Barriers to learning from incidents and accidents

ESReDA guidelines

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ESReDA Project Group *Dynamic Learning as the Follow-up from Accident Investigations*

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Executive summary

This document provides an overview of knowledge concerning **barriers to learning from incidents** and accidents. It focuses on learning from accident investigations, public inquiries and operational experience feedback, in industrial sectors that are exposed to major accident hazards. The document discusses learning at organizational, cross-organizational and societal levels (impact on regulations and standards). From an operational standpoint, the document aims to help practitioners to identify opportunities for improving their event learning process. It should be useful in the context of a process review of your organization's learning system. Finally, it suggests a number of practices and organizational features that facilitate learning.

The main messages of the document are summarized below:

- Learning from unwanted events, incidents and accidents, in particular at an organizational level, is not as trivial as sometimes thought. Several steps are required to achieve learning: reporting, analysis, planning corrective actions, implementing corrective actions, and monitoring their effectiveness. Obstacles may appear within each step, and learning is not effective unless every step is completed. The obstacles may be technical, organizational or cultural.

- Learning from incidents, both as a formal company process and as an informal workgroup activity, is an opportunity for dialogue and collaborative learning across work groups and organizations. There may be few other channels for communication on safety issues between industrial companies, subcontractors, labour representatives, regulators and inspectors, legislators and interested members of the public, but these actors need to work together more effectively on common problems.

- The implementation of an effective experience feedback process provides a strategic window for improving company equipment, operating procedures and organizational characteristics in an integrated manner, allowing different perspectives to converge towards better preparation for the next event.

- There are known symptoms of failure to learn, which you may be able to recognize within your organization thanks to the diagnostic questions suggested in chapter 3.

- Symptoms of failure to learn often point to an underlying pathogenic condition (or a combination thereof) afflicting the culture of the organization. A number of known pathogenic organizational factors have been discussed in chapter 4.

- Experience from a number of industries which have a long history of incident reporting and learning shows that a number of enablers can overcome obstacles to learning. Chapter 5 provides a list of enablers that may be applicable in your industry and organization.

Table of contents

1 Introduction

1.1 This document's objectives

The present document provides an overview of knowledge concerning the **barriers to learning from incidents** and accidents. It focuses on learning from accident investigations, public inquiries and operational experience feedback, in industrial sectors that are exposed to major accident hazards, but many of the principles are more widely applicable[1]. While most research on learning focuses on individual cognition, the focus in this document is mainly on **learning at an organizational level**, while also taking into account a **cross-organizational and even societal/cultural level**. It concerns both **organizational learning** (the flow of lessons into new practices and modified procedures) and **policy learning** (impact of lessons on public policy, law, regulations and standards). The document also suggests a number of good practices or organizational conditions, which have been shown, in certain situations, to **overcome obstacles to learning**.

From an operational standpoint, the document aims to help practitioners to identify opportunities for improving their event learning process. It should be useful in the context of a process review of your organization's learning system. Finally, it suggests a number of practices and organizational features that facilitate learning.

1.2 Target audience

The messages in this document primarily concern investigators and practitioners in industrial sectors with significant hazards, such as the process industries, energy and transport. The document is addressed primarily to:

- people who carry out safety investigations;
- people who manage operational experience feedback, including company HSE specialists, consultants, and safety inspectors in national safety boards;
- experts involved in developing the regulatory and legal framework of safety-critical activities;
- safety researchers and experts in academic and expertise organizations.

and more generally, to anyone who is interested by or involved in learning from incidents and accidents to improve safety.

The document analyses barriers to learning at various levels in a socio-technical system (see figure 1 below), within companies with hazardous activities, trade associations and professional bodies, insurers, regulators, and at the government level, as well as *multi-level learning*, which involves the identification of deficiencies and the implementation of changes that affect multiple system levels.

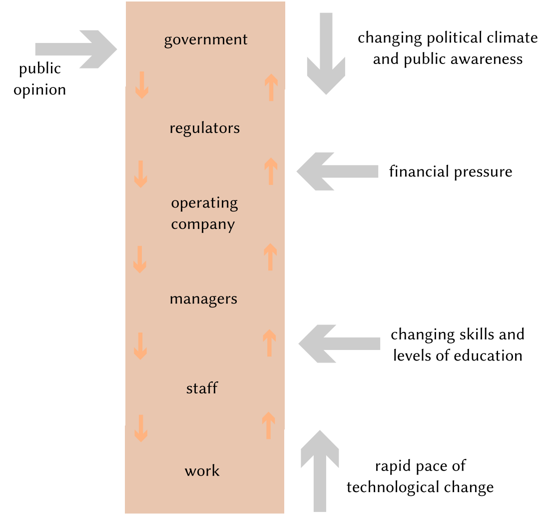

Figure 1: Structural hierarchy of actors in a complex socio-technical system, adapted from [Rasmussen, 1997]

[1] *Concerning applications in healthcare, see [Tucker and Edmondson, 2003, Wrigstad et al., 2014].*

We assume that the reader is familiar with accident investigation and experience feedback systems (learning from events), and do not attempt to replicate existing overview documents and guidance on these areas. The following documents provide useful background material:

- *Investigating accidents and incidents*, UK HSE, ISBN 978-0717628278, freely downloadable from http://www.hse.gov.uk/pubns/priced/hsg245.pdf (a step-by-step guide to investigations)
- C. W. Johnson, *Failure in Safety-Critical Systems: A Handbook of Accident and Incident Reporting*, University of Glasgow Press, Glasgow, Scotland, October 2003, ISBN 0-85261-784-4. Available online at http://www.dcs.gla.ac.uk/~johnson/book/.
- *Guidelines for safety investigation of accidents* (ESReDA, 2009), freely available from http://www.esreda.org/Portals/31/ESReDA_GLSIA_Final_June_2009_For_Download.pdf
- *Shaping public safety investigations of accidents in Europe* (ESReDA, 2005), ISBN: 978-8251503044, 183 pages.

1.3 Structure of this document

Chapter 2 on *Learning from incidents and accidents* provides an introduction to knowledge on learning, focussing in particular on organizational learning.

Chapter 3 on *Symptoms of failure to learn* proposes a number of conditions which may be observed in an organization and which suggest that learning opportunities are being missed.

Chapter 4 on *Learning pathologies* analyzes a number of underlying conditions within an organization which may contribute to failure to learn. The learning pathologies can be thought of as *underlying conditions* which can contribute to failure to learn. The chapter attempts to link these pathologies to some of the symptoms which an interested observer could identify.

Chapter 5 concerns enablers or promoters of learning, and provides a list of mechanisms or organizational practices which have been shown to facilitate learning and to tackle some of the learning pathologies identified in chapter 4.

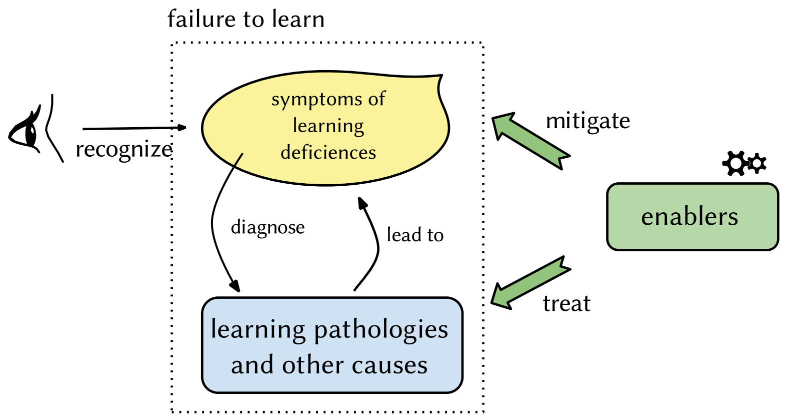

Figure 2: Structure of this document

Figure 2 above proposes an illustration of the medical metaphors (symptoms, pathologies, diagnosis) used in this document and their relationship with failure to learn. Please note that these metaphors are not intended to be read literally, but rather as an aid to understanding.

1.4 Authors

The ESReDA Project *Group Dynamic Learning as the Follow-up from Accident Investigations* (PG DLAI) stands in a tradition of consecutive projects exploring several aspects of accident investigation and of a series of seminars transferring knowledge and opening new perspectives of domains to be explored and studied.

The main objective of the Project Group has been to establish recommendations on how to capture, document, disseminate and implement insights, recommendations and experiences obtained in investigations of high-risk events (accident and near-misses, concerning both safety and security) to relevant stakeholders:

1. Proposing adaptation of investigation methods to specific features of each sector and aimed at facilitating more impact;
2. Identifying barriers within companies, public authorities and other involved stakeholders that may hamper implementation of recommended preventive measures;
3. Providing methods for dynamic learning from accidents;
4. Highlighting good practices on how to develop recommendations from accident investigation findings and understanding relevant preconditions for future learning (resilience, learning culture);
5. Providing decision-makers with advice regarding operational experience feedback systems.

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ESReDA, the European Safety, Reliability and Data Association, is a non-profit European association that provides a forum for the exchange of information, data and current research in Safety and Reliability. The safety and reliability of processes and products are topics which are the focus of increasing European wide interest. Safety and reliability engineering is viewed as being an important component in the design of a system. However the discipline and its tools and methods are still evolving and expertise and knowledge are dispersed throughout Europe. There is a need to pool the resources and knowledge within Europe and ESReDA provides the means to achieve this.

For more information: www.esreda.org.

1.5 Using this document

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2 Introduction to learning from incidents and accidents

This chapter introduces some background information and research into learning, organizational learning and dynamic learning from incidents and accidents.

Learning is a very general concept, with strong links to both performance (in a changing world, learning is a source of comparative advantage for individuals and for organizations) and organizational culture (culture can be thought of as the accumulation of prior learning based on past successes and failures). In this document, we focus on learning from incidents and accidents, a specific source of data, understanding and knowledge which serves a number of purposes:

- The understanding gained concerning the causal factors of unwanted events can allow preventive and mitigating measures to be put in place;
- The feedback to people's mental models of system safety allows the improvement of their safety behaviour;
- The reliability data collected concerning failure typologies and event frequencies is an essential input to the risk analysis process and provides inputs to safety performance indicators.

Learning from incidents and accidents is of special importance in high-hazard organizations, since they cannot allow themselves to learn in a traditional trial-and-error manner, and must avoid the complacency that can arise from learning only from successes. In fact, "what distinguishes reliability-enhancing organizations, is not their absolute error or accident rate, but their effective management of innately risky technologies through organisational control of both hazard and probability…" [Rochlin, 1993]. As stated by S. Sagan in his analysis of the safety of the US nuclear weapons programme, "*the social costs of accidents make learning very important; the politics of blame, however, make learning very difficult*" [Sagan, 1994].

2.1 Learning within organizations

The term *learning* is generally used to refer to an *individual* human activity. A famous quote of T. Kletz states that "Organizations have no memory. Only people have memory and they move on" [Kletz, 1993], embodying a view of learning as the processes of thinking and remembering that take place within an *individual*'s brain. However, a significant body of research over the last forty years suggests that it is useful also to think of *organizations* as having learning potential, in the sense that they have adaptive capacity and can incorporate knowledge in system artefacts (equipment, design rules, operating procedures, databases, documents) and organizational structure in order to improve their performance.

Researchers in disciplines ranging from management theory and organization studies to psychology have proposed multiple definitions of "organizational learning" [Jerez-Gómez et al., 2005]:

- the process within the organization by which knowledge about action-outcome relationships and the effect of the environment on these relationships is developed [Duncan and Weiss, 1979];
- the process through which organizations encode inferences from history into routine behaviour [Levitt and March, 1988];
- a dynamic process based on knowledge acquisition, information distribution, information interpretation, and organizational memory, which implies moving among the different levels of action, going from the individual to the group level, and then to the organizational level and back again [Huber, 1991].

