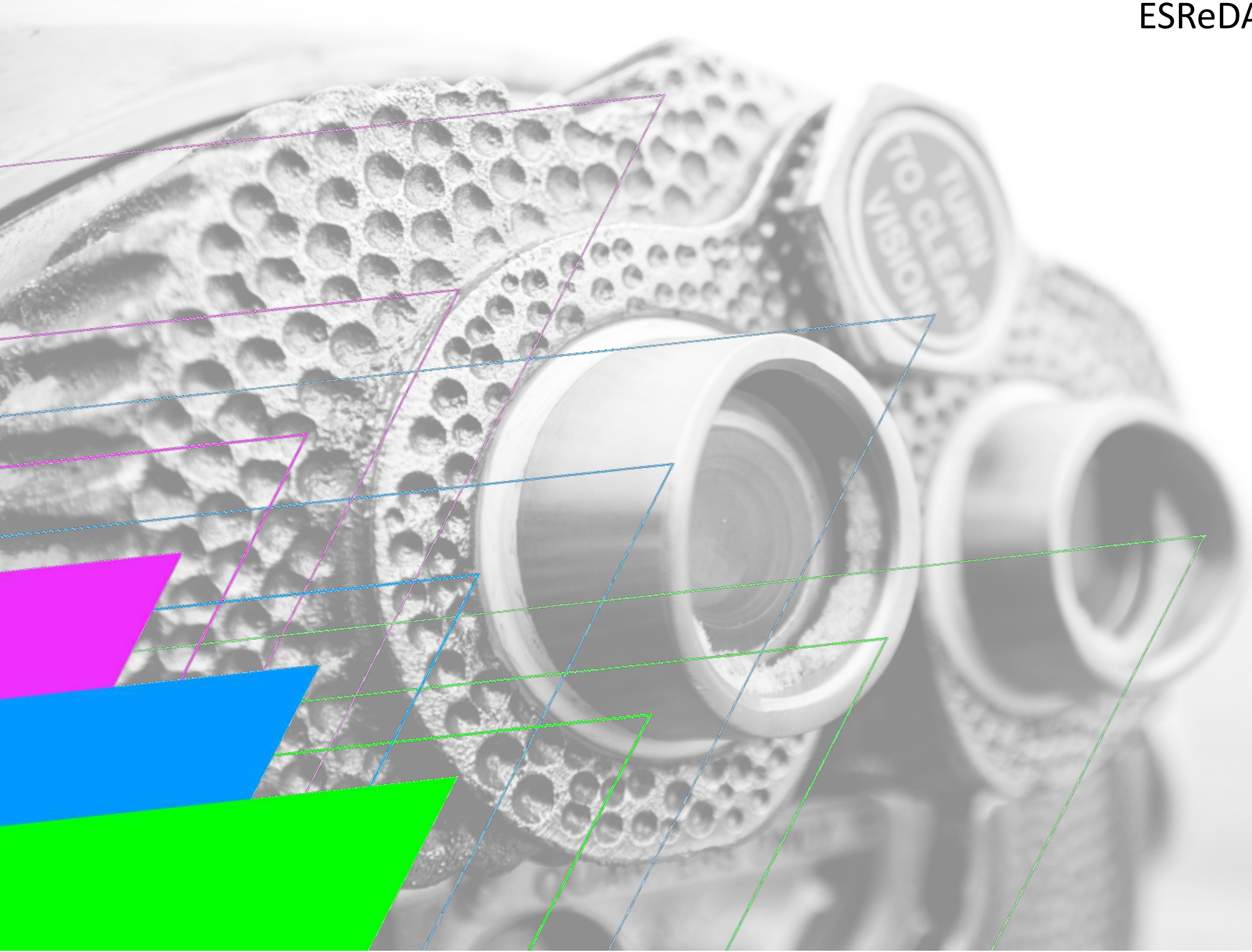
Enhancing Safety: The Challenge of Foresight

ESReDA Project Group *Foresight in Safety*



Chapter 8

Why and How to Employ Organizational Factors for Foresight in Safety?

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8 Why and How to Employ Organizational Factors for Foresight in Safety?

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8.1 Executive summary

Organisational factors, which are critical levers of the safety, reliability and resilience of operations and systems, are not considered enough. When in good order, these factors make it more likely that accidents will be prevented and have lower potentials to occur. However, when dysfunctional, these factors make accidents much more likely and serious because they impact many activities and equipment. In some organisations, top management and boards of directors may be unaware of the dysfunctionality of the organisations over which they preside. This unawareness may result from several causes. For example, not receiving or listening to bad news, not being proactive enough to seek out learning and improvement opportunities through event investigation, audit reports, organisational diagnosis in normal operation, or not anticipating future threats.

We provide some definitions and some guidelines for elaborating a framework of analysis that includes organisational factors and the dynamic status of the system state (improving or degrading safety). We illustrate these using some practices from inspection and regulatory assessment of safety management.

Our key messages are:

- organisational factors affect risk in the totality of the organisation, due to a multiplying factor;
- organisational factors have been and are still ignored or under-used;
- top management lack knowledge about the effects of organisational factors because of flawed investigations (hindsight problems), audits (insight problems) and perception of future threats (foresight problems);
- the lack of practical oversight of organisational factors and their interrelationships is an existing operational gap;
- a guiding framework with adequate questions could be developed to fill this gap.

8.2 Introduction: the organisational factors as an opportunity for safety I and II?

8.2.1 Purpose of the chapter

The purpose of the chapter is to provide some reasons and some guidelines for practitioners for investigating, auditing, diagnosing, inspecting and detecting whether organisational factors are leading to a more dysfunctional organisation that degrades safety, or enhancing the reliability and resilience of the organisation and improving safety.

More specifically, the goal is to encourage safety actors (managers, operators, investigators, auditors, and inspectors) to treat 'organisational factors' (OFs) as important variables that could, according to the type of OF, either limit or enable foresight about safety accidents and their prevention. For many safety analysts, those organisational factors have been and are still not enough used by operators and regulators to enhance risk prevention, though they offer a strategic multiplying factor that is worth investing in.

Safety actors' investigations and interpretations should address past and current weaknesses and strengths but should also foresee the future: the likely outcomes of existing trends, as well as forthcoming threats and opportunities. On this basis, improvement actions can be taken to increase safety margins and, perhaps, acknowledge the conditions that are essential to achieve current success.

The assumption is that organisational factors can be very powerful and durable conditions that lead to safety degradation, and which have contributed to many

[23] *DISCLAIMER: My experiences and insights are out of my Industrial career and my following career as Process Safety Inspector. However not all of my insights are those of my employer.*

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major accidents. However, it also assumed that OFs are key levers to reach a more reliable and resilient organisation and improve safety.

In general, accidents do not happen 'like lightning striking out of a clear sky'. Before major accidents happen, it has been observed that there occur early warning signs (EWS), such as near misses which were not recognised or alerts by some actors which were not treated early enough during the "incubation period" (Turner, (1978). This empirical lesson from accidents provides an opportunity for preventing other accidents, but it depends on investing sufficiently action-oriented effort in investigations, audits, inspections, and situation understanding / interpretation, as well as the management and regulatory actions that achieve effective change.

Concerning strategy (i.e. how to improve foresight and prevention by addressing organisational factors), two paths can be followed by safety actors:

- On the one hand, there is a normative route that starts by comparing the conditions in an organisation to some ideal model (founded on theory, experience or research findings) about organisational safety, reliability and accidents and implementation of measures for accident prevention, then makes recommendations designed to make things better.
- On the other hand, there is a more dialectical route, for example: obtain data and offer interpretations; then discuss different interpretations; act on some things, but on other things ask new questions; collect more data, encourage stakeholders continue to contest meanings, and so forth.

Of course, a combination of the two paths is also possible.

This chapter will first define in general the organisational factors and show the logic that connects facts to organisational factors of accidents (as root causes but especially as underlying (latent) causes). It will also provide readers with some examples, directions and guidance to inquire and act on organisational factors, such as from the BP Texas City accident, organisational diagnosis of safety management in the nuclear industry in France, and regulatory inspections of Seveso chemical plants in Belgium.

