMS and,

h) poor reporting of process upsets and a failure to learn from previous events. It appears that occupational safety performance was good, but the same concentration on process safety was not apparent.

F.4 TOKAI-MURA CRITICALITY ACCIDENT

This criticality accident occurred on 30 September 1999, at a Uranium reprocessing plant at Tokaimura in Japan. Two operators involved in plant operations were killed by the radiation released by the criticality and a third was highly irradiated but survived. Evacuation within a 350 m radius of the plant took place and sheltering was required within a 10 km radius. The accident was the first serious nuclear-related accident ever experienced in Japan and the consequences to the Japanese nuclear industry (for example in a reduction in the trust of the general public), were considerable. The operators were dissolving fuel in stainless steel buckets and then by-passing equipment designed to preclude criticality and pouring the material into a large mixing vessel through a funnel. The fuel on this occasion was at a much higher fissile content than the operators were used to working with, and the 16.6 kg of uranium material became critical, resulting in a large release of radiation.

Findings of IAEA (*IAEA, Report on the preliminary fact-finding mission following the accident at the nuclear fuel processing facility in Tokaimura, Japan, 26 November 1999*) and Nuclear Regulatory Commission (NRC) (US Nuclear Regulatory Commission, Safeguards, D of F.C.S, *NRC review of the Tokai-mura criticality accident*) reviews of the event identified significant organisational and cultural precursors. These included:

a) managerial ‘neglect’ of an ‘orphan plant’;

b) poor risk assessment;

c) failures to act conservatively in setting and following procedures with poor supervisory control and communication with the operators;

d) shortfalls in training and competence;

e) deficiencies in internal and regulatory oversight;

f) a SMS which had been changed without the application of adequate safeguards.

The 'neglect' of the plant/process requirements appeared to result from the fact that the process being used was no longer regarded as a mainstream commercial activity and, since the time that it had been, major resource reductions in the company had occurred. It is interesting to note that Tokaimura again had a good occupational safety record and took product quality seriously. It appears that this may have again given false confidence regarding process safety.

F.5 HATFIELD RAILWAY ACCIDENT

On 17 October 2000, an intercity passenger train travelling between London and Leeds derailed near Hatfield station, north of London. As a result, four passengers were killed and over seventy were injured, including four seriously. The subsequent Office of Rail and Road (ORR) investigation (Office of Rail Regulation, *Train derailment at Hatfield: A final report by the Independent Investigation Board*) found that the immediate cause of the derailment was the fracture and subsequent fragmentation of the rail at a curve in the line. This was due to the presence of multiple and pre-existing fatigue cracks in the rail.

The investigation findings included the following:

a) The maintenance contractor failed to manage effectively the inspection and maintenance of the rail in accordance with industry standards.

b) The infrastructure controller failed to manage effectively the contractor, and also failed to implement an effective rail renewal operation.

c) The event particularly highlighted issues relating to risk management. It had become increasingly obvious that risks were unacceptably high but, perhaps partly because of commercial pressures and as a result of major organisational changes, nobody took responsibility and ensured that risks were reduced to acceptable levels.

d) A failure to heed warnings and act in the light of a potentially serious deficiency.

e) A lack of conservative decision making, reinforced by failures in leadership, competence, communication and oversight.

F.6 DAVIS BESSE PRESSURE VESSEL CORROSION EVENT

In March 2002, the staff at Davis Besse Nuclear Power Station (DBNPS) in the USA discovered a 'football sized' cavity in the reactor pressure vessel (RPV) head during an outage. Only a thin internal liner of stainless steel cladding remained at the pressure boundary. This was not designed to withstand the primary circuit pressure. They found that several RPV vessel head penetration nozzles had cracked and leakage of borated water from one of these was the source of the corrosion of the carbon steel RPV head. The plant had remained in operation, and inspection of the plant had been deferred despite a thick boric acid deposit having built upon the head. The problem of cracking was a well-known phenomenon and both the regulator (the U.S. Nuclear Regulatory Commission, NRC) and industry body had recognised that it required licensee attention. The subsequent NRC inquiry (US Nuclear Regulatory Commission, *Davis-Besse reactor vessel head degradation lessons-learned task force report*) into the event concluded that the licensee had failed to resolve long-standing leaks, did not implement a boric acid corrosion control programme, and had not adequately implemented industry guidance and NRC recommendations.