This variety in definitions has led to a certain amount of conceptual fragmentation, but means that the practitioner can draw insights from research in a variety of scientific fields.

Nonaka and Takeuchi [Nonaka and Takeuchi, 1995] identified four steps within the transfer of knowledge from individuals to groups:

1 **socialization**: converting collective tacit knowledge[2] into individual tacit knowledge, by knowledge interexchange through communication, observation or practice.

2 **externalization**: converting individual tacit knowledge into individual explicit knowledge, through the use of metaphors, concepts or models.

3 **combination**: converting individual explicit knowledge into collective explicit knowledge, for instance by analyzing documents or by thinking.

4 **internalization**: converting collective explicit knowledge into collective tacit knowledge, through learning or knowledge assimilation processes.

Single and double-loop learning

A well-known distinction in the organizational learning literature is between so called 'single-loop' and 'double-loop' learning. Single-loop learning is based on detecting and correcting errors, within a given set of governing variables, leading to incremental change. If an organization exhibits single-loop learning, only the specific situation or processes which were involved in the incident are improved. When an organization exhibits double-loop learning, improvements are not limited to the specific situation; the values, assumptions and policies that led to actions in the first place are also questioned [Argyris and Schön, 1978, Argyris and Schön, 1996]. An important kind of double-loop learning is the learning through which the members of an organization may discover and modify the learning system. This "learning to learn" process (called *deutero learning* by Argyris & Schön) enables an organization continuously to improve [Senge et al., 1990].

[2] *Tacit knowledge (the opposite of formal or codified knowledge) is a kind of knowledge which is difficult to share with another person only with words (written or oral); it reflects the notion that "we know more than we can tell".*

2.2 Learning and knowledge

Learning from accidents is the acquisition of knowledge and skills from a thorough study of accidents and their antecedents. The knowledge acquired may concern the types of unwanted events which may occur, the factors that can contribute to these unwanted events, the barriers which can prevent their occurrence, the possible consequences of the unwanted events, and the protective measures which can limit the consequences of the events. The knowledge can also concern the factors that allow organizations to function effectively and to adapt to changes in demand and in their environment.

At an organizational level, the learning may be embedded within:

- organizational beliefs and assumptions: culturally accepted; worldviews about the system (what hazards are present, what risks are important, what is normal, what is taken for granted, what should be ignored[3]);
- organizational routines, procedures and regulations (precautionary norms);
- organizational structure and relationships within organizations within the sociotechnical system;
- the design of equipment and implementation of technologies within the sociotechnical system;
- the knowledge of people working within or interacting with the sociotechnical system.

2.3 Learning from catastrophes, incidents and anomalies

There is learning potential in events of various degrees of severity:

- **Catastrophes**: significant system failures attract attention from managers, regulators and outside stakeholders, and generate significant pressure to investigate, understand and implement changes (though

[3] *D. Vaughan's book on the Challenger space shuttle accident points out that NASA's culture "provided a way of seeing that was simultaneously a way of not seeing" [Vaughan, 1996, p.392].*

unfortunately, this attention is often relatively short-lived). There can be an implicit assumption that "a big accident must have been caused by a big mistake", accompanied by pressure to identify the person responsible for that "human error". The regulator may require the organization to hold a detailed investigation, or the legal system may put its own inquiry in place.

Large accidents provide resources. They allow the preventive and protective systems to be analyzed in detail. They may also provide impetus for change (including to the regulatory system, which tends to be resistant to evolution). However, they are (luckily!) infrequent in most high-hazard systems, so we cannot wait for such events to learn and trigger improvements, but must look for learning elsewhere.

- **Incidents**: within high-hazard organizations, operational experience feedback systems have been developed to analyze in a systematic manner anomalies, deviations from procedure, and unwanted events. If well implemented, these experience feedback systems allow learning from events which did not escalate to a catastrophic level of impact. Experience feedback also allows the detection of potentially dangerous underlying trends.

  The number of events of this type is much greater than catastrophic events, providing more data for learning. However, it may be more difficult to obtain a level of organizational goodwill that is sufficient to justify significant changes to the sociotechnical system.

- **Anomalies** and minor perturbations: many high-performance technical systems include routine online system performance monitoring and anomaly recording. Although this data is generally collected for quality control and production optimization, it may also be analyzed as a source of safety improvements.

  The degree of severity and attention raised by the event which triggers the investigation, analysis and learning will affect the resources available for analysis and the level of leverage to implement system changes. These factors will also lead to different biases in people's reactions to the investigation.

2.4 Learning from both success and failure

Safety investigations are classically launched in reaction to large and visible system failures (catastrophic accidents). These investigations focus on what went wrong, with an underlying assumption that safety is achieved by reducing the number of adverse events. Typical characteristics of these investigations are a search for underlying failures and malfunctions and an organized attempt to eliminate their causes and improve safety barriers [Hollnagel, 2014].

Researchers such as B. Wilpert refer to the "gift of failure" present in serious events and accidents [Hale et al., 1997]. In short, events offer an opportunity to learn about safe and unsafe operations, to generate productive conversations across engaged stakeholders, and to bring about beneficial changes to technology, organization and mental models (understanding). [Llory, 1996] argues that accidents are the "royal road" (referring to Freud's metaphor about dreams being the royal road to access the unconscious) to access the real functioning of organizations (especially hidden phenomena, the "dark side" of organizations referred to by [Vaughan, 1999]). The authors add that these lessons can be capitalized in the form of a *knowledge of accidents* and transferred as a *culture of accidents* in order to counterbalance work on safety culture, which the authors argue is excessively focused on best practices [Dien et al., 2012].

An alternative source of learning is to focus on "what goes right", and learn from success through the study of **normal operations**. This way of thinking sees safety as a result of the ability to succeed despite varying performance demands and environmental variability. Through audits and observation of work, in which organizational experts examine how real work is undertaken at the "sharp end", how routine deviations are detected and managed by operators, a better understanding of the system features that contribute to resilience, performance and safety is developed. This work may include the identification of "good practice".

Research in this area includes the High Reliability Organizations and the resilience engineering schools of thought on system safety.

These lessons from success and from failure may be of different natures, and most often are complementary.

There is a wide variety of methods available to investigate and to analyze accidents. A number of studies have been published which list, compare and classify accident analysis methods (for instance [Sklet, 2002, Qureshi et al., 2006, Qureshi, 2008, Kontogiannis et al., 2000, Le Coze, 2008]). The goal of incident analysis is gaining understanding of the origin of an event in order to determine options for improvement: i.e., the lessons learned. All events, such as accidents, disasters or near misses provide valuable information to learn from. Regardless of the severity of the outcome, similar causes can lead to different incidents. Therefore, to prevent future incidents, the factors that have contributed to the incident and the barriers that have failed to prevent the occurrence need to be identified and addressed. [Lampel et al., 2009] named the learning in which precedents of events are determined or so-called lessons learned are identified “learning *about* events” instead of learning *from* events.

2.5 Learning from others

The “hard lessons” one faces directly are easier for individuals to remember and have been a key factor in motivating people and organizations to take some actions to avoid the recurrence of a similar event.

However, another key driving force for learning, has been to learn from *other’s* hard lessons [Llory, 1996, Llory, 1999, Dien and Llory, 2004, Hayes and Hopkins, 2012, Paltrinieri et al., 2012]. This indirect form of learning is called *observational* or *vicarious* learning by learning theorists.

The exchange of lessons from accidents has been promoted across several industries for many years. For example, the civil aviation sector shares knowledge using the international databases are ADREP, the nuclear industry (under the umbrella of IAEA, WANO, EU) manages a number of databases, and the process industry in Europe shares knowledge via the Major Accident Reporting System - eMARS at JRC-Ispra and the Hydrogen Incident and Accident Database - HIAD at JRC-Petten.

This learning is inter-organizational, between countries, and sometimes between industrial sectors, especially with disaster cases. This transversal learning is inherently difficult, in particular because it is necessary to translate events to one’s operating environment and compensate for the loss of context which is unavoidable when describing what happens in complex systems [Koornneef, 2000].

2.6 Learning as a process

The aim of learning lessons through analyzing events is to identify possibilities for improvement. Several stepwise models have been developed that present learning as a *process* that starts with anomaly detection and reporting, continues to event analysis and establishment of recommendations, concluding with the practical application of the lessons learned (such as [Drupsteen et al., 2013, Jacobsson, 2011, Kjellén, 2000, Lindberg et al., 2010]). “These models include determining the lessons learned but also a follow-up on these lessons. For successful learning, the information that is handled at all steps of the learning process needs to be sufficiently detailed and of high quality” [Jacobsson et al., 2010].

The Chain of Accident Investigation (CHAIN) model [Lindberg et al., 2010] comprises 5 steps for learning from experience: reporting, selection of incidents for further investigation, investigation, dissemination of results and finally the actual prevention of accidents. This process should also be self-reflective and include evaluation activities that lead to improvement of the process itself. The typical learning cycle, according to [Jacobsson et al., 2010], includes data collection and reporting, analysis and evaluation, decisions, implementations and follow-up. This cycle is derived from the safety, health and environment (SHE) information system of Kjéllen [Kjellén, 2000]. [Drupsteen et al., 2013] also describe learning from events as an organizational process. In this process events such as incidents are analyzed and used to improve the organization and to prevent future occurrences. The ‘learning from events process’ is modelled as five sequential stages:

1 reporting a situation

2 analyzing the situation

3 making plans for improvement

4 performing those plans

5 evaluating their effect and the learning process itself.

2.7 Dynamic learning

The world is changing, so safety requires continual adaptation. Learning is not a one-time act, but is an ongoing process in which the organization (and society, culture, *etc.*) continually improves and adapts to new conditions. It includes *unlearning* existing ways of work, procedures, processes and behaviour. The counterpart to dynamic learning is static, one-off learning.

2.8 Levels of learning

A study by [Cedergren and Petersen, 2011] describes a categorization of accident causes in three hierarchical levels, based on the models of [Rasmussen, 1997] and [Sklet, 2004]. In accordance with the suggestion by [Stoop, 1990], the levels are labeled micro-, meso- and macro-levels. The highest level (the macrolevel) includes factors related to inter-organizational aspects, regulatory bodies, inspectorates, associations and even governments [Rasmussen and Svedung, 2000]. The next level (the mesolevel) includes organizational aspects such as management issues and other intra-organisational factors, whereas the lowest level (the microlevel) includes equipment, actor activities, and physical processes [Rasmussen and Svedung, 2000].

[Hovden et al., 2011] combine two meanings of "*multilevel learning*":

1. the level where learning is supposed to take place (micro, meso or macro level);
2. how learning takes place within and between these levels.

An example where several lessons were identified at different levels of the sociotechnical system (as classified by [Rasmussen, 1997]) is the Toulouse disaster ([Dechy et al., 2004], a case described in the ESReDA Cube report which is a companion document to this document). A second example involves the US Chemical Safety and Investigation Board (CSB), which integrated learning concerning investigation methodology from the Columbia Accident Investigation Board (CAIB). The CSB adopted the organizational investigation model developed by the CAIB during its investigation into the disintegration of the Columbia space shuttle in 2003 [CAIB, 2003]. A third example is the Fukushima-Daiichi disaster, which by its extent, has pushed several industries in multiple countries to review scenarios of technological disasters triggered by natural hazards, and also worst case scenarios beyond the design basis.

3 Symptoms of failure to learn

In this chapter, we describe a number of **symptoms of failure to learn**: behaviours or features of an organization or of a society which may suggest the existence of a "learning disease" and which can be observed by people working within the system, for example during a review of the event-analysis process, or by people external to the system, such as accident investigators. The aim is to help a person recognize "we may be running into symptom λ…", by suggesting a number of "diagnostic questions". This document also suggests a number of possible **pathogens** (underlying organizational conditions, which are detailed in chapter 4), which may be linked to each symptom.