As a final element, the future principles for elaborating a framework are explained. This 'OF Framework for questioning Foresight in Safety' is a work in progress[25]: the present authors aim to develop a 'part two' to this 'part one'. This kind of framework could be used by safety actors (managers, operators, investigators, auditors, and inspectors) to develop their own "road map" to guide themselves during processes of investigation, diagnosis and inspection, specific to the features of the organisation investigated. For instance, it aims at giving further plausible directions and targets for organisational investigation once a dysfunctional organisational factor is detected and confirmed.

8.2.2 Organisational factors and failures of foresight: BP Texas City refinery accident

The Texas City BP refinery accident that occurred in 2005 is a reference case. It illustrates the key concepts: organisational factors[26], early warning signs and opportunities for Foresight in Safety (FiS) through organisational analysis of safety. It is a typical case where the accident confirms the prognosis "an accident waiting to happen" that was made by several actors (managers, workers, and health and safety engineers) and by different processes (internal audits, event investigations, and an external audit by a consultant) (Dechy et al., 2011).

On March 23, 2005, an explosion and fire at the BP refinery in Texas City led to 15 deaths and 180 injuries. The board member and CEO of the US Chemical Safety Board (CSB), Carolyn Merritt (2007) said: "The combination of cost cutting, production pressures, and a failure to invest caused a progressive deterioration of safety at the refinery." But the accident has its roots deeper in the past. The CSB report (2007, p. 20) found that "cost-cutting in the 1990s by Amoco and then BP left the BP Texas City refinery vulnerable to a catastrophe." The CSB (2007, p. 18) noted also that "The Texas City disaster was caused by organisational and safety deficiencies at all levels of the BP Corporation. Warning signs of a possible disaster were present for several years, but company officials did not intervene effectively

[25] *1/ our work is in Progress, because not fully tested; 2/ we only provide directions, guidelines on how to develop a framework for specific inspection, audit, investigation, because the examples provided do not cover all topics*

[26] *We chose this accident as paradigm, knowing that many other events could have been chosen (e.g. the nuclear power plant accident at Three Mile Island (1979), head on collision of trains at Ladbroke Grove (1999), disintegration of the space shuttle Columbia (2003, …). https://www.csb.gov/u-s-chemical-safety-board-concludes-organizational-and-safety-deficiencies-at-all-levels-of-the-bp-corporation-caused-march-2005-texas-city-disaster-that-killed-15-injured-180/*

to prevent it." Merritt (2007) also said that "adhering to and enforcing federal regulations already on the books would likely have prevented this accident and its tragic consequences."

Indeed, the CSB investigation showed that some BP members had identified the major risks already in 2002. The new director of BP's South Houston Integrated Site observed in 2002 that the Texas City refinery infrastructure and equipment were "in complete decline" (CSB, 2007, p. 151). In consultation with senior managers based in London, the director ordered a study that looked at mechanical integrity, training, safety, and economic opportunities. The study, which was shared with London executives, concluded that mechanical integrity was one of the biggest problems (CSB, 2007, p. 151).

The BP Group Refining Vice-President suggested a follow-up inquiry asking in an e-mail (August 16th, 2002), "How has [South Houston] gotten into such a poor state?" This follow-up report, entitled "Texas City Refinery Retrospective Analysis," was issued later in 2002, and had the objective of determining why Texas City refinery performance had deteriorated. The analysis concluded that "the current integrity and reliability issues at TCR [Texas City Refinery] are clearly linked to the reduction in maintenance spending over the last decade." Capital spending was reduced 84 percent from 1992 to 2000 (CSB, 2007, p.153).

Several other studies, surveys, audits and also serious incidents alerted and signalled the severity of deficiencies, but the response of BP managers was "too little and too late" (CSB, 2007, p. 26) with the implementation of corrective action plans that were poor. CSB found that "at the end of 2004, the Texas City site had closed only 33 percent of its PSM [process safety management] incident investigation action items; the ISOM [isomerisation] unit closed 31 percent. Furthermore, CSB note that BP management made a presentation in November 2004 on the reality of safety, saying: "Texas City is not a safe place to work" (CSB, 2007, p. 172).

BP managers were not alone in holding these views. A safety culture assessment conducted by an external consulting company (Telos Group) alerted the managers in January 2005 to the critical and degraded state of the refinery. The Telos report identified many of the same problems later found by the CSB in retrospect after the March accident. The business unit leader who initiated the Telos survey was looking for "brutal facts" concerning "our management systems, our site leadership, our site cultures, and our behaviours for safety and integrity management" (CSB, 2007, p.168).

The CSB (2007, p. 169) stated that the Telos safety culture assessment findings included:

- Production pressures impact managers "where it appears as though they must compromise safety."
- "Production and budget compliance gets recognised and rewarded before anything else at Texas City."
- "The pressure for production, time pressure, and understaffing are the major causes of accidents at Texas City."
- "The quantity and quality of training at Texas City is inadequate…compromising other protection-critical competence."
- "Many [people] reported errors due to a lack of time for job analysis, lack of adequate staffing, a lack of supervisor staffing, or a lack of resident knowledge of the unit in the supervisory staff."
- Many employees also reported "feeling blamed when they had gotten hurt or they felt investigations were too quick to stop at operator error as the root cause." There was a "culture of casual compliance."
- Serious hazards in the operating units from a number of mechanical integrity issues: "There is an exceptional degree of fear of catastrophic incidents at Texas City."
- Leadership turnover and organisational transition: the creation and dismantling of the South Houston site "made management of protection very difficult."
- The strong safety commitment by the Business Unit Leader "is undermined by the lack of resources to address severe hazards that persist," and "for most people, there are many unsafe conditions that prove cost cutting and production are more important than protection. Poor equipment conditions are made worse in the view of many people by a lack of resources for inspection, auditing, training, and staffing for anything besides 'normal operating conditions.'"
- Texas City was at a "high risk" because of a widespread "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."

When the business unit leader received the results, he wrote (in an e-mail March 17, 2005) that "seeing the 'brutal facts' so clearly defined was hard to digest, including the concern around the conflict between production and safety. The evidence was strong and clear, and I accept my responsibility for the results" (CSB, 2007, p.171). But the same day he wrote a summary to all plant supervisors stating that "the site had gotten off to [a] good start in 2005 with safety performance that "may be the best ever," adding that Texas City had had "the best profitability ever in its history last year" with over $1 billion in profit—"more than any other refinery in the BP system" (CSB, 2007, p.171).

The downward trend of reduction in the numbers of occupational incidents was misinterpreted by some managers as a sign of improvement of industrial safety, while the number of losses of containment increased (from 399 to 607 per year from 2002 to 2004) and costly accidents occurred (e.g. 30 million $ in 2004). But at the same time, the 2005 Texas City HSSE Business Plan (presented March, the 15th) warned that the refinery likely would "kill someone in the next 12-18 months." This fear of a fatality was also expressed early 2005 by the HSE manager: "I truly believe that we are on the verge of something bigger happening," referring to a catastrophic incident (CSB, 2007, p. 173).

Thus, the lessons learned from this accident clearly show that signs of deteriorating safety had been detected by many actors, despite the differences in their approaches and methods (observations from operators and from managers, internal and external audits, safety culture survey, incident investigation) and were confirmed after the accident by the CSB investigation (Dechy et al., 2011). In general, 'advanced' industrial systems are resistant to errors and the accident is "hard to obtain" (Perrow, 1984). An 'incubation period' (Turner, 1978) is observed, implying an accumulation of EWSs. The systematic study of accidents (Llory, 1996) demonstrates that the deficiencies are sometimes severe, often visible to a certain number of actors that are able to make the adequate diagnosis or prognosis if they are given adequate resources.

8.2.3 Why do organisational factors have such potential to enhance or endanger safety?

The BP Texas City case is a trenchant example and costly reminder of the significance of organisational factors to accident prevention. Organisational factors are of strategic interest for accident prevention because they create the conditions in which safety efforts benefit from a multiplication factor on the positive side (safety II) and are the basis on which to counter negative effects on a larger scale (safety I).

This multiplication factor deals with the impact of local factors versus macroscopic factors on probabilities of errors and failures (as illustrated in the following scheme). This multiplication factor is the key strategic reason why it is worth employing and investing in organisational factor leveraging for safety enhancement.