The NRC also concluded that the event had occurred because of a wide range of broader issues including:

a) strained engineering resources and an approach which addressed symptoms rather than causes;

b) a long-standing acceptance of degraded plant;

c) a lack of management involvement and questioning attitude, together with a lack of engineering rigour;

d) a lack of awareness of external experience - and a failure to address the lessons learned from past events;

e) ineffective and untimely corrective actions and an inability to recognise or address a recurring problem;

f) ineffective self-assessment of safety performance;

g) weaknesses in response to - and implementation of - employee concerns, and

h) a lack of compliance with procedures.

F.7 LOSS OF SHUTTLE COLUMBIA

The mechanical causes of the Columbia Shuttle disaster are now well known. In brief, during the launch, a small piece of insulating foam (about the size of a laptop) and weighing less than a kilogram, came off an external tank and collided at about 500 mph with the leading edge of the left-wing of the orbiter. As a result of the damage caused, the shuttle overheated and disintegrated on re-entry to the earth's atmosphere, whilst travelling at 14,000 mph and at a height of 205,000 feet. The crew of seven were killed. Some 84,000 pieces of debris were recovered. Fortunately, nobody on the ground was injured, but as the debris (hitting the ground at 10,000 mph) dropped 70 miles north (over Dallas/Fort Worth), the consequences could have been much worse.

The independent inquiry into the disaster (Columbia Accident Investigation Board, *Columbia Accident Investigation Board report*) concluded that 'NASA's organizational culture had as much to do with this accident as the foam did'. Organisational and cultural issues were in some respects similar to those of the Challenger disaster in 1986. Among the issues found were the following:

a) NASA had become 'reactive, complacent and dominated by unjustified optimism'. For example, requests to examine the leading edge in flight were denied. A culture existed which required those raising concerns to prove that it was unsafe rather than the reverse.

b) NASA did not provide effective checks and balances.

c) Communication was ineffective (with resistance to new information).

d) NASA did not have an effective independent safety programme, and had not demonstrated the characteristics of a learning organisation.

e) An issue (foam hitting the wing) that had once been seen as a significant safety risk had been 'normalised' over time into a maintenance issue.

f) External pressures to meet schedules and the impact of organisational changes (such as the greater use of contractors and the loss of in-house expertise), had significantly increased prior to the disaster.

F.8 PAKS NUCLEAR PLANT FUEL CLEANING EVENT

Paks nuclear power station in Hungary had been experiencing an accumulation of corrosion deposits in the primary circuit of its units. Magnetite deposits on fuel cladding had reduced flow through coolant channels, thus affecting heat transfer to the coolant and leading to a reduction in output and potential safety implications. In October 2002, it was decided to build an ex-core cleaning system on a considerably increased scale compared with an earlier test. A very aggressive schedule agreed with the assigned contractor sought to have the new system designed, installed and ready for use by March 2003. In December 2002, a preliminary design was submitted to the regulator with a request for urgent action, and about a month later a license was granted with only one regulatory comment on the safety analysis. After one successful cleaning run, on 10 April 2003, fuel assemblies were again transferred to the newly installed fuel cleaning tank. At the end of the subsequent cleaning process, the assemblies were left in-situ and the tank was not opened within the timescale designated by the assigned procedure. Radiation alarms then sounded within the reactor hall and staff were evacuated. It was assumed that a fuel assembly was leaking, but several days later, pictures revealed that most of the fuel had suffered significant damage. Analysis showed a range of design deficiencies, including an inadequately sized pump; wrong assumptions about coolant flows in a flawed thermo-hydraulic analysis for the scaled-up design which was cleaning 'hot' fuel straight from the reactor (unlike an earlier small scale test); inadequate instrumentation and, poorly communicated and understood arrangements for lifting the tank head.