Note that some barriers to learning (organizational or cultural issues which contribute to learning deficiencies) may be difficult to classify as a symptom or as a pathogen; we invite readers not to remain fixated on this distinction, which we use primarily to provide a first level of structure for this document.

People sometimes assume that learning has occurred once an event has been analyzed and lessons have been drawn from it. This omits an important component of learning, that of **change** (in system design, in organizational structure, in behaviour). Analysis is not learning. Learning includes both understanding and action. If the system has not changed and no one behaves differently, learning has not occurred. If new behaviours are not accompanied by new understandings, then learning cannot be robust and sustainable across time and ever-changing circumstances.

The symptoms described in this chapter are generally not the result of explicit decisions to disregard safety concerns, but arise over time as a result of organizational drift[4]. For instance, complexity can appear in a progressive manner over time, without any explicit objective to introduce it.

[4] *When facing pressure towards cost-effectiveness in aggressive, competitive environments, organizations tend to migrate towards the limits of acceptable performance. This phenomenon, called organizational drift, is generated by normal incremental processes of reconciling differential pressures on an organization (efficiency, capacity utilization, safety) against a background of uncertain technology and imperfect knowledge and the absence of a global view of system safety.*

3.1 Under-reporting

Voluntary incident reporting systems often suffer from chronic under-reporting or under-logging, in which incidents are simply never reported. This means that opportunities to learn are missed. It can lead to mistaken confidence in the safety of one's system ("admire our low recordable incident rate!"). If the repository of reported events is used for statistical analyses (analyzing trends in safety-related indicators, deciding on priorities for future investments in safety equipment or organizational changes…), the analyses will be affected by epidemiological biases[5].

Under-reporting can be caused by:

- a blame culture (see box below) and the fear of reprisals;
- concern that incident reports will be used in litigation or interpreted in a negative way in performance assessments;
- **perverse incentives** which reward people for the absence of incidents. For instance, performance bonuses linked to the rate of occupational safety accidents and safety challenges such as "1000 days without an accident in the facility" constitute negative incentives for reporting incidents;
- a feeling that the event learning process is not useful to shop floor ("sharp end") workers, who may see it as mainly aimed at providing statistics for managers, instead of as a source of learning and safety improvement which provides benefits to all;
- insufficient **time available for reporting**: if people have to report during breaks or after hours, under-reporting is more likely;
- uncertainty as to which events should be reported (scope or perimeter of the reporting system);
- insufficient feedback to reporters on lessons learned from the incident report, and the absence of visible system changes linked to safety

[5] *Information bias in epidemiology arises from measurement error or from selection bias in observations, and can lead to incorrect conclusions being drawn from the observations.*

reports (reporting system seen as a “black hole”, with doubts as to whether time and effort invested in reporting is well spent);

- deficiencies in the reporting tool (too complex, inappropriate event typologies…);
- a belief that accidents are “normal” in certain lines of work [Pransky et al., 1999];
- insufficient promotion by management of the importance of incident reporting and the safety benefits it generates.

More generally, there is evidence that under-reporting of safety-related incidents is affected by the organizational safety climate [Probst et al., 2008].

A blame culture

A blame culture over-emphasizes the fault and responsibility of the individual directly involved in the incident (who “made the mistake”), rather than identifying causal factors related to the system, organization or management process that enabled or encouraged the mistake. Organizations should instead aim to establish a “just culture”, an atmosphere of trust in which people are encouraged, even rewarded, for providing essential safety-related information (including concerning mistakes made), but in which they are also clear about where the line must be drawn between acceptable and unacceptable behaviour[6].

As stated in [Dekker, 2007]:
“Responses to incidents and accidents that are seen as unjust can impede safety investigations, promote fear rather than mindfulness in people who do safety-critical work, make organizations more bureaucratic rather than more careful, and cultivate professional secrecy, evasion, and self-protection. A just culture is critical for the creation of a safety culture. Without reporting of failures and problems, without openness and information sharing, a safety culture cannot flourish.”

[6] *Just culture proponents do not suggest that the notion of blame is entirely negative for safety; indeed, the link between responsibility and accountability motivates individuals and organizations to analyze their activities and their possible consequences. In many organizations, however, the negative features of blame are insufficiently recognized and defended against.*

Concerning incidents of a technical or technological nature, under-reporting can be abated by the implementation of automated reporting systems. For example, the frequency of the undesirable event *signal passed at danger* in the railway sector can be measured using automated systems, as a complement to reports made by train drivers. Automated reports are likely to be more numerous, but provide less contextual information than a report made by a human. They also raise the risk of “false positives”, which require additional investigative effort in order to identify them.

Beyond under-reporting in the organization’s internal event database(s), the level of reporting to the competent authority (the regulator or the safety authority) should be examined. External reporting of events that fit certain criteria is a useful manner of demonstrating and enhancing transparency in safety management; it helps regulators to obtain a realistic per-industry viewpoint on incident characteristics, and it is required by law in some industries.

Items to help you in your diagnosis of under-reporting:

- An incident database which has only a few incidents reported *could* be an indication of possible under-reporting, which may require further investigation as to why this may be the case. Note however that it is difficult to judge externally what the “ideal” number of events per time period is, since this is dependent on the technology used and the industry within which one is operating.
- Ask about the latest occasion on site where someone could have been injured, or environmental damage could have occurred, and check whether it was reported in the incident database.
- Study a major accident which occurred on the site, identify possible precursor events, and ask whether they have occurred in the past year.

For more information:

- Chapter 5 of [Johnson, 2003].

3.2 Poor quality of the reports

Some reports provide little help in identifying safety improvements. The data collected may be **incomplete** (facts missing, unclear sequence of events, superficial description of the context of the event). The data may also be **biased**, since a person reporting an incident will have a natural tendency to include some subjective information on the event, and may attempt to lead the reader to an interpretation of events which puts the reporter's actions (or that of his colleagues) in a more favourable light.

Can be caused by:

- a feeling that the event learning process is not useful to shop floor ("sharp end") workers, who may see it as mainly aimed at providing statistics for managers, instead of as a source of learning and safety improvement;
- poor (incomplete, biased, superficial) data collection in the aftermath of an accident;
- lack of access to important data collection tools, such as a digital camera, during fact-finding;
- lack of management follow-up to implement lessons learned;
- focus of performance indicators and of investment on reliability rather than on safety;
- non-involvement of key actors (witnesses or victims, labour representatives, workers with strong knowledge of the technical functioning of the system) in the fact-finding stage;
- checklist mentality: in some systems there is an obligation to file a report for every detected event. If these events are not followed up on and do not lead to visible improvements, people can over time fall into a "do the minimum" response to such obligations;
- strategic behaviour where information is seen as a source of power, and thus there is a tendency to keep some essential information to oneself.

Some items to help you diagnose poor report quality:

- Ask several people involved in an event to critically review the incident report for that event, and see whether they identify oversights, missing information, biases.
- Analyze the quality of incident reports using your own judgment and experience.
- Organize an inter-site comparison of experience feedback reports in which workers from two sites of the same company undertake a collaborative critical review of their reports.
- Is the experience feedback database thought of as a "cemetery for reports" (reports accumulate there to die, without receiving any attention)?

3.3 Analyses stop at direct causes

In some learning systems, the analyses of the causal factors contributing to events tend to be superficial, and are limited to the identification of the direct causes, such as the technical failure of a piece of equipment, or the behaviour of an operator who skipped a step in a procedure. The **underlying contributing factors** − often called "root causes" − which allowed the direct cause(s) to exist, and which are generally organizational (for instance, insufficient budget for maintenance leading to corroded equipment; high production pressure and supervisor tolerance of "temporary shortcuts") and related to the safety management system, are not identified.

To use terminology from the organizational learning literature, we can say that recommendations are limited to **single-loop learning** (immediate fixes), and do not include double-loop (underlying values) or deutero-learning ("learning-to-learn" capability).

The “bad apple” safety model

A **safety model** is a set of beliefs and assumptions about the sources of risk in a system and the features and activities which allow it to operate safely. A common safety model is based on the belief that mature systems, in which designers have had the time to learn from early mistakes, would work fine if it were not for a few careless individuals who do not pay attention to procedures. The work of safety managers in these systems is to identify these “bad apples” and retrain or reprimand them [Dekker, 2006].

However, experience shows that in large, complex sociotechnical systems, variability in human performance is inevitable, and it contributes as much to safety (through skilful recovery actions) as it does to incidents and accidents. What some analysts still call “human errors” are more a *symptom* of an underlying problem (often related to design or system management) than a *cause* of accidents.

Considering the notion of multilevel-learning, it is important to note that the contributing factors to some incidents are not limited to the firm directly responsible for the hazardous activity, but may also involve contractors, insurers, the activity of the regulator, the legal system, and the legislative framework within which the firm operates. In such cases, the recommendations resulting from the analysis should address these other organizations, and not only the firm directly responsible.

Superficial analyses can be caused by:

- insufficient training of the people involved in event analysis (identification of causal factors, understanding of the systemic causes of failure in complex systems, human factors training to help identify organizational contributions to accidents);
- use of accident investigation methods that build on linear accident models, rather than on multi-linear/systemic models[7], which provide less structure helping to identify causal factors;
- insufficient time available for in-depth analysis;
- managerial bias towards technical fixes rather than organizational changes (managers may wish to downplay their responsibility in incidents, so downplay organizational contributions to the event).

WYLFIWYF & WYFIWYF

Safety researcher E. Hollnagel guards against the results of biased accident investigations with the acronym WYLFIWYF (‘What You Look For Is What You Find’) [Lundberg et al., 2009]. These reflect the notion that accident investigation is not a fully objective exercise, and investigators’ background, training and preconceptions on factors which lead to accidents will inevitably influence their findings. This bias inevitably influences the corrective actions implemented, because WYLFIWYF (‘What You Find Is What You Fix’).

Items to help you diagnose overly superficial analyses:

- Experience feedback reports allocate responsibility (and recommendations for improvement) to lower-power individuals such as operators (for instance: “improve training of the operator”) rather than managers, who are responsible for organizational issues;
- Examine the balance in recommendations between reactive fixes (“send the operator to training”, “add extra personal protective equipment”) and deeper, more long-term modifications (“change the organization”, “change the system’s design”, “implement inherent safety principles”).

3.4 Self-centeredness (deficiencies in external learning)

Insufficient sharing between sites, firms and industry sectors: There are many institutional and cultural obstacles to the sharing of information on events and generic lessons between sites from a same firm, firms in the same industry sector, and − even more − between industry sectors.

[7] Examples of systemic accident models are STEP, Tripod-Delta and FRAM.

In several major accidents and disasters, failure to learn from other's incidents and accidents was a cause, among others, of the severe events. The nuclear industry is an international affair that is subject to several levels of exchange under the umbrella of organizations including IAEA, the OECD NEA and WANO. A first example of this external learning deficiency is the Three Mile Island accident in 1979, which had precursors in Beznau in Switzerland in 1974 and in Davis-Besse in 1977. A more recent example is the Fukushima-Daiichi disaster in 2011, where TEPCO (the operator of the nuclear power plant) and the Japanese nuclear regulator did not implement a safety mechanism that could have prevented escalation of the accident, and which is widely implemented in US and European plants[8].

Several factors contribute to this difficulty in learning from others:

- the feeling that "that couldn't happen to us; we operate differently" (better!);
- fears related to reputation or prestige (for oneself, one's colleagues, one's company); the idea that you "don't wash your dirty laundry in public";
- the inherently contextual nature of much learning.