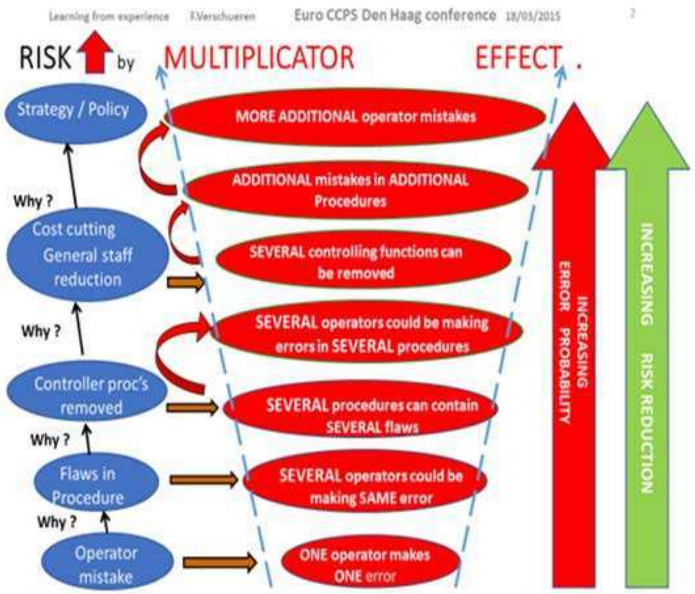

Figure 1. Organisational factors strategic interest for prevention-the "Multiplication Factor" (adapted from Verschueren, 2015)

Figure 1 shows how an investigative process (accident investigation, organisational diagnosis, or audit) could develop on different levels of the socio-technical system (e.g. Rasmussen, 1997) and how measures to reduce risk could be implemented at all levels although not with the same impact.

It starts with one of the direct causes of an accident/incident (investigation) or a direct potential disturbance and weakness or deviation (audit). A generic example of a direct cause is 'operator makes a mistake'. If lesson learning reduces a complex event to a single human error and marries this to a corrective action 'fire the scapegoat of the organisational chain' or 'train the individual', then the 'multiplication factor' at this most local level is the smallest: 1 to 1: one operator fired or better trained. This at best stops the repetition of one mistake or some mistakes at this level. We are on a 'human error' level.

What if someone else was in a similar work situation: could an error occur or recur? If one searches for the possible causes of the operator error, the verification by auditor/investigator of the procedure used by the operator could lead one to find errors in the written procedure. So, the next level cause would be the 'faulty procedure'. Here the multiplication factor will be more than 1, especially if the task is performed by more than one person or when someone else takes the position: one erroneous procedure => several operators could make similar mistakes.

We are now at the 'human factors' level related to 'working situations'. Faulty procedures are not the only factors influencing working situations (e.g. human-machine interface, staffing, fatigue, etc.). Of course, an investigator or auditor shouldn't and usually will not stop here (beware of 'stop rules'[27]) but should further ask 'why'; for example, why this procedure contained an undetected error(s). The investigator might find that, in the past, there existed a person/function who checked every new written procedure before it was put into use and that at the time of investigation/audit this function no longer existed. If one procedure contains error(s), then it brings into question the whole process of designing and verifying procedures. In this situation, the multiplying factor would be even greater than those restricted to one working situation. This is because a flawed process of designing and checking procedures => possible more procedures contain errors => even more errors could be made by operators.

Once more the auditor or investigator should ask why this function/person was removed from the existing control chain if that is the reason that explains the flawed organisational process. One of the possibilities he could find is that this function was removed during (and due to) a cost reduction campaign.

Depending on the size of the company/organisation (several services, several departments) it could be that during this cost-reduction campaign, several other control functions were removed. It should be clear that in that way the 'semi quantitative' relation will be enhanced again. Thus, due to cost cutting => removing several control functions => possible even more procedures or measures to manage risks over the whole organisation contain undetected errors => even more errors could be made by operators in all departments and all working situations.

The cost reduction in this example might have been decided in a company-wide overall strategy definition and policy review aimed at finding a new financial balance and, of course, this cost-cutting campaign may have other transversal effects to other organisational controls beyond just reducing the "procedure designing and checking activity". We are now on the "highest organisation" level.

The investigation would continue, of course, to question the rationales and the evidence for such decision-making processes. This was done by the US CSB for BP Texas City refinery from the business unit level in South Houston to the top of the BP Group at BP headquarters, the board of directors in London and even questioned the role of regulators, especially in the US (OSHA and EPA).

The essence of all this, is that with every new level [operator => procedure => checking function => cost reduction => strategy], the probability of having errors and the negative impact of a flawed process gets multiplied.

If we state this in a positive manner to enhance robustness and resilience: if the organisation responds with the related measure on a higher level, the gain in risk reduction will be larger: many more potential mistakes will be prevented (green arrow: 'increasing risk reduction'. In other words, the higher the level of organisational factors the auditor/investigator gets to and that a manager corrects, the more they open windows of opportunity to prevent many types of accidents (and not only a similar one).

[27] Several 'stop rules' have been defined (e.g. Hopkins (2003)); the main idea is that an investigator may explicitly or implicitly stop asking why when he believes he has a satisfying explanation of failure that fits with its worldview categories of thinking and acting (e.g. if it is human error, then train the individual, or improve the safety culture) hiding the complex causal relationships.

8.2.4 History of accidents and the importance of organisational factors

ESReDA has campaigned since the 1990s for better analysis of events and investigation of accidents (ESReDA, 2003, 2005, 2008; Roed-Larsen et al., 2004; Dechy et al, 2012, Dien et al., 2012), for 'dynamic learning' to consider the issues of the follow-up of lessons from investigations, and for the removal of barriers to learning (ESReDA, 2015a, 2015b, 2015c). However, many event and accident reports were still not "well investigated and analysed" meaning that they did not correctly address organisational factors (Dien et al., 2012). This issue is revisited in subsection 8.3.3. We will define these organisational factors (also known as organisational influence factors) in table 2 of 8.2.5 and distinguish them from human and technical factors.

Researchers who reviewed many 'well' investigated and analysed accident reports (e.g. Cullen, 2000; CAIB, 2003; CSB, 2007;…) observed recurring root causes, similar patterns, "striking similarities", "echoes", "parallels" between accidents (Turner, 1978; Llory, 1996, 1999; Reason, 1997; Rasmussen, 1997; Dien et al., 2004, 2012; Hayes and Hopkins, 2015). These recurrences offer the opportunity to capitalise them into a 'Knowledge of accidents' (Dechy et al., 2010, 2016, 2018). This knowledge of accidents is then useful for guiding and for interpreting in organisational analysis of accidents (Llory and Dien, 2010a, 2010b; Llory and Montmayeul, 2010, 2018) and organisational diagnosis of safety (Rousseau and Largier, 2008; Dechy et al., 2011, 2016, 2018).

One outcome is related to the identification of a pattern of accident causation. An accident model has been observed and defined (Dien, 2006; ESReDA, 2009) with weak signals of safety degradation (Turner, 1978), latent failures (Reason, 1990, 1997) that go unrecognised during an incubation period (Turner, 1978). For Foresight in Safety (FiS), this accident model and definition have implications for risk prevention and specially to provide an opportunity to detect and act on early warning signs (EWS) before a severe or major accident happens.

A socio-technical system generates uncountable gigabytes of data every day; some information, and potentially some EWS, will get buried in the noise. Some of the EWSs are the symptoms of a safety degradation caused by a root cause of an accident waiting to happen.

To establish or enhance FiS, the goal of an investigation, audit, inspection, diagnosis that aims at preventing an accident is to capture those EWSs. Strategies to collect data, to generate and filter information, to recognise and interpret signs related to negative and positive organisational factors) will be proposed.

8.2.5 Definitions of Organisation, Technical, Human and Organisational Factors

As many writers and disciplines use the terms' 'organisation' and 'organisational factors', for a practitioner perspective, it is important at this stage to start to clarify our definition of these terms in the context of technical, human and organisational factors in high-risk industries. The document also suggests a classification scheme for organisational factors. For example, it locates management systems as a subset of organisational factors, and suggests governance 'functions' as another subset.