An investigation by the IAEA (*Report of the expert mission conducted under the IAEA technical co-operation project*) revealed indicative 'safety management and safety culture weaknesses'. These included the following:

a) The responsibility for operation of the fuel cleaning system was turned over to the contractor, despite the fact that safe operation required an interface with - and depended upon - plant systems.

b) The aggressive schedule for an unproven system led to a safety (risk) assessment which was not rigorous and was not subject to conservative decision making.

c) The operational and emergency procedures were not reviewed and approved by the client, and procedures relating to the lifting of the tank head and for positioning fuel assemblies were inadequate.

d) Problems in implementing procedural requirements were not reported and addressed - indicating a poor reporting culture.

e) There was no challenge of the design or operation of the fuel cleaning system, even though analysis showed that boiling could occur in only nine minutes.

f) There was poor communication and inadequacies in training, and these reduced the ability of the plant to act as a learning organisation.

F.9 TEXAS CITY OIL REFINERY EXPLOSION

This event has been a major source of learning and has been the subject of three comprehensive investigations. On 23 March 2005, a distillation column overflowed during the start-up of an isomerisation unit. This occurred as a result of known faulty equipment, misleading and inadequate information, inadequate communication, poor use of procedures and a lack of competent supervision and oversight during the process. Liquid hydrocarbons vented through a blowdown stack into the atmosphere and the consequent large flammable vapour cloud was ignited by a nearby vehicle. This led to a series of explosions and fires killing 15 workers and injuring 180. It also led to offsite damage and was also very costly, both in direct business terms and in reputational damage.

From the many organisational and cultural issues which were identified as precursors to the accident, the Baker Panel (Baker et al, *The report of the BP U.S. refineries independent safety review panel*) emphasised:

a) the need for improved safety leadership, with process safety as a core value. There was a high turnover of refinery managers and sometimes inadequate resources combined with 'initiative overload' within a weak management of change system;

b) failure to provide an integrated and comprehensive SMS;

c) the need for greater process safety competence;

d) a requirement for improvements in process safety culture - including greater operating 'discipline' and the need to develop a trusting, positive and open environment;

e) clearer expectations and accountabilities and better support to line management and,

f) the need for better process safety performance indicators, more effective auditing, and more effective board monitoring within a longer-term focus.

A US Chemical Safety Board (CSB) Study (Chemical Safety Hazards Investigation Board, 2007, *Investigation report: Refinery explosion and fire*) identified similar issues. Key organisational findings included:

a) cost-cutting and failure to invest, together with production pressures and the failure to address the impact of organisational change;

b) lack of a reporting and learning culture;

c) a failure to respond to deficiencies (e.g. long-standing mechanical integrity and instrumentation shortcomings), with a response that was 'too little, too late' with a lack of focus on controlling major hazard risks, and

d) a dysfunctional safety culture with a 'check the box' mentality (even when requirements had not been met).

BP also published an open, very informative and wide-ranging report (Mogford, J, *Fatal accident investigation report - Isomerization unit explosion final report*) which highlighted among other things:

a) a working environment in which trust and motivation had eroded, with resistance to change;

b) poor reporting, hazard identification and upward communication of safety issues with adequate 'challenge';

c) significant failures to follow procedures which were not updated and appeared not to be regarded as important, together with a lack of awareness of company standards;

d) a lack of rigour and follow-through in training;

e) audits which appeared to ignore the history of previous incidents and near-hits;

f) acceptance of high process safety risks and a general inability to see them;

g) poor supervision (lack of role models) and handover provision and,

h) a lack of accountability, unclear roles and responsibilities within a complex, siloed, inward-looking organisation.

BP rightly prided itself on an excellent occupational safety record and this may have, again, provided false confidence regarding process safety.