Items to help you diagnose self-centeredness:

- Are people able to point to a recent incident on another site which led them to make changes to an operating procedure, the design of some equipment, some organizational issue?
- Do you often hear comments such as "that couldn't happen to us", without an accompanying explanation?
- Does your site have a systematic approach to internalising lessons learned from incidents/accidents/near misses reported in other sites or significant events reported in the news around the world?

3.5 Ineffective follow-up on recommendations

Certain recommendations or corrective actions are not implemented, or are implemented very slowly.

Investigations in Swedish railways

[Cedergren, 2013] analyzed the implementation of recommendations from accident investigations in the Swedish railway sector. The author found that almost one in five recommendations made by the accident investigation board did not lead to any corrective action at all. The main reasons for absence of change identified by the people interviewed were:

1. actions not falling within the receiver's mandate (the target felt that they could not implement the recommendation, because it was outside of their scope of actions), due to limited knowledge of respective organizations' roles and mandates;
2. recommendations that were somewhat imprecise or lacking in guidance in the specific areas which required change.

Ineffective follow-up can be caused by:

- insufficient budget or time to implement corrective actions (production is prioritized over safety, management is complacent concerning safety issues);
- lack of "ownership" of recommendations, i.e.no one feels responsible for the recommendations - there is a lack of "buy-in". This may be due to investigations being "monopolized" by people who are external to operations, for instance the investigation and selection of

[8] When nuclear fuel rods are insufficiently cooled, they can react with water steam to produce hydrogen. In the Fukushima-Daiichi accident, hydrogen gas built up inside reactor buildings and had to be vented to external buildings; the resulting explosive mixture detonated and severely damaged several buildings, including a containment building. Most nuclear plants in the US and Europe have for many years been equipped with units which are able to recombine hydrogen and oxygen to produce water, before the explosive limit for hydrogen is reached.

recommendations and corrective actions being run by HSE experts without input from operators or from local management;

- resistance to change;
- inadequate monitoring within the safety management system (missing indicators, insufficient management supervision, significant turnover in management positions leading to lack of historical knowledge by the person holding a supervisory role);
- poorly controlled interface with the **management of change** process, which should ensure that the recommendations do not introduce new risks or produce other unanticipated side-effects.

Concerning the timescale for implementation, practitioners should recognize that it generally takes years for investigations of major accidents to result in changes at the system level (typically involving the regulatory and legislative processes).

Some items to help you diagnose ineffective follow-up:

- Look through investigation reports to see whether recommendations have been followed up on, and check whether they have led to real change.
- Analyze the strategic influence of the safety and investigate staff (their position in the organizational chart): if they have a concern which may require action from top management, do they have the power to be heard by the necessary people? Is there past evidence of concerns raised by investigators having led to reactions from top management?

3.6 No evaluation of effectiveness of actions

In order to make sure that the learning potential of incidents is consolidated, organizations should ensure that the effectiveness of corrective actions is evaluated. Did the implementation of recommendations really fix (or contribute to fixing) the underlying problem that triggered the initial event?

Inadequate evaluation can be caused by:

- political pressure: if the organization does not have an open, evaluation-based culture, a negative evaluation of an action's effectiveness may be seen as an implicit criticism of the person (likely a manager) who made the decision to approve the action;
- compliance attitude (checklist mentality, in which people go through the motions that are required of them, without thinking about the real meaning of their work);
- system change can make it difficult to measure effectiveness (to isolate the effect of the recommendation from the effect of other changes);
- overconfidence in the competence of the safety professionals ("no need to reassess our previous excellent decisions");
- lack of a systematic monitoring and review system that evaluates effectiveness of lessons learned.

Items to help you diagnose inadequate evaluation:

- When was the last review of the learning from incidents process undertaken?
- What changes were made as a result of the review?
- Can you identify the organizational role (function, entity) which is in charge of the evaluation of effectiveness? Do such evaluation loops exist for each phase in the system lifecycle (design, operations, maintenance, *etc.*)?

3.7 Lack of feedback to operators' mental models of system safety

Excellent reporting and root-cause analyses are not sufficient for learning to take place. The safety of complex systems is assured by people who control the proper functioning of the system, detect anomalies and attempt to correct them (operators, maintenance personnel, managers, regulators, *etc.*). These experts have built over time a mental model of the system's operation, of the types of failures which might arise, their warning signs and the possible corrective actions. If they are not presented with new information which challenges their mental models, such as feedback from the reporting/learning system, then the learning loop will not be completed.

If the organizational culture does not value *mindfulness* or *chronic unease*, then people's natural tendency may be to assume that the future will be similar to the past, and there will be organizational rigidity of beliefs as to what is risky and what is normal. Psychologist J. Reason stated "If eternal vigilance is the price of liberty, then chronic unease is the price of safety".

Collective mindfulness

Collective mindfulness [Weick et al., 1999] is "a rich awareness of discriminatory details". A body of research on *Highly Reliable Organizations* (HROs) [Lekka, 2011] suggests that they are *preoccupied with failure*, treating any deviation from the standard as something which is wrong with the system. They are *reluctant to simplify*, resisting oversimplification and trying to see more. They have a detailed understanding of rising threats and of causes that interfere with such understanding. Their mindfulness allows them to see the significance in weak signals and take action.

The Piper Alpha disaster

Senior management at the firm running the Piper Alpha production platform in the North Sea, which suffered a massive explosion in 1988, leading to the death of 167 workers, were found to be too easily satisfied and to rely on the absence of feedback. They failed to ensure that training was sufficient, adopted a superficial response and did not become personally involved [Cullen, 1990, p. 238]. They allowed a "culture that did not discourage shortcuts, (thus) multiple jobs could be performed on a single permit" [Paté-Cornell, 1993].

Questioning attitude[9]

Individuals demonstrate a questioning attitude by challenging assumptions, investigating anomalies, and considering potential adverse consequences of planned actions. This attitude is shaped by an understanding that accidents often result from a series of decisions and actions that reflect flaws in the shared assumptions, values, and beliefs of the organization. All employees are watchful for conditions or activities that can have an undesirable effect on safety.

This lack of feedback can be caused by:

- operational staff are too busy to reflect on the fundamentals which produce safety in the system;
- the organizational culture allows people to be overconfident;
- **mistrust** of the analysis team;
- reluctance to accept change in one's beliefs.

Questions to help you diagnose lack of feedback:

- Ask whether in the last year, people have encountered a "surprise" with respect to safety, something that was unexpected.
- Are shortcuts tolerated amongst colleagues?
- When discussing large accidents that occurred in another organization, do people display a "couldn't happen to us" attitude?
- Does your senior management tend to focus attention on avoiding small (and frequent) safety problems that may disrupt production, with seemingly little or no attention given to the possibility of severe (but rare) accidents?

[9] *This text is based on the INPO (Institute of Nuclear Power Organizations) definition.*

3.8 Loss of knowledge/expertise (amnesia)

People forget things. Organizations forget things[10]. The lessons learned from incidents and accidents are slowly lost with the passing of time.

Loss of knowledge can be caused by:

- poor management of subcontracting/outsourcing (knowledge is transferred to people outside the organization that is responsible for the hazardous operations and interfaces between organizations are badly managed);
- loss of information in case of change of ownership of a plant: design information and records may not be transferred to the new owner, who may lose information on why a facility was designed in a certain way, which modifications have been made, the rationale for the inspection and maintenance policies;
- poor implementation of the learning repository: if reports are not easily accessible to people working within the organization, the lessons they contain will not feed into operations and design. The repository (which will generally be computerized) should be accessible to all staff categories, should allow easy to use searching (including full text searches, with synonyms), and should allow the creation of categories of events and feed into statistical tools;
- aging of the workforce (a significant issue in many industrial sectors in Europe) and insufficient knowledge transfer from more experienced workers to incoming workers;
- insufficient use of knowledge management tools;
- insufficient or inadequate training;
- lack of adaptation (including unlearning), which is necessary to cope with changing environment/context.

Note that any deviation which is not properly processed through the reporting system will eventually be forgotten.

Space shuttle Columbia disaster
In February 2003, the Columbia space shuttle disintegrated upon re-entry into the atmosphere, leading to the death of all seven crew members. The shuttle's heat shield had been damaged during take-off by fragments of foam insulation which broke off from the external fuel tank. Loss of parts of the thermal foam insulation had been noticed on previous flights of the shuttle, but had not led to any adverse effects and over time became considered a "normal" phenomenon. The investigation into the disaster concluded that NASA had, over time, accepted deviations from design criteria as normal when they happened on several flights and did not lead to mission-compromising consequences. This phenomenon of "normalization of deviance" had been identified by the sociologist D. Vaughan as an organizational cause of the Challenger disaster, 10 years earlier.

Questions to help you diagnose this symptom:

- Are people within the organization (frontline staff, managers at different levels, safety staff, design engineers) familiar with the accidents and high-potential incidents that have affected their site or company or sector within the last 15 years?
- Do people understand the *reasons* for various elements of procedures that were introduced in the past as a result of learning from accidents?
- If the length of maintenance shutdowns/stoppages or the level of spending on maintenance has decreased in the last 15 years, is there a record of a risk analysis undertaken to justify this change?
- If the plant is operating above the design flow rates or pressures, is there a record of a risk analysis undertaken to justify these changes?

[10] Despite the famous quote of T. Kletz that "Organizations have no memory. Only people have memory and they move on." [Kletz, 1993], organizational memory incorporating knowledge from incidents or accidents is present in system artefacts such as operating procedures and design rules. Systems should be designed such that newcomers don't have to undertake "safety archaeology" to try to reconstruct hypotheses on the motivation of prior generations in deciding upon various technical and organizational features of the system.

- Does the organization have group-level (centralized) standards for safe design, maintenance and inspection? What local "adjustments" are made with respect to these standards?

3.9 Bad news are not welcome and whistleblowers are ignored

A number of major accidents have been preceded by warnings raised by people familiar with the system and who attempted, unsuccessfully, to alert people with an ability to change the system or the nature of the threat that they perceived. The message of these *whistleblowers* is often not heard by the organization, because of a culture in which bad news are not welcome and contrarian voices are frowned upon.

Whistleblowers and Cassandras

In general usage, whistleblowing means making a disclosure in the public interest. In the safety literature, the term has a narrower meaning of reporting things that may constitute a threat to safety, such as the presence of a risk which has not been properly managed.

The Herald of Free Enterprise disaster

In 1987, a car ferry named the *Herald of Free Enterprise* capsized in the Belgian port of Zeebrugge, leading to the death of 193 passengers and crew. The ship had left port with its front door open. The investigation found that employees had aired their concerns on five previous occasions about the ship sailing with its doors open. A member of staff had even suggested fitting lights to the bridge to indicate whether the doors were closed. The inquiry concluded: "If this sensible suggestion […] had received the serious consideration it deserved this disaster might well have been prevented".

Paddington Junction railway accident[11]

Before the tragic collision at Paddington train station in 1999 in a suburb of London, several signals passed at danger (red colour signal with no stop) occurred in that area, leading A. Forster, a manager from one of the operating train companies, to ask the company managing the track infrastructure to take actions. However, although the infrastructure operator replied to her, and several working groups were put in place, there was much discussion but little action.

Bad news at Texas City

In March 2005, a massive explosion at a BP-owned oil refinery in Texas killed 15 people and injured nearly 200. Under-investment in maintenance on the site, resulting from cost-cutting campaigns driven by top management, was identified as having contributed to the accident. Analyzing the culture on the site prior to the accident, A. Hopkins identified a reluctance to communicate "bad news" to senior management [Hopkins, 2008], which together with inappropriate use of safety indicators contributed to senior management's distorted view that safety levels were high at the site.

The radical nature of whistleblowing (alerting the media or the regulator) should not mask the fact that most whistleblowers attempt to raise their concerns within their organization through different channels, often more than once and to several different people, before using the blunt instrument that is media attention. Organizations can usefully implement confidential reporting systems[12], with a well-defined treatment path for the reports, to ensure that messages are heard internally.