Definition of 'Organisation'

An organisation is an entity comprising multiple people that has a particular purpose and is more than a crowd of acting actors.[28] It can operate in the public sector (fulfilling public duties) or private sector (developing commercial activities) or in both. For the purpose of this chapter on organisational factors for FiS, we will look into the organisations as found in high-risk industries. In this perspective, an organisation is viewed as an entity being organised, reorganised and where the focus is to support processes, tasks, decisions and actions that enable sustainable performance and risk management.

An organisation may be therefore understood as the planned, coordinated and purposeful action to reach a common goal or construct a tangible product or service. Part of the organisation is governed by formal and management provisions, structures, systems, processes, rules, procedures, auditing, inspections to implement, enforce, enable the different activities of workers at all levels of the socio-technical system; part of the organisation is controlled by real practices of workers in the field, taking into account informal aspects, making sense of signals,

[28] An organisation is more than a crowd. Because it has a particular purpose, an organisation imposes constraints on actors' behaviour. In contrast, each actor in a crowd of undifferentiated individuals has more freedom to act on his own accord, albeit within the wider dictates of society at large.

individual and collective decision-making processes and the influence of power, social and cultural aspects as well.

Other authors refer to an organisation also as a socio-technical system (e.g. Rasmussen, 1997; Rasmussen and Svedung, 2000; Leveson, 2004) as it is a combination of social elements (individual and groups of people belonging to the organisation), technical elements (infrastructure, installations and individual apparatus), interacting and performing different activities to produce or operate safely. Additionally, an inter-organisational dimension is to be considered (Wilpert and Fahlbruch, 1998), or organisational network (Dien, 2006), implying to consider interactions with regulators, subcontractors, competitors, non-governmental organisations, citizens.

By coordinated and planned cooperation of all these elements the organisation can solve tasks that lie beyond the abilities of the single elements. This is the positive side of the mix of these socio–technical–organisational elements. The negative side is that because of the same mix most organisations tend to be complicated or even complex by nature.

Definition of 'Causal' and 'influence' factors: technical, human and organisational

In accordance with research on accident and system models (e.g. 'organisational accident' in Reason, 1997; 'socio-technical system' in Rasmussen, 1997) and accident investigation such as Management Oversight Risk Tree (Johnson, 1973), Tripod (e.g. Groeneweg et al., 2010) developed on basis of the Swiss Cheese model (Reason, 1990, 1997), Accimap (Rasmussen and Svedung, 2000), STAMP (Leveson, 2004), organisational analysis (Dien et al., 2004, 2012), we can distinguish three types of causal and influence factors influencing safety in an organisation: technical causal factors, human and organisational influence factors.

Technical factors can be considered as causal factors because they refer to a mechanistic and deterministic causality, while human and organisational factors are better considered as influence factors because they refer to complex relationships, with cause-consequence relationships transformed and belonging to a different paradigm (Morin, 1977), and that are more probabilistic (e.g. Dien, 2006; ESReDA, 2009; Vautier et al., 2018).

In many accident investigation methods (Sklet, 2004; Institute of Energy, 2008), it is common to distinguish direct or immediate causes, which are the last "stage" of the event, meaning that they are both the visible phenomena and consequences of root causes. Direct causes are generally technical failure and / or human error, while root causes are related to underlying deficiencies in upper levels of the socio-technical system and latent effects (Reason, 1990) such as an inadequate maintenance policy.

Table 1. Definitions of technical, human and organisational factors.

Type of causal and influence factors	Definition
Technical, causal factors	Technical causal factors related to technical elements: processes used in the industrial organisation and technical components (equipment, apparatus and installations) used in these processes. In the immediate chronology of events, often, the failing of critical equipment can lead to the start of an incident sequence or can lead to the failure of a technical barrier, so an incident sequence is not interrupted but continues and escalates. In the remote chronology of events, the failures of equipment and barriers are influenced by underlying human and organisational factors levels (e.g. poor maintenance action because of inadequate competencies and resources for adequate maintenance).
Human, influence factors	Human influence factors are factors that influence and may determine the performance of an individual, such as fatigue in some working situations. They are related to all humans (operational people, as operators and planners; people in all supporting services, such as maintenance, design, research, logistics, and procurement; decision makers on all levels from front-line operators and front-line technicians, the supervisors, the managers, every senior manager up to the CEO and the Board of Directors. They can also be identified in the work situation and activity of each actors (does he/she have the resources and tools (e.g. man-machine interface, procedure) to properly achieve the required job?), which lead to human errors such as omissions and faulty human

	decisions which impact an individual action or (possible and mostly worse) the actions of many others.
Organisational, influence factors	They are the factors relating to the influence of the organisation. We propose to distinguish here three groups of organisational factors (Table 2.)

Table 2. Different groups of organisational influence factors.

Organisational influence Factors	Definition
Management system failures	Indeed, an organisation has several essential Management Systems to "manage" its activities, especially its key functions (production, safety…). Examples of Management Systems (MS) are Production, Safety, Quality, Project, Maintenance, Logistics, Procurement, Human Resources, Facility, and others such as risk analysis, learning from experience, management of change, emergency management… Each of these Management Systems can fail and produce "System Failures" which directly impact the equipment and barriers deficiencies, unsafe acts. When these Management system failures emerge, they can generate or contribute to other failures (technical or human factors). The criticality of these Management system failures depends on their direct or indirect impact on safety critical elements in the scenarios of major accidents. As production, quality or maintenance management systems tend to be more closely related to safety, their failures are more often critical.
"Organisational dysfunctionalities"[29] [30]	Organisational dysfunctionalities have a direct or indirect impact on almost every part of the organisation. They can directly cause safety management system failures. There is an internal part of the organisation (usually, at the 'top' of the organisation: Board, Senior Managers, decision makers) that has greater responsibility than other actors for the adequate internal governance of the total organisation. This top part of the organisation has the role and power to define internal governance functionalities as the strategy of the organisation (mission and vision, priorities, and strategic objectives), the policy of the organisation (setting of objectives and deployment in tasks in order to reach the strategic objectives) and the structure of the organisation (roles and functions with their authorities and responsibilities, power distribution, trade-off processes). But also, on top of formal dimensions of the organisation, historical, social and cultural factors may facilitate or hamper organisational performance. If this strategy, policy or structure is poorly defined, implemented or protected, then the organisation will be in a state of dysfunction and will not reach its purpose (as per definition) with inadequate decision-making processes and trade-offs.
Regulation dysfunctionalities	There is an external part of the operating organisation, the regulatory context (laws), and their enforcement by control authorities (e.g. inspection). The external directed governance of the system includes the operator and his relationship with the regulator but also internal (health and safety committees, trade-unions) and external stakeholders (NGOs, neighbours…).

[29] In this work, the term "dysfunctional" is used for all organisational factors that lead to an impaired function, a failing to serve an adjustive purpose (here, the safety of an organization with all its constituents especially including people).

[30] Presentation by Frank Verschueren "Learning from Organisational Dysfunctionalities" at Energy Institute Conference on "Human Factors Application in Major Hazard Industries", (17 - 18 Oct 2017); London.

8.3 How to employ organisational factors for Foresight in Safety? Some guidance and examples in investigation, auditing and inspecting

8.3.1 Hindsight, insight, foresight

We distinguish three temporal perspectives where organisational factors can be employed to the benefit of accident prevention: hindsight, insight and foresight.

In our view, the goal is to turn hindsight (past) or insight (present) into foresight (future).

In our definition, foresight has two main activities: interpreting the weaknesses/strengths and vulnerabilities/resiliencies and making a prognosis of their outcome or sufficiency (safety margins); and, eliminating deficiencies to reduce or eliminate risk factors of recurrences of accidents; creating new measures to prevent accidents.

In this chapter, to create some foresight in safety, we will see and study events in the past or present to proactively prevent accidents in the future and also give an example of foresight of future risks. Other chapters of this ESReDA deliverable address the three parts.

As mentioned in the introduction, concerning the strategy of how to improve foresight by addressing organisational factors, there seem to be two paths that safety actors can follow (the normative route or the more dialectical route), taking in consideration that a combination of the two paths is also feasible.

8.3.2 Past/Hindsight: Improving Investigation of Accidents and Incidents to gain Foresight

A first source of FiS, foresight in safety, is exploring the system or organisation in hindsight, meaning studying the past. It implies studying the accidents and events which happened in the past and deducing all the pertinent and likely recurring causes related to organisational factors.