F.10 LOSS OF CONTAINMENT AT THE THORP SELLAFIELD REPROCESSING PLANT

In April 2005, British Nuclear Group Sellafield (BNGSL) discovered a leak from a pipe that supplied highly radioactive liquor to an adjacent cell. Approximately 83,000 litres of liquor had leaked onto the floor of the cell. It was estimated that the leak had remained undiscovered for about eight months because leak detection equipment was not in working order and there had been a failure to follow operating instructions. The most likely cause was fatigue failure from the swinging motion of the suspended tank during an agitation process which was part of normal operation. This resulted from 'design inconsistencies' and a modification which overlooked the impact on pipework and which was not subject to an adequate risk assessment.

The HSE carried out an investigation (HSE, *Report of the investigation into the leak of dissolver product liquor at the thermal oxide reprocessing plant (THORP), Sellafield*) leading to 55 recommendations. In summary, findings and recommendations that were relevant to this report included:

a) changes to design had not been risk assessed by competent assessors;

b) alarms were ignored, non-compliance with procedures were allowed, and there was a failure to keep the plant in working order;

c) there was the lack of a questioning attitude and 'challenge' (failure to regard a leak as credible in a new plant which was viewed as being very well-designed);

d) a deficient associated safety culture - with senior managers not setting an example;

e) a lack of training of the workforce so that they did not understand key precautions, why relevant procedures were necessary, and why related 'workarounds' were unacceptable;

f) shortcomings in arrangements, roles and responsibilities;

g) questions about the effectiveness of monitoring, audit, and review and,

h) a failure to learn from previous events using a structured system which implemented learning and was supported by reviews of effectiveness.

F.11 BUNCEFIELD FUEL STORAGE EXPLOSION

A delivery of unleaded petrol was in progress at the Buncefield oil storage depot in Hertfordshire, UK in December 2005. The receiving tank (holding six million litres) overflowed and the resulting vapour cloud ignited leading to a major explosion. Because it was early on a Sunday morning there were many fewer casualties than might have occurred at other times, but although there were no fatalities, forty people were injured. The ensuing fire was 'the largest in the UK in peacetime' and 'the devastation was enormous'. Because fuel and fire-fighting chemicals flowed from leaking bunds, significant environmental contamination occurred. The report into the event concluded that 'the environmental, social and economic toll was considerable'. During the filling operation, an automatic tank gauging system 'flat-lined' and could not record the tank levels. The control room supervisor was not alerted to the situation. Furthermore, an independent high-level switch was inoperable and had been 'sticking' for some time. Thus, automatic shutdown did not occur.

A wide range of organisational and cultural deficiencies were identified by the inquiry into the event (jointly, the HSE, the Environment Agency [EA] and the Scottish Environmental Protection Agency [SEPA]) (*The Buncefield incident, 11 December 2005 - The final report of the major incident investigation board*). These were judged to reinforce findings from Texas city and Longford. Among the key issues identified were:

a) a lack of clear and positive process safety leadership with the necessary competence. A joint venture corporate structure led to insufficient board involvement in which leaders did not apply effective control, with insufficient time and resources made available;

b) growing working pressures on staff and increasing throughput, together with a lack of clear information and inadequate management of change provisions;

c) management systems which were both deficient and not properly followed;

d) a culture which did not encourage the detection of signals of failure with a sufficiently quick and effective response, together with a lack of a questioning attitude;

e) lack of a clear understanding of major accident risks (there was again a concentration on occupational safety), with risk control processes that were inadequate;

f) supplier inputs were taken for granted and the client did not act as an intelligent customer;

g) communication at shift handover was poor and,

h) auditing on the SMS and its application, and board oversight were not effective.