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[11] *From the Cullen inquiry report Volume 1, pp 117 to 119, available at http://www.railwaysarchive.co.uk/documents/HSE_Lad_Cullen001.pdf.*

[12] *It is important to distinguish between **confidential reporting and anonymous reporting**. Many successful voluntary reporting systems contain provisions covering the way the person making the report is to be contacted if necessary to obtain a better understanding of the events.*

Questions to help you diagnose this symptom:

- Do people feel comfortable bringing bad news to management? Is information simplified or watered down before it is passed to managers? Does management expressly ask for bad news?
- Is there a “shoot the messenger” mentality[13] with respect to dissenting views?
- Does the organizational culture favour 100% consensus on important decisions? In a healthy high-hazard — and complex — organization, the absence of dissenting views is a suspicious sign that dissent is in general discouraged[14].
- Is a confidential reporting system available to staff, allowing them to communicate serious concerns directly to higher management? Are they aware of its existence? Is it used?
- Is critical, safety-related news that circumvents official channels welcomed?
- What follow-up is given to concerns raised using this channel?
- Do messages get altered, with the tone softened, as they move up the management chain? Is there a “bad news filter” in the reporting process?
- Are there any cases of outside whistleblowing (pressure on safety concerns raised through the media, via the regulators)? How were they handled?

[13] *More usual is a “not a team player” attitude with respect to people who raise concerns.*

[14] *Note that organizations can be seen as being defined by what they ignore, by the collective simplifying assumptions that members of the organization make in order to be able to work collectively. These assumptions are called the worldview or mindset of members of the organization, or their safety model for assumptions concerning risk and safety in the system; they are a component of the organization’s culture. This collective mindset becomes pathological if it leads to the immediate rejection of unwanted contrarian views, without reflection on their validity.*

For more information:

- British Standards (BSI) has published *Whistleblowing Arrangements Code of Practice* under the classification PAS1998/2008. Available for free from http://shop.bsigroup.com/forms/PASs/PAS-1998/.
- UK: the *Public Concern at Work* charity provides advice to businesses on ensuring that concerns are raised at an early stage.

3.10 Ritualization of experience feedback procedures or of accident investigation

Ritualization, or a compliance attitude, is a feeling within the organization that safety is ensured when everyone ticks the correct boxes in their checklists and follows all procedures to the letter, without thought as to the *meaning* of the procedures. It is related to *safety theatre*, the empty rituals and ceremonies that played out after an accident, in order to show that “things are being done”, and to the “procedure alibi”, the tendency to implement additional procedures after an event as a way for safety managers to demonstrate that they have reacted to the accident [Størseth and Tinmannsvik, 2012]. This kind of organizational climate is not conducive to learning.

Safety management becoming divorced from safety in the field
The 1999 Report of the Longford Royal Commission into the explosion at Esso’s Longford gas plant in Australia found that although Esso had a world class safety management system, the system had taken on a life of its own, “divorced from operations in the field” and “diverting attention away from what was actually happening in the practical functioning of the plants at Longford” [Dawson and Brooks, 1999, p. 200].

Safety management as the BP Texas City refinery
Before the March 2005 Texas City accident, some audits identified that Texas City was a plant at a "high risk" for the "check the box" mentality. This included going through the motions of checking boxes and inattention to the risk after the check-off. "Critical events, (breaches, failures or breakdowns of a critical control measure) are generally not attended to."

Items to help you diagnose ritualization of safety procedures:

- When asking people why they reacted in a certain way, their responses always focus on "the procedure" as the motivation for their action.
- Safety audits are undertaken using checklists, with little thought to reasons for possible deviations from the checklist.
- People are unable to explain the reasons for various elements of procedures or operating guidelines.

4 Pathogens causing learning deficiencies

This chapter lists a number of pathogenic organizational factors which hinder the effectiveness of the event-learning process. These underlying characteristics, or *pathogens* in the medical metaphor used in this document, are generally more difficult to detect or diagnose at an operational level than the symptoms described in the previous chapter, and may be responsible, to various degrees and possibly in combination with other problems, for a number of symptoms. Their relationship with the symptoms described in the previous chapter is illustrated in figure 3. Note that these pathogens or underlying organizational conditions should not be thought of as *causes* of potential accidents, but rather as *conditions* which allow accidents to develop.

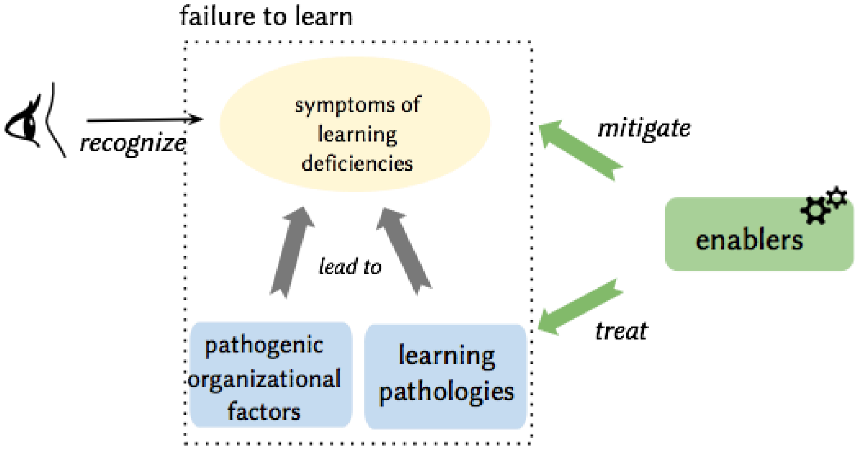

Figure 3: Symptoms and pathogens related to failure to learn

Pathogenic organizational factors

Pathogenic organizational factors [Reason, 1995, Dien, 2006, Rousseau and Largier, 2008, Llory and Dien, 2010] are an aggregation of convergent signals (markers, signs and symptoms) that allow the characterization of a negative influence on the system safety. Reason was the first to use a medical metaphor in analyzing organizational contributions to accidents, stating that "For determining whether an organization is in good health, it is far simpler to know the causes of the sickness. It is far more accessible to define a set of pathogenic organizational factors than to exhaustively list the organizational factors required and sufficient to ensure a good level of safety within the organization." They include weaknesses in organizational safety culture, failures in day-to-day management of safety, weakness of control mechanisms, difficulty in adapting to feedback, difficulty in handling experience feedback and failure to re-examine design hypotheses.

4.1 Denial

Denial is the idea that "it couldn't happen to us". At an individual level, denial is related to *cognitive dissonance*[15], a phenomenon which can lead people intellectually to refuse to accept the level of risk to which they are exposed. At an organizational and institutional level, group-think phenomena[16] or commitment biases can lead to denial (rationalization of decisions).

Failure indicates that our existing models of the world are inadequate, requiring a search for new models that better represent reality [Cyert and March, 1963]. This challenge to the status quo is expensive, which can

[15] Cognitive dissonance is a concept from social psychology designating the discomfort which arises from holding conflicting beliefs [Festinger, 1957]. People aim to make their beliefs consistent with one another, so can reject new information which is inconsistent with their current beliefs.

[16] Groupthink is a phenomenon observed by social psychologists which occurs when people work together as a group to reach decisions, in which the desire for harmony or conformity in the group results in an irrational decision. Group members try to minimize conflict and reach a consensus decision without critically evaluating alternative viewpoints, by actively suppressing dissenting viewpoints, and by isolating themselves from outside influences.

encourage people not to look too closely into warnings that something is not exactly as one would like it to be.

Fukushima-Daiichi Nuclear Accident
The independent Investigation Commission into the 2011 nuclear accident in Japan stated in its report: *"The construction of the Fukushima Daiichi Plant that began in 1967 was based on the seismological knowledge at that time. As research continued over the years, researchers repeatedly pointed out the high possibility of tsunami levels reaching beyond the assumptions made at the time of construction, as well as the possibility of core damage in the case of such a tsunami. TEPCO overlooked these warnings, and the small margins of safety that existed were far from adequate for such an emergency situation."*

Questions to help you identify a pattern of denial:

- Do you hear remarks such as "We have always done things this way; it's only when people are careless that accidents happen"?
- Are workers in the facility familiar with the major accident hazard scenarios that are described in the plant's safety case document? Do they know what the consequences of such accidents would be?

4.2 Complacency

Complacency occurs when there is a widely held belief that all hazards are controlled, resulting in reduced attention to risk. The organization (or key members within the organization) views itself as being uniquely better (safer) than others, and, as a result, feels no need to conform to industry standards or good practices, and sees no need to aim for further improvement. Complacency is the opposite of *vigilance*, or the sense of vulnerability, or *chronic unease*[17].

The importance of avoiding complacency with respect to major accident hazards was emphasized by the High Reliability Organizations theorists in the 2000s [Weick and Sutcliffe, 2001].

Complacency can be caused by:

- Overconfidence in the safety system and its performance (possibly due to a lack of accidents in the last few years, and a feeling that past success guarantees future success).
- Reliance on occupational safety statistics as the sole safety performance indicator (no monitoring of process safety indicators), with incentives and rewards based on this narrow – and possibly misleading – safety indicator.
- The organization's inattention to critical safety data.
- Superficial investigation of incidents, with a focus on the actions of individuals rather than on systemic contributing factors.

Questions to help you identify a pattern of complacency:

1. Do you detect a feeling of invulnerability at any level of the organization?
2. Do supervisors perform frequent checks to confirm that workers – including contractors – are obeying safety rules and procedures? If deviations are detected, are the rules and procedures reviewed to ensure that they are still relevant and appropriate?
3. Do people discount information that identifies a need to improve? Do they prefer to receive information which confirms the organization's superior performance, or also look for warning signs of a negative trend?

[17] *Chronic unease is a belief that despite all efforts deployed, errors will inevitably occur and that even minor problems can rapidly become system-threatening. As stated by [Reason, 2002], "chronic unease along with continuous vigilance and adjustment are still the main weapons in the error management armoury".*

4. Do people express an interest in learning from other organizations or industries, and are lessons from related industry accidents routinely discussed within the organization?
5. Are those who raise concerns viewed negatively?
6. Are people who take safety risks tacitly rewarded when their risk-taking is successful?
7. Is the response to safety concerns focused on explaining away the concern rather than understanding it?

4.3 Resistance to change

Change is uncomfortable for most people, bringing uncertainty and lowering the degree of control we have over situations; we have a natural tendency to resist it. At an individual level, resistance to change may be caused by mistrust, lack of information, lack of ability or lack of sufficient incentives.

Note however that “resistance to change” is a complaint often made by managers concerning resistance of shop-floor workers to a proposed reorganization, which when analyzed in detail may be due to workers having identified that the proposed change will lead to degraded working conditions or lower safety.

At an organizational level, resistance to change means that trying new ways of doing things is not encouraged. It is well known that organizations have a very low level of intrinsic capacity of change, and often require endogenous pressure (from the regulator, from changes to legislation) to evolve. It may also be caused by a “competency trap”: since repetition and practice build competence, a team may have developed high performance in their standard approach to a problem, which is an obstacle to trying out other, potentially superior approaches.

Questions to help you identify a pattern of resistance to change:

1. Do you hear comments such as “We have done things this way for 30 years, why should we do it any differently now?”?

4.4 Inappropriate organizational beliefs about safety and safety management

In mature industries dealing with hazards, accidents too often act as a trigger which shows us that our worldview is incorrect, that some fundamental (but sometimes unstated) assumptions we made concerning the safety of the system were wrong. Some examples of these inappropriate beliefs or “urban myths”[18] concerning safety:

- The structuralist view of the Bird pyramid (the attractive but mistaken view that “chipping away at the minor incidents forming the base of the pyramid will necessarily prevent large accidents” [Hale, 2002]). This interpretation of the accident statistics compiled by Heinrich then by Frank Bird is attractive, since it suggests an intervention strategy that is fairly easy to implement: “focus people’s attention on avoiding minor incidents (slips, trips and falls) and their increased awareness of minor safety problems will prevent the occurrence of major events”. While there is some evidence that this is true concerning certain categories of occupational accidents, it is likely to be false concerning process safety and major accident hazards.