It is important to develop approaches to address the real root causes and to detect the relevant organisational dysfunctionalities that contributed to an event. The lessons from past accidents and incidents can help to show how organisational factors can improve or degrade safety within an organisation or in general for all high-risk organisations if the study is enlarged to all industries' accidents.

It can be valuable also to study past normal functioning to establish the former state of SMS performance, organisational and regulatory performance as well.

It may seem paradoxical that an approach of FiS advocates first looking at the past, but the idea is to find specific and generic factors to prevent similar events to recur in the future elsewhere as well.

Searching for underlying root causes to prevent next accidents

Investigating root causes related to underlying deficiencies in the depth and history of organisations is far from an easy task. It requires a multi-disciplinary approach aiming at questioning the different dimensions of the socio-technical system that may influence accident causation. The investigation commission into the space shuttle disintegration, the Columbia Accident Investigation Board put it this way: "Many accident investigations do not go far enough. They identify the technical cause of the accident, and then connect it to a variant of "operator error" – the line worker who forgot to insert the bolt, the engineer who miscalculated the stress, or the manager who made the wrong decision. But this is seldom the entire issue. When the determinations of the causal chain are limited to the technical flaw and individual failure, typically the actions taken to prevent a similar event in the future are also limited: fix the technical problem and replace or retrain the individual responsible. Putting these corrections in place leads to another mistake – the belief that the problem is solved. The Board did not want to make these errors" (CAIB, 2003 - p. 97).

Examples are numerous and can be easily found on the web, so we do not need to develop an example here. Several very good accident investigations (e.g. Cullen, 2000; CAIB, 2003; CSB, 2007) highlighted that some incidents and events before accidents were not properly investigated. In the British rail network, several signals were passed at danger (signal was at red) by train drivers, highlighting systemic vulnerabilities in a complex system. However, rather than consider the systemic effects of privatisation, specifically the fragmentation of the system, the passing of signals at danger were considered by railway management as wholly the responsibility of drivers (Cullen, 2000). The CAIB (2003) found that prior foam losses were not well analysed by NASA, especially why the foam losses occurred more frequently on the left side of the bipod. The CSB (2007) found that several incident investigations by BP Texas City refinery failed to address root causes, especially an investigation of a 30-million-dollar accident in 2004.

Multi-layered approach or "Why does an investigation need to be considered on multiple levels?"

Reason (1990, 1997) developed an accident model that included the concept of "latent causes". These latent causes could be, for example, an undetected deficiency in an equipment design or the consequence of a poor maintenance policy, which opened the questioning towards the engineering and management failures (in decision making). Those failures of decision making were situated in the front-line team and its management, middle management or senior management. So, these alone made already three levels of an 'organisational accident' model (Reason, 1997).

The simplest methods for investigating accidents focus on one level (Frei et al., 2003; Sklet, 2004): the actors in the front line, typically, operators and technicians, such as train drivers. They produce direct causes (activities and decisions of these "front liners") with a very limited "penetration insight".

Many accidents have shown that by questioning upwards the role of hierarchical lines, one can detect how the decision making of higher management levels play a large role in degrading the working conditions of several frontline actors. These conditions are later involved in combination with other direct causes, triggering events, and are therefore influencing the causation of incidents and accidents as underlying causes. Only a thorough investigation of the accident will reveal the different connections between direct and underlying causes.

A thorough investigation of the accident should consider the multiple levels of the organisation, which interact (e.g. human resource management impacts the skills available in working situations) and with the environment (e.g. technological and political changes have an impact on: the skills needed to operate new technologies; the level of regulation, and; the acceptability of high-risk industries). Several researchers recommended this multi layered approach, and among them, Reason (1997), Rasmussen (1997) and with Svedung for Accimap (Rasmussen and Svedung, 2000). It was followed by others, such as Nancy Leveson's STAMP (2004). Several other examples exist (in Sklet, 2004; Dekker, 2006; Dien et al., 2012; Institute of Energy, 2008).

The layers of governance or supervision levels should be considered in those organisational 'cause–consequence' schemes that can be visualised in a top-down perspective in accordance with the organisational accident view (Swiss cheese model of Reason, 1997). A complementary but consistent view integrates the bottom-up flows of information. An important issue is to consider the system behaviour as a product of interactions, with consideration of systemic effects as a whole (e.g. Vautier et al., 2018).

It remains a challenge to go up to the top (i.e. senior management and the board of directors) who make the decisions on strategy, policy, structure, and "steer" the whole organisation. As they make very important decisions on resources and budgets, they can either limit or enable discretion at lower levels. Examples of policies of cost cutting are numerous (e.g. Texas City) and can paralyse the management of integrity maintenance and the whole departments related to safety.

For that reason, it is rare that internal people from lower organisational levels doing investigations or auditing do ask questions in their investigation all to the top of their own organisation to show how strategy, policy or structure were dysfunctional or not. There is self-censorship, stop rules, pressures from management and taboo subjects (e.g. Dien et al., 2012).

8.3.3 Present/Insight: Improving Auditing and Diagnosis to improve Foresight in Safety

A second source for gaining FiS is exploring the system or organisation in insight, meaning studying the present. It requires that the company governance, provisions and practices related to safety are investigated and assessed to detect dysfunctionalities and assess the quality of safety management.

Organisational performance can be assessed in a range of dimensions, production, quality, safety, environment, social… For our safety purpose, it is important to develop approaches that provide insight into on-going performance, through the knowledge of influencing factors on daily performance, that can be related to company's governance and safety management. When we use the term 'real performance, in practice', our meaning goes beyond effort to formalise safety management processes, provisions, procedures and is related to the concepts of activity and work, that are more than applying procedures. These approaches require as well, collecting formal and informal data, interpreting information, signs and infer EWS, symptoms or indicators of weaknesses or strengths related to best practices, reliability and resilience organisational factors.

Analogies of Auditing with Investigating

Conducting an organisational diagnosis in hindsight differs from conducting it on the basis of real-time data. Some analysts consider that the two configurations are radically different. Indeed, analysis of events is often criticised for its hindsight bias (e.g. Reason, 1990; Vaughan, 1996). Knowing the end of the story brings an effect of wisdom (Reason, 1990) to the investigator (however investigating root causes is not easy!) while the actors in the system did not benefit from this knowledge prior to the accident. Hindsight bias can be "harmful" if the aim of the investigation is to find (only/mainly) one or more people to blame. Especially, EWS would be easy to detect in a retrospective approach, while actors seeking insight in real time have inherent difficulties to extract EWS from daily noise. On that point, Vaughan (1996) considered that some weak signals could not be understood before the accident because they were normalised in NASA culture.

It is partly true, but we disagree with the generalisation to all cases. The Texas City accident just recalled in this chapter is a contrary example and shows that many EWS were, indeed, recognised before the major accident by operators, managers, audits and event investigations.

In fact, there are similarities in the two configurations of organisation's diagnosis (hindsight and insight) (Dechy et al., 2011). Background knowledge in human and organisational factors used by analysts (investigator, auditors, inspectors) are mainly common requirements for both. The interviews with people might be biased (people who refuse to speak-up or misinform investigators) in the two configurations, but not on a dichotomous basis.

In both cases, we can find events that can reveal symptoms of organisational weaknesses prior to the accident or the diagnosis in normal operation (e.g. Texas City refinery accident). In both cases, making an expert judgment upon the complex causalities of influence factors remains uneasy, though evidence and proofs of (un-)reliability might differ.

Auditing and Inspecting: Looking for underlying deficiencies in Safety Management

An example from Belgium Competent Authority for Seveso plant regulation[31]

The following example relates to a normative approach which is especially efficient for compliance-oriented approach, but also because there is consensus on the expectations of what are good practices for the management of safety. For instance, it requires that safety management systems are implemented (a regulatory requirement of the Seveso Directive). Also, safety actors know that good event investigations should address root causes. But, is it the case?