F.12 LOSS OF THE NIMROD XV230 AIRCRAFT

A Royal Air Force (RAF) Nimrod aircraft (XV230) was lost in September 2006 on a mission over Afghanistan as a result of a catastrophic fire. It led to the deaths of the fourteen personnel on board. A full investigation of the causes of the accident at the accident site had to be curtailed for military reasons, but some limited information was obtained. An internal board of inquiry was held followed by an independent in-depth inquiry led by Charles Haddon-Cave QC (*The Nimrod review - An independent review into the broader issues surrounding the loss of the RAF Nimrod MR2 aircraft XV230 in Afghanistan in 2006*). This concluded that the most likely cause of the loss was an escape of fuel during air-to-air refuelling, with the cross-feed/SCP duct acting as the ignition source. The Haddon-Cave report presented a comprehensive discussion of the potential physical causes of the loss, together with a detailed analysis of the organisational and cultural issues involved. Many similarities to other disasters were noted (e.g. Columbia and Texas City). The title of the inquiry report includes the phrase 'A failure of leadership, culture and priorities' and an important quote of relevance is 'The importance of investigating and understanding the organisational causes of accidents cannot be overstated' (page 459).

Of the very large amount of material contained in the Haddon-Cave report of relevance to this document, the following points are particularly relevant:

a) There was 'insufficient leadership' and an 'overview' was not taken. There was also a lack of management attention, supervision and oversight.

b) Major organisational changes, many arising from changes to defence provision, had led to ever-reducing resources with increasing demands affecting safety and a failure to prioritise.

c) The safety culture was deficient with 'can do: will do' becoming 'make do'. The culture was process dependent and relied on box-ticking - leading to a safety culture 'which does not work'.

d) The development of the safety case was very poor ('a lamentable job') and no overall risk assessment was carried out.

e) There were many concerns regarding contractor interfaces (including procurement), failure to act as an intelligent customer, and management and communication shortcomings.

f) The SMS (airworthiness) was of 'byzantine complexity'.

g) Competence and learning issues were not adequately addressed.

ANNEX G
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ANNEX H
ABBREVIATIONS AND ACCRONYMS

Acronym	Definition
ACSNI	Advisory Committee on the Safety of Nuclear Installations
AEB	evolution and barrier function
ALARP	as low as reasonably practicable
BNGSL	British Nuclear Group Sellafield
CLD	causal loop diagram
CLM	causal loop modelling
COM-B	capability, opportunity, motivation and behaviour model
CREAM	cognitive reliability error analysis method
CSB	U.S. Chemical Safety Board
DBNPS	Davis Besse Nuclear Power Station
EA	Environment Agency
EI	Energy Institute
FMEA	failure modes and effects analysis
FRAM	functional resonance analysis method
GMB	group model building
HAZOP	Hazard and operability study
HMSO	Her Majesty's Stationery Office
HR	Human resource
HRA	human reliability analysis
HRO	High reliability organisation
HSC	Health and Safety Commission
HSE	Health and Safety Executive
IAEA	International Atomic Energy Agency
IOSH	Institution of Occupational Safety and Health
ISO	International Organization of Standardization
IT	information technology
KPI	key performance indicator

Acronym	Definition
LOPA	layers of protection analysis
NASA	National Aeronautics and Space Administration
NATM	new Austrian tunnelling method
NICE	National Institute for Health and Care Excellence
NRC	Nuclear Regulatory Commission
OE	operational experience system
OH	occupational health
ONR	Office for Nuclear Regulation
ORR	Office of Rail and Road
PPE	personal protective equipment
PRA	probabilistic risk assessment
QA	Quality assurance
QMS	quality management system
QRA	qualitative risk assessment
RAF	Royal Air Force
RCA	root cause analysis
RIDDOR	Reporting of Injuries, Diseases and Dangerous Occurrences Regulations 2013
RPV	reactor pressure vessel
SEPA	Scottish Environmental Protection Agency
SMS	safety management system
SQEP	suitably qualified and experienced
STAMP	systems-theoretic accident model and processes
THORP	thermal oxide reprocessing plant
UK	United Kingdom
US	United States (of America)
USA	United States of America