[18] *A. Hale refers to “beliefs which seem so plausible that they command immediate acceptance” [Hale, 2002].*

H. Heinrich was a pioneering occupational safety researcher, whose publication *Industrial Accident Prevention: A Scientific Approach* in 1931 was based on the analysis of large amounts of accident data collected by his employer, an insurance company. This work, which continued for more than thirty years, identified causal factors of industrial accidents including "unsafe acts of people" and "unsafe mechanical or physical conditions". The work was pursued and disseminated in the 1970s by F. Bird. The most famous result is the incident pyramid, which posits a relatively constant frequency ratio between minor incidents, injuries and accidents, and is often misinterpreted to mean "frequency reduction will trigger a severity reduction".

This work was pioneering in encouraging managers to think about and invest in prevention of occupational accidents. It was also ground-breaking work on causality and the different ways of interrupting an accident sequence. However, some of the ideas are no longer appropriate for safety management in large, complex socio-technical systems. For instance, Heinrich stated that *"predominant causes of no-injury accidents are, in average cases, identical with the predominant causes of major injuries, and incidentally of minor injuries as well."*

This is incorrect and can lead to inappropriate allocation of safety resources. Accident causality is often more complicated than Heinrich's quote suggests, as indicated by the following extract from the BP report into the Deepwater Horizon accident: *"The team did not identify any single action or inaction that caused this incident. Rather, a complex and interlinked series of mechanical failures, human judgments, engineering design, operational implementation and team interfaces came together to allow the initiation and escalation of the accident."*

- A related myth is the "improving occupational safety improves process safety" (avoids majors accidents) worldview. In fact, the underlying causal factors of major process accidents are mostly unrelated to those responsible for occupational safety incidents. Accidents such as the BP Texas City explosion in 2005, in a refinery which had very good occupational safety results, demonstrate that occupational safety and process safety can be quite uncorrelated in practice.
- The "we haven't had an accident for a long time, so we are now safe as an organization" myth (believing that past non-events predict future non-events)[19].
- The "fewer undesirable events means higher safety" hypothesis. Though this may seem to be quite an intuitive notion, there is some evidence in civil aviation that airlines with the lowest rate of minor incidents are also those with the largest likelihood of experiencing major accidents. It is as if people working in highly controlled systems, where deviations are very rare, lose the ability to compensate for abnormal situations and their understanding of how a system works (including outside of its nominal conditions) disappears over time, so when a (very rare) deviation occurs, they no longer know how to react. This notion is called *immunization* in the resilience[20] community.
- Attitudes of learned helplessness such as "we won't be able to change anyway"[21].
- "Zero-risk" doctrines: if targets are set in terms of number of undesirable events, there will be some tendency for these targets magically to be reached, but most likely at the expense of knowledge on real performance. For example, goals such as "1000 days without an accident" are known to lead to under-reporting of safety-related events.

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[19] This is similar to a central theme in the film "La Haine" (1995), in which a person falling from a skyscraper, thinks on his way down "so far, so good" as he passes each floor. But the way in which one lands is more important than the way one falls.

[20] After [Hollnagel et al., 2006], we define a resilient system as one which is able effectively to adjust its functioning prior to, during, or following changes and disturbances, so that it can continue to perform as required after a disruption or a major mishap, and in the presence of continuous stresses.

[21] In psychology, learned helplessness [Seligman, 1975] is a condition of a person or an animal in which it has learned to behave helplessly, even when the opportunity is restored for it to help itself by avoiding a negative circumstance to which it has been subjected. Coping mechanisms are limited to stoicism (symptoms of depression).

- Confusion between reliability and safety: reliability is the ability of a system or component to perform its required functions under stated conditions for a specified period, whereas safety (in its most common definition) is the absence of harm. Although in many cases both properties will be correlated, they occasionally pull in opposite directions. One example, given by [Hopkins, 2007], is an electricity company, in which safe operation during maintenance on the network may require cutting power to the network, compromising reliability.

Improving safety sometimes requires a **paradigm shift**[22]. Unfortunately, paradigm shifts are very expensive to individuals (since they require changes to mental models and beliefs) and take a long time to lead to change. Safety practitioners (and more generally, workers), have often invested many years in their profession, and suggesting that some of their fundamental beliefs, acquired over so many years, may be wrong, is threatening to them. Once change in people's beliefs and assumptions has occurred, they must then re-examine the design basis of their system, the assumptions made concerning its operation, and the resulting effects on maintenance procedures, operating procedures, etc.

4.5 Overconfidence in the investigation team's capabilities

The investigation and analysis teams may lack certain skills necessary for quality investigations, or have inadequate knowledge of the system's functioning and elements responsible for its safety, leading to substandard investigations, poor credibility of the corrective actions decided and little learning.

This overconfidence may result from:

- lack of adequate proficiency/training;
- insufficient resources;
- lack of **readiness to investigate**. In addition to the training of the future investigator and contributor to investigations, the structure and protocols for investigation should be designed and tested [ESReDA, 2009, Kingston et al., 2005].

4.6 Anxiety or fear

Accidents and incidents often arouse powerful emotions, particularly where they have resulted in death or serious injury. On the positive side, this means that everyone's attention can be focused on improving prevention (awareness). On the negative side however, the same emotions can also cause organizations and individuals to become highly **defensive**, leading to a rejection of potentially change-inducing messages. This is natural and understandable but needs to be addressed positively if a culture of openness and confidence is to be engendered to support a mature approach to learning.

Another area for fear or anxiety is the effect of reporting a negative event on the company's (or a colleague's) **reputation**.

4.7 Corporate dilemma between learning and fear of litigation/liability

In a legal context where investigators work to allocate blame and lawsuits for corporate manslaughter follow major accidents[23], certain companies may be advised by their legal counsel not to implement an incident learning system, or downplay its performance (encouraging a "don't get caught" attitude to deviations from prescribed operations). Indeed, the incident reporting database (which may be seized by the police after an accident) may contain information concerning precursor events, which demonstrate that managers "knew" of the possible danger in their system, but had not yet taken corrective action. Organizations may wish to avoid the accumulation of what can be seen as **incriminating knowledge**. However, suppressing the safety lessons which can be derived from this information can create an organizational learning disability [Hopkins, 2006].

[22] Consider for example a move from a "rotten apple" safety model to a more systemic approach, or the integration of Safety-II ideas [Hollnagel, 2014] in one's safety thinking.

[23] The legal world tends to hold the view that systems are inherently safe and that humans are the main threat to that safety.

This tendency towards the "criminalization of human error" [Dekker, 2011] has many negative consequences for learning.

Organizations may also fear an increase in their **legal liability** after an accident if they admit to the need to change some element of their design or operations as a result of an event investigation. Certain pressures may be indirect, via their insurer for example.

4.8 Lack of psychological safety

Psychological safety
A shared belief within a workgroup that people are able to speak up without being ridiculed or sanctioned. When psychological safety is present, team members think less about the potential negative consequences of expressing a new or different idea than they would otherwise. As a result, they speak up more when they feel psychologically safe and are motivated to improve their team or company. There are no topics which team members feel are "taboo" (an unspoken understanding that certain issues are not to be discussed and resolved) [Edmondson, 1999].

In the absence of psychological safety, people will hesitate to speak up when they have questions or concerns related to safety. This can lead to under-reporting of incidents, to poor quality of investigation reports (since people do not feel that it is safe to mention possible anomalies which may have contributed to the event), and to poor underlying factor analysis (it is easier to point the finger at faulty equipment than at a poor decision made by the unit's manager).

When psychological safety is low, it may be improved by:

- incentives for reporting incidents and making suggestions;
- training for managers in encouraging feedback from their colleagues;
- a more participatory management style (empowering employees to participate in organizational decision-making, encouraging workers to voice their concerns).

4.9 Self-censorship

In many workplace situations, people do not dare to raise their concerns: they choose silence over voice, withholding ideas and concerns about procedures or processes which could have been communicated verbally to someone within the organization with the authority to act. They have developed self-protective *implicit voice theories*, socially acquired taken-for-granted beliefs about the conditions in which speaking up at work is accepted, which they have internalized from their interactions with authority over many years [Detert and Edmondson, 2011].

Self-censorship can be caused by a variety of factors:

- concerns for one's reputation within the work group, or for one's career development;
- fear of damaging a relationship or of embarrassing a peer;
- peer pressure;
- feeling that one needs solid data, evidence or solutions to raise concerns;
- hierarchical conformity (conformity with rules such as "don't embarrass the boss" and "don't bypass the boss");
- investigation stop-rules for causes of identified corrective measures which are outside the scope of the investigation team's mandate, its ability to communicate, its ability to influence.

This effect is related to the concept of psychological safety described in section 4.8.

Engineer/management approaches to risk communication

The famous physicist Richard Feyman was a member of the Rogers commission into the Challenger space shuttle disaster. In his book *Why do you care what other people think?*, Feynman describes the investigation of the pre-launch teleconference between NASA and a subcontracting company, concerning the effect of cold weather on O-rings in the booster rockets. A group of engineers were worried that the cold would prevent proper operation of the O-rings (and it did indeed lead to the explosion of the launcher). A senior manager participating in the teleconference asked one of the engineering managers to put on his "management hat" instead of his "engineering hat", and the dissenting manager then changed his position on delaying the launch.

Feynman describes how he asked each of the engineers and a manager to write down an estimate of the probability that a flight would fail due to loss of an engine. The engineers each produced a number, ranging between 1 in 200 and 1 in 300. Mr Lovingood, the manager, wrote some lines about past experience, quality control, and engineering judgment. Feyman recounts:

""Well", I said, "I've got four answers, and one of them weaseled."
I turn to Mr Lovingood, "I think you weaseled."
"I don't think I weaseled."
"You didn't tell me what your confidence was, sir; you told me how you determined it. What I want to know is: after you determined it, what was it?"
He says, "100 percent" — the engineers' jaws drop, my jaw drops; I look at him, everybody looks at him — "uh, ugh, minus epsilon!"
So I say "well yes, that's fine. Now the only problem is, WHAT IS EPSILON?"
He says "10 to the minus 5"."

This illustrates both self-censorship in communication on risk and misperception of the magnitude of risk (the "Feynman gap").

4.10 Cultural lack of experience of criticism

In some national cultures, there are strong obstacles to producing and addressing criticism or suggestions for improvement (which can be seen as implicit criticism of the people who designed or manage the system).

Fukushima-Daiichi: a disaster Made in Japan

The foreword to the report[24] by the National Diet of Japan Fukushima Nuclear Independent Investigation Commission (NAIIC) states:
"What must be admitted — very painfully — is that this was a disaster 'Made in Japan'. Its fundamental causes are to be found in the ingrained conventions of Japanese culture: our reflexive obedience; our reluctance to question authority; our devotion to 'sticking with the program'; our groupism; and our insularity."

4.11 Drift into failure

Performance pressures and individual adaptation put systems in the direction of failure [Rasmussen and Svedung, 2000], and thereby gradually reduce their safety margins and take on more risk. Operators know their systems well. However, when reactive quick fixes are implemented more frequently, i.e. when staff are more frequently required to work outside the normal operating envelope, alarm bells should ring. This effect will generally be difficult for operators within a system to observe (since it occurs gradually and is related to people's aim to continually improve performance), but it can hopefully be detected by external auditors.