A study by the Belgium Competent Authority found that a sizeable minority of companies have in their incident investigations a 'blind spot' to organisational factors. In a representative sample of Seveso companies, the study found that 36% carried out investigations that poorly identified the underlying organisational causes of events, and 27% carried out investigations using procedures that were very poor at identifying underlying organisational causes and organisational factors. [32]

All companies under the Major Hazards regulation in Belgium are obliged to have a complete and well-functioning Major Accidents Prevention Plan (MAPP). The core element of this MAPP is a safety management system to prevent major accidents. One of the components of a safety management system is the investigation of accidents and incidents; this is audited by Seveso inspection agencies in their role as enforcers of the Seveso regulation in Europe.

In 2013, the Belgian Seveso inspection agencies studied specific regulatory audits to get a more detailed view on the strengths and weaknesses of companies' accident and incident investigation systems. The data for the study were drawn from seventy audits that had been carried out by 14 inspectors over four years.

[31] Presentation "Inspection of Investigations of Accidents and Incidents" by Frank Verschueren at MJV Seminar on Learning of Incidents (11 - 13 September 2013 Gothenburg, Sweden)

[32] These findings are consistent with the practices declared fifteen years ago (limited use of investigation procedures, very limited investigation of root causes, very limited involvement of experts in investigation, learning, human and organisational factors (ESReDA, 2003; Roed-Larsen et al., 2004, Dechy et al., 2012) though we can observe some improvements.

The seventy audited companies are a representative sample of the total 375 companies under Seveso regulation in Belgium.[33]

Each company was audited in the same way using a specific inspection instrument. This instrument contains 53 questions arranged in eleven question blocks. The general topic of incident/accident investigation is spread across a number of these blocks, such as those focused on the reporting system, investigation & analysis, and remedial actions. Each of these blocks is subdivided into smaller subtopics, each with a set of questions for the auditor. Each question block has a set of criteria based on the expectations of the inspection agencies and have been discussed in advance with the relevant industrial bodies.

In recent years, the Belgian Competent Authority has made efficiency a priority in the design of its inspection instruments. Inspection agencies have decreasing resources, often less time, and an increasing number of companies to inspect. Therefore, every question asked in an audit instrument must count in the sense of demonstrable relevance. All audit questions in the inspection instrument are of the closed type: the answer is 'yes' or 'no' and reflects the presence or absence of certain objects in the company's system. For the purposes of this special study, these objects or items comprise the elements of a company's investigation system.

The questions are focused on objects or items established as essential and necessary for an effective and efficient investigation system. Each question addresses an enforceable requirement, justified with reference to:

- Legal compliance;
- Official Standards;
- Codes of good practice[34]; and,
- Accepted (and necessary) risk analysis measures.

Furthermore, the questions must be capable of producing answers that can be verified by the company's documents, standard operating procedures, investigation reports, or by interviews. The necessity and verifiability of the questions are critical qualities for regulatory inspections. Because each item is established as necessary, its absence from a company's system can be considered as a deficiency and registered as a shortcoming. This also allows the inspection agencies to enforce improvements.

The seventy audits (each asking 53 questions) produced a total of 537 shortcomings. To see patterns of weaknesses in the companies' investigation systems, the results from the sample of seventy companies were expressed as frequencies. For each audit question, the maximum possible frequency is 70, meaning that 100% of the companies had this shortcoming in their system. The higher the frequency of observed shortcomings per question, the greater the significance of this item as a weakness in the investigation systems of the Belgian Seveso companies in general.

When ranking the frequency of all shortcomings, the observed result showed that some of the questions with the highest frequencies were directly related to organisational factors:

- "Were the underlying organisational causes identified?" was the question associated with the largest number of shortcomings (highest frequency). This shortcoming was registered for 25 companies out of the total of 70, or 36% of the audits.
- Another question high in the ranking (top 5) and germane to this chapter was: "Does the general instruction specify an investigation technique that is explicitly focused on not only investigating the immediate causes but also the underlying organisational causes?" This shortcoming was registered for 19 companies, or 27% of the audits.

The upshot of this finding is that a sizeable proportion of companies seek to explain accidents and incidents without examining the organisational conditions that may be undermining how they manage the major risks created by their operations.

An example from Institut de Radioprotection et de sûreté nucléaire (IRSN)

As mentioned previously and in the previous example, one strategy to enhance prevention of accidents and their foresight relies on a normative strategy which references organisational factors. Another one relies on a more dialectical route within organisational diagnosis. For instance, and referring to the previous

[33] In Belgium, two-thirds of Seveso companies belong to the following sectors: Oil and Gas; Chemical, Petrochemical, and Pharmaceutical manufacturing, and; Distribution and Warehousing of dangerous goods. The remaining third are dispersed across several smaller sectors.

[34] Codes of good practices are practices that are considered by one or more industrial sector(s) as practices who should be used as they have shown by multiple experiences to have a proven reduction in risk.

example, when the company does not investigate root causes, the judgment is automatic. But for companies who do so, how can we rank the most and less performing and how can we judge if their practices and outcomes are good enough or bad? How can we make a judgment of the quality of analysis, the depth of organisational analysis and the relevance of the organisational factors addressed? This kind of approach is necessary as well to improve safety management but requires more data collection and collective expert judgment. The following example aims at illustrating the approach and some challenges.

Institut de Radioprotection et de Sûreté Nucléaire (IRSN) is the technical support organisation to the French nuclear safety authority (ASN). IRSN experts are in charge to conduct safety assessment on engineering provisions but also in-depth organisational diagnosis on safety management effectiveness of French nuclear power plants all operated by Electricité de France.

For our example here, the main scope of the safety assessment conducted was on maintenance activities performed during the 50 outages per year for the 58 nuclear reactors in France. Between 3,000 to 15,000 maintenance activities are performed per outage, involving several hundreds of workers over a period of one to six months. Most workers are subcontractors. So, a first challenge is related to the scale and complexity of the system: a nuclear reactor fleet of 58 reactors operated in 19 plants involving around 30,000 employees (including central engineering divisions) and 20,000 subcontractors employed by 400 companies.

A second challenge is related to the definition of the scale, scope and focus of an "open" audit or an organisational diagnosis. This can become especially challenging if the approach combines formal and informal data collection, interpretation of evidence of vulnerabilities or reliability/resilience, and debates about the necessity to implement preventive measures.

A multidisciplinary team of ten IRSN experts in human and organisational factors, safety and radiation protection engineering, conducted the safety assessment. Its goal was to assess the risk management efficiency in the 'daily' 'normal' functioning. In other words, it focuses on real practices, not on paper, nor it is rule or compliance based. It relied on an in-depth investigation over 2.5 years, 150 interviews, and 70 days spent observing working situations during three outages on three NPPs. Data collected is more or less subjective and therefore an objectification process aims at establishing evidence, facts and findings. It also relied on an in-depth review of documents running into thousands of pages from several hundred of documents (e.g. safety procedures of the nuclear operator, reportable events analysis, inspections findings).

Six months were necessary to prepare the diagnosis, its scope and framework of analysis and the strategy for data collection. The preliminary analysis implied reviewing procedures to understand the safety management policy, structure, provisions implemented by the operator in a complex system. A determining factor to escape 'cognitive capture' was to benchmark across other strategies and provisions implemented by foreign nuclear operators. It required identifying the key organisational factors to be investigated. Investigating all organisational factors is not possible in one diagnosis for such a complex system, so the idea is to justify the selection of the most relevant organisational factors, based on major safety issues, such as the ones raised by organisational changes, or the vulnerabilities found in event analyses, known former vulnerabilities and new provisions dedicated to improve safety management. Five key organisational factors were selected (Dechy et al., 2016, 2018): organisational changes due to a new program of multiple changes; human resource management (in quantity and quality in a context of a wave of retirements); decision-making challenges within a complex organisation with multiple interfaces between people and processes of which subcontracting was a particular topic; and learning as efforts to improve the processes were undertaken. A transversal perspective, related to the historic dimension with the picture of a previous organisational diagnosis conducted five years before by IRSN (Rousseau, 2008) helped to address if safety management was improving or not.