[24] *The report, which has been translated into English, is available at http://warp.da.ndl.go.jp/info:ndljp/pid/3856371/naiic.go.jp/en/.*

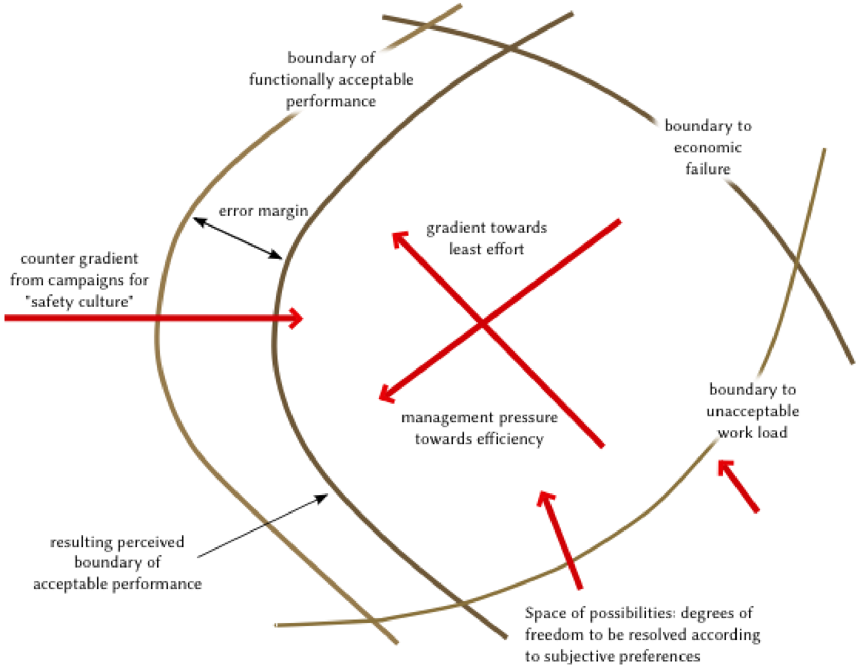

Figure 4: Migration and erosion of safety margins, after [Rasmussen, 1997]

From [Rasmussen, 1997]:
"Companies today live in a very aggressive and competitive environment which will focus the incentives of decision makers on short-term financial and survival criteria rather than long-term criteria concerning welfare, safety and the environment. Studies of several accidents revealed that they were the effects of a systematic migration of organizational behavior toward accident under the influence of pressure toward cost-effectiveness in an aggressive, competitive environment."

A 2007 statement by C. Merritt, chair of the US Chemical Safety and Hazard Investigation Board, on the Texas City accident, indicates: *"The combination of cost-cutting, production pressures and failure to invest caused a progressive deterioration of safety at the refinery."*

This migration, and the associated erosion of safety margins, tends to be a slow process, with multiple steps which occur over an extended period. Because each step is usually small, the steps often go unnoticed, a "new norm" is repeatedly established ("normalizing deviance"), and no significant problems may be noticed until it's too late.

Normalization of deviance occurs when it becomes generally acceptable to deviate from safety systems, procedures, and processes. The organization fails to implement or consistently apply its management system across the operation (regional or functional disparities exist). Safety rules and defenses are routinely circumvented in order to get the job done.

The period during which deviations accumulate and are normalized is also called the incubation period by B. Turner [Turner and Pidgeon, 1997].

Excessive production pressure occurs when there is an imbalance between production and safety as leadership overly values production, such that the emphasis is placed upon meeting the work demands, schedule or budget, rather than working safely. Organizational goals and performance measures are heavily weighted towards commercial and production outcomes over protection and safety. Business strategy, plans, resourcing and processes fail adequately to address safety considerations.

Normalization of deviance at NASA
Behaviour that led to the Challenger and Columbia accidents, where people within NASA became so much accustomed to a deviant behaviour that they didn't consider it as deviant, despite the fact that they far exceeded their own rules for elementary safety [Vaughan, 1996].

The Piper Alpha platform
The Piper Alpha platform in the North Sea was operating at three times the pressure it had been initially designed for. Accident reports state that "the level of activity had been gradually increased without appropriate checking that the system retained an appropriate margin of safety".

Buncefield oil terminal
Since the late 1960s, throughput of product had increased four-fold, resulting in a system that put supervisors under considerable pressure, developing their own systems to overcome this, e.g. working overtime (12 hr shifts). Additionally, during the filling process, although there were three oil tank 'high level' alarms (*user high*, *high* and *high high*) in place, each of the eight supervisors employed did not have the same way of using these alarms (COMAH, 2011).

The phenomenon can be caused by:

- pressure to push more for production rather than safety. This occurred for example in the leadup to the Challenger disaster, and was also identified as a factor contributing to the Buncefield accident (increased throughput led to increased pressure on operators [COMAH, 2011]);
- pressure of cost reduction overriding safety concerns (for example BP Texas City, Grangemouth) – chequebook mentality identified by internal BP audits, in which safety spending is based on budgeted amounts rather than on risk analysis;
- confusion between reliability and safety, including reliance on past success as a substitute for sound engineering practices [CAIB, 2003];
- a "limit ourselves to compliance" mentality, in which safety innovations which have not yet been mandated by the regulator are not put in place (due to cost or to overtrust of the effectiveness of regulators);
- organizational barriers which prevent effective communication of critical safety information, stifle professional differences of opinion and suppress minority viewpoints [CAIB, 2003];
- evolution of an informal chain of command and decision-making processes that operates outside the organization's rules [CAIB, 2003];
- insufficient oversight by the regulator, or regulators who do not have sufficient authority to enforce change in certain areas;
- a tendency to weigh operational ease/comfort/performance more than the restrictions which are often required for safe operation.

Questions to help you identify drift into failure:

- Are workarounds and shortcuts regularly used by workers to meet deadlines?
- Are there some systems that operate in a significantly different manner to that originally designed (higher flow rate, pressures or temperatures than the design capacity, lower staffing levels, higher maintenance intervals)? If so, have formal risk assessments been undertaken to assess the safety impact of the change?
- Do managers become less strict in requiring work to be undertaken according to procedures and safety guidelines when work falls behind schedule?
- Does the organization appear to provide insufficient financial, human and technical resources for certain tasks or activities?
- Are project deadlines often set based on overly optimistic assumptions? Are they frequently revised later on in the project?
- Are operational deviations risk assessed? Are they linked with the management of change system?
- Is it clear who is responsible for authorizing deviations from standard practice and established procedures? Is there a formal procedure for authorizing such deviations?
- Is there a significant backlog of scheduled maintenance activities?
- Are rewards and incentives heavily weighted towards production outcomes, with little weight to safety and quality related indicators?

BP Texas City
In the startup operation, the level of liquid used by operators in the distillation column was higher than that recommended by the procedure. This was due to operational concerns (underfill leading to production problems) whose safety implications had not been checked.

4.12 Inadequate communication

Organizational learning requires communication between the people who are witnesses to the learning event, the people who analyze it and establish recommendations, and the people who can implement changes and internalize the new information. Communication is often impaired by the organizational structure of a company: organization charts, policies, regulations, budgeting, security systems. Efficient organizations with enforced lines of communication and clearly demarcated responsibilities mean that a manager in one department may not talk to a manager in another department.

Inadequate communication may be caused by:

- the communication medium: problems with the tools (for instance the computer system or the newsletter) used to store and share information;
- cultural issues, such as the retention of information for issues of power;
- poor filtering of information to decide which information can be useful to which categories of participants, leading to information overload or to excess scarcity;
- the increasing specialization within certain worker trades;
- the effects of subcontracting.

Information dissemination, and thus learning, will be facilitated by the existence of shared spaces such as cafeteria and coffee spaces where informal discussions can help overcome failings in the formal communication channels.

4.13 Conflicting messages

The sociologist E. Goffmann has analyzed organizational behaviour using a dramaturgical metaphor, in which individuals' identity plays out through a "role" that they are acting. In his dramaturgical model, social interaction is analyzed in terms of how people live their lives like actors performing on a stage. Goffmann distinguishes the "front-stage", where the actor formally performs and adheres to conventions that have meaning to the audience, from the "back-stage" where performers are present but without an audience. When there is a disconnect between management's front-stage slogans concerning safety (such as "Safety first") and the reality of decisions or actions on the back-stage ("let's wait until the next planned shutdown to do this maintenance"), management messages lose their credibility.

[Langåker, 2007] has analyzed the importance of compatibility between the front-stage and back-stage messages (management's ability to "walk the talk", or commitment to the meaning of safety messages, as opposed to appearances) for the effectiveness of organizational learning.

4.14 Pursuit of the wrong kind of excellence

Safety is a complex issue, and difficult to characterize in the form of indicators. Some organizations focus on **occupational safety** indicators (such as lost time at work), and do not measure or follow **process safety** indicators, which estimate the level of technological risk. A further dimension of safety which is not necessarily correlated with the previous two dimensions is that of **product safety**. Accidents such as the explosion at the BP Texas City refinery in 2005, where the occupational safety record was very good but where budget restrictions had led to under-investment in the maintenance of equipment and where the number of incidents such as losses of confinement was high, demonstrate that following an incomplete set of safety performance indicators can lead to a mistaken belief that the level of safety on one's facility is high.

Some organizations attempt to improve safety by providing **incentives** for poorly chosen safety targets, such as "zero spills" or "no accidents": such objectives cannot be achieved in the long term, and will tend to discourage reporting of incidents (no-one wants to be the worker who was "responsible" for his colleagues not obtaining the bonus for a million hours worked without a recordable injury…). Incentives concerning "leading indicators" such as the number of corrective actions implemented will generally be more effective in leading to safety improvements [Hopkins, 2009].

5 Enablers of learning

Enablers of learning are characteristics or procedures within an organization that facilitate the recognition of the need for change, the identification of relevant new knowledge and the implementation of changes. The next paragraphs describe a selection of identified *learning enablers*. These diverse practices should ideally be promoted within an organisation to evolve towards a more learning culture.

5.1 Importance of appropriate accident models

Safety research over the last 30 years shows that chain-of-events analysis is only the *beginning* to identifying organizational and systemic factors underlying unwanted events. Each human working within the system (operators, managers, maintenance staff) has a mental model of the system that they control, concerning the interconnections between its elements, the types of hazards present, the warning signs of degraded operation, and the appropriate actions in each system state. They build this *safety model* over time based on their observation of system operation, on discussion with colleagues, training provided and information from the experience feedback system. If there are significant divergences between this safety model and real operation of the system (for example in some unusual, transient phase), their control actions will be inappropriate, and may lead to an accident. Incident investigations and experience feedback provide important information to managers, regulators, and others about the system. If the audience for this communication is not capable of handling the feedback (too busy, overconfident, suffering from fixed ways of thinking, paralyzed by fear of being wrong), then their safety models and their knowledge will not be updated [Carroll and Fahlbruch, 2011].

In discussing an investigative process with outsiders, the rationale and results frequently are explained through metaphors. Over decades, domino theory, the iceberg principle and Swiss cheese models have been popular representations. However, the powerful communication capabilities of these theories, principles and models can be mistaken for descriptive, analytic and even explanatory authority, which is not always present when these simple metaphors are applied to complex socio-technical systems.

5.2 Training on speak-up behaviour

As described in section 4.8, *psychological safety* is a shared belief within a workgroup that people are able to speak up without being ridiculed or sanctioned. Higher levels of psychological safety increase information sharing, trust and the acceptance of lessons learned.

Psychological safety can be increased by training managers on **coaching behaviour** and training team members on **speak-up behaviour** or assertiveness. These elements are typically included in Crew Resource Management (CRM) training, as applied for some time already in civil aviation and other sectors.