All the key organisational factors selected were related to a 'pathogenic organisational factor' (Dien et al., 2004, 2012) though this was not the main selection criterion. Indeed, several other background knowledge references were used from human and social sciences, and good practices seen abroad. This 'knowledge of accidents' (Dechy et al., 2016, 2018) that contains pathogenic organisational factors helped to raise assumptions and support interpretations. IRSN experts were able to recognise echoes of accidents: a programme of multiple changes to improve performances (production, safety,…) echoed the 'torrents of change' at NASA before the Columbia accident; 'inversion of burden of proof' deviations at NASA that contributed to both Challenger and Columbia space shuttles accidents; and also a drift pattern of erosion of defence-in-depth, echoing the Swiss Cheese model (Reason, 1997). Collective expert judgment was produced to consider if the organisational weaknesses were serious and would need to implement strengthened prevention measures, or if the safety management provisions in place were robust enough based on evidence of their efficiency. IRSN made fifteen recommendations, whose relevance and efficiency were assessed and challenged within a contradictory debate with the nuclear operator and thirty experts from the advisory committees[35] to the nuclear safety authority, before being translated by the safety authority in a new regulation to be enforced.

8.3.4 Foresight of Future Risks for Proactive Management of Risks as used in an organisational diagnosis

After hindsight and insight, the third temporal perspective where organisational factors could (and should) be employed to enhance proactive risk management is related to the future. For this chapter on employing organisational factors for FiS (Foresight in Safety) the act of gaining FiS is translated as getting the knowledge about how accidents in future could happen due to organisational causes or could become more likely due to new threats. In this perspective, the organisational dysfunctionalities to investigate, recognise and assess are not only the past ones nor only the current ones, but some that could occur in the near, mid-term and longer-term future. In other words, the goal is to implement an approach like risk analysis but related to plausible future threats to organisational safety. As a consequence, it requires developing all measures to counter those organisational causes and threats and to reinforce or to seize opportunities to implement new reliability/resilience factors to prevent these accidents from occurring, reoccurring or to decrease their likelihood by adding safety margins.

An example from Institut de Radioprotection et de sûreté nucléaire (IRSN)

A practical experience we can refer to is related to the organisational diagnosis performed by IRSN and described in previous pages. As mentioned earlier, the historical perspective of organisational analysis (Dien et al., 2006) was useful to investigate if in the current situation, one could notice safety improvements or degradations compared to the past diagnosis performed a few years previously (Rousseau et al., 2008). The historical perspective integrated also the future of the organisation towards potential forthcoming threats.

Indeed, the rationale was that IRSN experts had to consider if the dysfunctionalities found so far and the countermeasures to increase risk management robustness were enough to cope with new threats forthcoming in the next few years. The main threats that were recognised at that time in 2013 were the lasting effects of the wave of retirements, ageing of the equipment especially because the nuclear operator was aiming for operating the nuclear reactors over forty years of operation (which was their design assumptions), which implied to increase up to 50% the workload in some maintenance domains and refurbish some critical equipment.

However, in 2012, IRSN experts observed a vicious circle (delays in outages that shorten time and resources available for learning post outages and the preparation of next outage; in such a case, it would generate new delays in outages). This drift was considered as a clear EWS by IRSN experts and they recommended to the nuclear operator some measures to counter it. This kind of safety degradation that is theorised (Dien, 2006) within accident models (such as the 'incubation period' (Turner, 1978), "latent failures" (Reason, 1990), and EWS that are not recognised or treated (Vaughan, 1996; Llory, 1996)) is not familiar to nuclear operators who are culturally educated with the so-called mantra of "continuous improvement" as a natural outcome of quality approaches and changes, which in itself is a fallacy (Dechy et al., 2011; Rousseau et al., 2016). The company for instance decided to reduce the maintenance workload in order to better manage the maintenance activities during outages of the next year and reduce therefore the vicious circle.

The company was also advised to reduce the frequency of changes so as to enable their implementation and ownership by an overloaded workforce that was coincidentally stressed by a wave of retirements and a heavier workload in maintenance work. This should enable better consideration of the impact of changes and especially the risks related to interactions of changes which remained under-investigated so far. In short, the company was invited to reconsider the overall strategy of changes which it finally did by delaying some changes and by giving more subsidiarity to local nuclear power plants than to central engineering and management departments of the nuclear fleet.

Last, the company was invited to consider the concept of organisational resilience and the need to diagnose and reinforce its resilience to potential new troubles.

[35] *Advisory committees (Groupes permanent d'experts), http://www.french-nuclear-safety.fr/ASN/Technical-support/The-Advisory-Committees*

8.4 Key elements of an OF Framework for guiding and questioning Foresight in Safety

The last suggestions in the previous example fit with our proposal to employ the positive sides of organisational factors to lever management of safety for the future.

After explaining the reason why organisational factors are a key lever for prevention and specifically for foresight in safety and providing examples in the way they were employed in inspection and auditing contexts conducting organisational diagnosis, this part addresses the practical challenges of employing organisational factors to prevent accidents. It outlines some guidelines for enquiring into the organisational factors of FiS. It also uses lessons learned from the nuclear and chemical industries that can be applied to other industrial sectors.

8.4.1 Background and foundations for elaborating a framework

This subsection aims to develop additional definitions about organisational factors in relation to safety, either positive and negative, by illustrating some of them in multiple literature sources, and their combined outcome on system states.

Diagnosing the dynamic state of functioning with opposite forces?

As explained (figure 1), quality and efficiency in organisational functioning has a great impact on safety, whether its outcome is positive or negative. Our diagnostic challenge is to anticipate risks and enhance safety.

If we look at the impact on safety, the functioning of an organisation can be placed on a continuum, moving from time to time and oscillating between different states. Of course, an organisation has different parts, and these may differ, but we consider that the functioning of the whole is dependent on the weakest part. At least, in a simple manner, we can identify three specific organisational situations that lead to three different safety states: **dysfunctional**, **normal**, and **resilient**.

The impact on safety of a **dysfunctional organisation** ranges from negative to very negative. Chronically dysfunctional organisations are sometimes called 'pathological' (Reason 1990, 1997; Westrum, 1992; Dien et al., 2012). In these organisations, the degradation of safety is severe enough to be detected with relative ease by several actors or processes (audit, investigation, as in Texas City 2005 accident). However, many EWSs and alerts are not treated accordingly. Part of the culture within the dysfunctional organisation does not want to know and discourages 'bad news'. These are the organisations who 'shoot their messengers', punish whistleblowers, blame individuals for failures and discourage new ideas (Westrum, 1992). In such organisations, the likelihood of a system accident grows as negative organisational factors accumulate. Dynamically, the effect may be seen as a 'system drift' (e.g. Dekker, 2011) accompanied by normalisation of deviance (Vaughan, 1996). In the longer term, the likelihood of accidents may become very high as the system becomes critically vulnerable, and its ability for adaptive change becomes embrittled (Woods, 2009). In such an environment, an event can trigger cascading effects because several lines of defences are already weak or lack safety margins. Foresight is low and even reactive measures are lacking. For the present authors, the Texas City accident is a case that demonstrates the effects on safety in a severely dysfunctional, pathological organisation.

A **normally functioning organisation** has adequate safety in normal conditions. This would be the minimum expectation of a responsible, law-abiding management. Its approach to safety is characterised by adequate preventive and protective measures; a reactive and proactive attitude towards near misses (e.g. what if?); regular auditing, and; looking for root causes when investigating and inspecting. It is already doing more than treating safety in a bureaucratic manner (Dekker, 2014) which would be limited to listening to messengers if they arrive, and responding with local repairs only (Westrum, 1992). It does not mean there would be no incidents or local accidents, but their impact would be limited, as some safety margins and barriers would block their escalation into a major accident. The likelihood of a system accident remains low, and although some limited drift may occur, it can be recovered in time if action is focussed. Unlike the dysfunctional organisation with its eyes closed, foresight in the normally functioning organisation is practiced with conventional tools. Overall, we could say that the normally functioning organisation is a robust system: it can withstand deviations and anomalies to degree, especially if these stay within the design basis.

A **resilient organisation**, in contrast, can withstand and even repel unforeseen events and disruptions and still stay safe. It is highly reliable (e.g. Roberts, 1990) and resilient in the sense set out by Hollnagel et al. (2006). The resilient organisation is highly proactive (sometimes called generative, Westrum 1992) about tackling residual risks. This proactive behaviour is characterised by challenging and reinforcing their defence-in-depth, conducting stress-tests on beyond design basis events (e.g. in the nuclear industry after Fukushima), learning from their own events and opportunistically from others, and challenging basic assumptions and questioning the status quo. Bad news is welcome in the resilient organisation, in fact it searches for divergent opinions (messengers are trained and rewarded, Westrum, 1992). Its approach to foresight goes beyond the use of conventional tools. It involves outsiders, sponsors 'red teams', investigates root causes—not just of near misses but even of EWSs. The resilient organisation conducts organisational reforms and invests in additional safety margins without regulatory requests.