5.3 Safety imagination

Risk analysis, and discussions on safety within organizations, concerns a number of anticipated and well-known hazards, often with a focus on those that are unique to the industry within which the organization operates. This focus, together with group-think effects, may lead organizations to overlook less obvious, emerging hazards. The concept of *safety imagination* proposed by [Pidgeon and O'Leary, 1994] concerns the ability the "think outside the box" and develop richer accident scenarios than those normally considered in quantitative risk assessments.

[Pidgeon and O'Leary, 2000] propose a number of guidelines for fostering 'safety imagination':

- attempt to fear the worst;
- use good meeting management techniques to elicit varied viewpoints;
- play the 'what if' game with potential hazards;
- allow no worst case situation to go unmentioned;

- suspend assumptions about how the safety task was completed in the past;
- approaching the edge of a safety issue a tolerance of ambiguity will be required, as newly emerging safety issues will never be clear;
- force yourself to visualize 'near-miss' situations developing into accidents.

Such exercises can help to reduce complacency on safety issues, can trigger discussion on new approaches to managing risks and emerging hazards, and are conducive to learning.

5.4 Workshops and peer reviews

Whilst the historical focus in organizational learning research has tended to be on operational experience feedback, there is increasing recognition that organizational learning is much wider and draws on many different mechanisms, such as workshops, secondments[25], peer group exchange forums, peer review and assist missions[26]. These provide the opportunity to learn from routine operational experience as well as from events.

Some examples of practices that facilitate learning:

- **Workshops and conferences**, which allow interaction between academia and industry, between different industrial sectors, are an important way of being exposed to new ideas, new questions and alternative manners of handling problems. Examples are the conferences organized in the nuclear power area by organizations such as IAEA, the OECD NEA, the WANO group of nuclear operators, etc.
- **Peer reviews**, as used in the nuclear industry. A team of 10–20 people from several plants in different countries visits a host plant for a period of 2–3 weeks to assess performance in several organizational areas. This practice gives a learning opportunity both for the host plant and for the people taking part in the review. The effect of learning is enhanced by revisiting the host plant some 18–36 months later after the peer review.
- **Leadership and safety walkthroughs**: in general, unit and site management walk around their facility/site, looking for hazards, and making an effort to point out safe conditions along with areas for improvement. Often based on a checklist of questions to address.

5.5 A learning agency

The existence of a *learning agency* (see box below) is posited by C. Argyris and F. Koornneef [Koornneef, 2000] as being an enabler of learning. The learning agency should comprise some members who understand operations well, and others able to take a more global view. It helps to re-contextualize the information provided by front-line workers and add any additional necessary information. The learning agency can play the role of intermediary between individuals and the organization, analyzing operational surprises, disseminating the lessons to other parts of the firm, and ensuring the lessons are captured in the corporate memory.

Learning agency
The learning agency consists of people who learn on behalf of the organization and ensures that the learning experience becomes embedded in the organization. This learning agency has a crucial role in recapturing and preserving the contextual information lost in the notification process. It should not be seen as a way of "handing off" the responsibility for learning to someone else.

[25] *A secondment is the temporary detachment of a person from their regular organizational position to an assignment in another department or organization.*

[26] *Assist Missions on Knowledge Management are a mechanism used by the IAEA (nuclear energy sector) in which a small team of specialists visit a counterparty organization and transfer good practice and suggestions for improvement.*

5.6 Dissemination by professional organizations

Most industrial sectors have national or international professional bodies, which play an important role in promoting discussion and vicarious learning across organizational boundaries (working groups, conferences, safety bulletins, etc.). They play a positive role in encouraging learning by professionals who work within the industry. These dissemination activities help organizations to avoid accidents by learning from other organizations' failures and crises.

The dissemination is generally materialized either in written form (magazine, safety bulletins…) or presented orally at conferences and safety meetings. This work requires good editorial capability to maximize reader engagement: first-hand stories are useful for capturing attention, but should be focussed; a clear and concise description of events (possibly including photos) and lessons learned should be made available; possible links with similar incidents should be made, including statistical or trend information if it is available.

Examples of successful dissemination activities include:

- the *Safety Bulletin* of the American Society of Chemical Engineers;
- HindSight magazine[27], published by Eurocontrol for the air traffic management community, and which always includes a segment on a near miss, presented from different viewpoints of actors working in different roles, together with reactions and analysis from experts and people in operations. The focus on rich variety of points of view helps the reader to reflect on the safety dimension of various interactions in their daily work;
- The Flight Safety Foundation organizes well attended annual conferences on safety in civil aviation, organizes working groups on various safety topics, and publishes a magazine called *AeroSafety World*;
- The World Association of Nuclear Operators (WANO) organizes the exchange of operating experience between nuclear facility operators worldwide, as well as technical support and peer reviews;
- The European Clearinghouse on Nuclear Power Plant Operating Experience for dissemination between nuclear safety authorities in EU countries, using newsletters, publication of reports, and management of databases;
- The Major Accident Hazards Bureau disseminates publications[28] such as *Lessons Learned Bulletins* and *Seveso Inspection Series* to the Seveso Competent Authorities of the 28 Member States, including Norway and Iceland.

5.7 Standards

Sector-specific technical standards are a good way of accumulating knowledge from past failures and from good practice into common design principles. Standards are typically improved over time with input from industry workgroups and from specialists from the insurance industry [Brusson and Jacobsson, 2000]. They evolve more slowly than industrial practice, but more quickly than legislation.

Examples:

- American Petroleum Institute[29] standards are regularly updated to include knowledge from accidents and near misses.
- The US National Fire Protection Authority[30] standards on sprinklers and other preventive equipment (often mandated by private insurers) provide guidance on best practice in designing new facilities and upgrading existing ones. The organization is mostly funded by the insurance industry, and insurers are able to provide strong incentives for the implementation of their guidelines by setting differentiated premiums according to which standards are put in place.

[27] *Available for free online at https://www.eurocontrol.int/content/hindsight.*

[28] *https://minerva.jrc.ec.europa.eu/en/content/f30d9006-41d0-46d1-bf43-e033d2f5a9cd/publications*

[29] *API: http://www.api.org/.*

[30] *NFPA: http://www.nfpa.com/.*

- Voluntary programmes such as Responsible Care™ [ICCA, 2006] in the chemicals industry encourage companies to share information on incidents and accidents.

5.8 Role of regulators and safety boards

Regulators and safety boards have a responsibility to encourage learning across organizations in the regulated industry. In the nuclear power sector, for example, industry organizations such as IAEA play an important role in disseminating lessons learned, establishing principles and standards, and assisting individual organizations to self-assess and improve (despite clear demonstrations of the inadequacy of this learning that arose from the Fukushima-Daiichi accident). Commercial aviation is another example of an industry that has become expert at collecting information from both near-miss incidents and major events and then transferring knowledge across the entire industry.

Examples:

- EASA, the European civil aviation authority, publishes safety recommendations and airworthiness directives on the basis of the analyses of incidents undertaken by safety authorities of member states. Implementation of these recommendations is mandatory for airlines, air traffic management organizations and aircraft manufacturers alike.
- The pedagogical animations and safety videos created by the US Chemical Safety Board[31] are a powerful mechanism for improving awareness of various types of risks, and are widely used in safety training worldwide.

5.9 National inquiries

Large public inquiries into major accidents tend to play a very positive role in leading to changes in the legal framework and public attitudes with respect to certain industries. Indeed, without the public pressure generated by large accidents, it is difficult to generate sufficient political momentum and public goodwill to allow such complex changes. However, the financial and emotional cost of these inquiries should not be underestimated.

Some noteworthy examples of public inquiries which examined multi-level factors contributing to an accident and led to changes at the system level:

- The Cullen inquiry into the 1988 Piper Alpha accident in the North Sea led to better internal design of offshore platforms, more stringent inspection standards, and the obligation for firms operating offshore platforms to prepare a safety case, an evidence-based demonstration that the major accident hazards are well managed.
- The Cullen inquiry into the 1999 Paddington Junction (Ladbroke Grove) railway accident in the UK led to major changes in the regulation of railway safety and the implementation of a train protection system nationwide.
- The Columbia Accident Investigation Board produced a fantastic in-depth analysis of the organizational factors that led to the failure of the Columbia space shuttle in 2003[32].
- The investigation into the Prestige oil tanker spill off the coast of Galicia in 2002 led to changes in regulations on liability for shippers in case of accidents.

5.10 Cultural factors

The main enablers at a cultural level for successful learning can be summarized as follows [Størseth and Tinmannsvik, 2012]:

- **Cooperation** is a non-competitive joint activity of two or more parties whose outcome is mutually beneficial. Cooperation is most common between parties in the same organization, but can also exist between firms, between a company and an authority, between a firm and an industry group, between a firm and a stakeholder group, for instance.

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[31] *See http://www.csb.gov/.*

[32] *Report available at http://www.nasa.gov/columbia/home/CAIB_Vol1.html.*

- **Motivation** is the willingness of personnel, management, authorities, etc. to go "head to head" with the problem in the honest quest for change/learning. Extrinsic motivating tools used to motivate personnel are based on physical and monetary rewards and can be effective to some extent. But intrinsic motivators are much more difficult to define due to different personalities and psychological needs of individuals. Motivating process is continuous and adequate company policy should define it well. Only a motivated individual can learn effectively from many different sources and even without special external help.

- **Trust** refers to both intra-types of trust (within a given company or organization) and inter-types of trust (company-authority, company-sector organizations, employee-company organization, etc.). Trust is in most cases based on own or others experience gained through time in communication and activities with the other party. Trust is also dependent on the interest of parties but even if there are competitive parties involved trust could be based on mutual, many times unwritten, agreement. There are also many additional factors like openness, transparency and congruency which increase. A trustful approach in learning is essential to avoid unnecessary time for "finding proof" i.e. wasting time.

- **Existence of a shared language and concepts.** Understanding each other is usually taken as natural but in fact it is many times big unrecognized issue. The problem could be multifold but a typical part is when the receiver of information doesn't provide adequate feedback of his/her interpretation to the sender of the information. This is in many cases the reason for misunderstanding. If the information is accepted the wrong way it could later result in tangible problems. According to typical taxonomy of causes (e.g. IAEA/NEA Incident Reporting System), the main (root) cause of this deviation (occurrence, event…) is lack of a questioning attitude. Deeper investigation could reveal that differences in culture, dialect, terminology or some external obstructers could lie behind the ineffectiveness of the communication. There are usually two parties in the communication process and at least from one side effort is needed to enable mutual understanding i.e. learning.

- **Individual curiosity and vigilance** depends on his/her interest. This enabler could be of crucial importance to switch someone's awareness to active listener/learner state. Whether the interest to learn is professional or not, both sides (in person(s) to person(s) learning) should apply sufficient effort to ensure the lesson is interesting and turn this switch on.

- **Ability to embrace new ideas and change** at both the individual and organizational levels. In other words it is necessary to be open-minded to accept possible improvements. And vice versa: blind-minded individuals or organizations are continuously missing opportunities to learn i.e. they are creating fruitful ground for disaster.

- **Presence of a supporting culture** (learning culture, just culture per [Reason, 1997]). Many discussions are conducted about this enabler but, to understand it better, Schein's model of organizational culture [Schein, 1990] is widely used to explain the basis. Three distinct levels in organizational cultures are artefacts and behaviours; espoused values; and assumptions. Understanding all three levels is a good starting point if someone wants to improve learning abilities as well as other characteristics needed to enable positive changes in an organization.

Furthermore, organizations must also be willing to **unlearn outdated or ineffective procedures** if they wish to learn better safety management strategies. Unlearning is usually not defined as a process or activity in the organization but increasing demand on acquiring new knowledge means that it has to be considered and appropriately managed. Unlearning simply provides the space for new knowledge and thus can be treated as additional enabler for learning.

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