Table 3. Three organisational situations leading to three different safety states.

Organisational situations	Dysfunctional	Normal (even robust)	Resilient
State	Unsafe to very unsafe	Safe within design basis in normal conditions	Safe, even when under stress beyond design basis
Trend	Degrading safety Increasing vulnerability Organisational dysfunctionalities can become pathological	First target is maintaining safety. There is a positive balance between positive and negative forces with the safety margins that remain	Safety is maintained by adding safety margins
Descriptors	Signs of safety degradation are recognised by several actors within or outside the organisation. Alerts are not treated adequately. Messengers are "shot". Blame culture. Local repairs, only.	Reactive and proactive safety management system functions are performed with energy in more than a merely bureaucratic way. Addresses root causes.	No self-satisfaction; challenges assumptions and status quo (stress tests their defence in-depth). Uses unconventional methods to see and think differently (e.g. 'red teams'). EWSs are treated at the "right" level and may lead to organisational reforms. Adds safety margins without regulatory requests.

8.4.2 Which are the relevant organisational factors to investigate to enhance safety and foresight in safety?

Investigating, for prevention purposes, the potential or actual effects of organisational factors on the system requires a general mapping of the relevant organisational factors that could be addressed.

Review of Lists of Organisational Factors

Since Turner (1978) and Reason (1990, 1997) broke the ground, a lot has been said and written about organisational accidents, reliability, resilience and safety. The literature contains several lists of organisational factors that are claimed to be relevant. Each of these lists has its own logic and arises from its author's theoretical tradition (safety, psychology, sociology, management sciences or economics). In this paper, we call them organisational factors (OFs) as defined in part 8.2.5. However, other authors have used terms such as pathogenic and resilient organisational factors, dysfunctional factors, latent causes, and so forth.

We reviewed about 30 of those lists, but there are more. This work is still in progress, but readers are invited to regularly update their lists with insights from accidents and new researches. The lists we reviewed came from different sources, researchers and safety analyst but also safety organisations including: the US Center for Chemical Process Safety, who published a book on the subject; the Energy Institute; inspection agencies, such as the Health and Safety Executive in United Kingdom; and many individual authors writing about safety, or about organisational management.

The review found that the lists exist in isolation and do not, except in a very few cases, refer to each other or have common links. We see this as an important missing characteristic; it is one of the reasons why we wish to develop a guiding framework.

Moreover, many lists included either positive OFs, negative OFs, or both, without distinction. This can sometimes mislead readers. We took from this that OFs should be labelled or stated in a way that makes it absolutely clear whether it purports to have a positive or a negative impact on the safety of an organisation. In future work, we want to fulfil this requirement by providing an assessment question for each OF in the framework.

In the next two subsections, we provide illustrative lists of purely negative OFs, and purely positive OFs.

An Illustrative list of negative organisational factors

Here are three examples of entries on a list of organisational factors that are purely negative in their effects on safety. Those below are presented as illustrations; many other negative OFs could be included.

- **Production pressures.** These result in behaviours and injunctions aimed at overriding or voluntarily ignoring certain dimensions of safety in order to favour short-term technical or economic performance. Production pressures arise when the production culture—a set of knowledge, know-how, etc. contributing to technical or economic results—is no longer counterbalanced by the safety culture. Often in a competitive environment, the strategy and priorities set-up by top management initiate or reinforce those production pressures. A first difficulty of detection comes from the confusion between the culture of production and the pressures of production, that is to say that the pressures of production can be assimilated within a dimension of the culture of production.
- **Weakness of operational feedback.** The feedback (lesson learning) process comprises: the detection of malfunctions, the collection of these data, the analysis and synthesis of the causes of these malfunctions, the definition of corrective measures, the implementation of these measures, the evaluation of the effectiveness of the measurements, and the memorisation of the treatment. The implementation of corrective measures aims to prevent the occurrence of new incidents and accidents. This process is iterative and dynamic, and in this sense the feedback is 'alive'. The lesson becomes 'unlearned' when the organisation has difficulty in recalling the experience. This difficulty appears when the feedback process is either weak or not at all supported in the organisation, or when the associated resources are insufficient, or when a step is (systematically) absent or deficient.
- **Weakness of control bodies.** Control bodies are the entities responsible for verifying compliance with duties for safety. These duties, owed by the operator of the socio-technical system at risk, arise from various obligations: legal, regulatory, contractual, procedural, social, moral, and so forth. The control bodies reflect these different classes of obligation. They include those attached to the installation (local safety departments, for example), those at a "corporate" level of the company in charge of the installation, and those outside the company (safety authorities for example). The possible weaknesses of control bodies refer to the weaknesses of their interventions and actions, meaning that they do not play the role of counterweight and counter-powers as they are supposed to.

Several other negative organisational factors have been identified by investigators and researchers. Among the most important recalled here, we could add the lack of re-examination of design assumptions, flaws in human resource management and the organisational complexity including subcontracting (e.g. Dien et al., 2013). More examples are e.g. the POFs, called "pathogenic organisational factors", as described in Pierlot et al. (2006).

An Illustrative of a list of positive organisational factors

In general, positive OFs are those that either maintain or improve the level of reliability of the system or its robustness and resilience, and therefore have a positive impact on its safety performance. Note, however, that compiling a full list of positive OFs may be complicated. For example, the benefits to safety that are associated with positive OFs might in some cases be indirect or may depend on circumstances that change. Furthermore, some organisational provisions can improve both production performance and safety but can oppose as well. There are also conceptual differences between reliability and safety (see Nancy Leveson, 1995 and 2004; Llory and Dien, 2006).

The items below are presented as illustrations; many other positive OFs could be included. These particular items arise from studies of highly reliable organisations (Weick and Sutcliffe, 2001).

- **Efficient treatment of malfunctioning.** A major negative event is never a standalone situation. It does not occur by chance. It is (almost) always preceded by 'little' events which are all early warning signs—symptoms of the deterioration of the safety level. So, if every event is detected, analysed in terms of its generic aspects (i.e. considering what could have been worse) and, if the corrective measures designed cover also generic aspects, then the organisation increases the likelihood of avoiding a more serious event. Too often, 'little' events are treated as 'here and now', meaning the only corrective measures defined are those that will only avoid reoccurrence of this specific event. To treat an event as unique and wholly exceptional is to deny its significance. It is fair to say that an organisation with 'a lot' of small events treated well is safer than an organisation with no events. As well as stimulating the search for improvements, feedback keeps an organisation watchful for danger. One could say that when this OF is present, people in the organisation are mindful of failure rather than blinded by success.

- **Real operations oriented.** Every activity and organisation, and especially those with large safety risks, are governed by rules, procedures and regulations. In general, these are attempts to define and describe boundaries of operations. Unfortunately, makers of rules cannot foresee all the possibilities of real life, which contains unexpected events and unforeseen situations that operators must cope with on the front line. Furthermore, these situations or events can arise in any of several domains of activity: operations, maintenance, or training. Because of this complexity, a feature of maintaining an appropriate level of safety is a great reliance on those closest to the process. 'Great reliance' does not mean 'blindly' relying on everything done by front line workers. It means that regulators, designers and managers must pay attention to everything done beyond procedures and to check how right (or wrong) it was.
- **Deference to expertise.** Some situations, mainly hazardous situations (e.g. crises, incidents, and accidents) demand that decisions are made quickly. In those cases, especially if complex, the real-time processes of decision making cannot be based on the organisational hierarchy. Rather, decisions are made by the people locally in charge of operations, based on their knowledge and skills. An organisation needs to have prepared for this change in how decisions are made. Amongst other things, hierarchical leaders must be ready to allow these knowledgeable, skilled people to speak freely. Moreover, by virtue of their knowledge and skills, these people may also be able to improve decision-making in everyday, non-emergency, circumstances. Deference to expertise is the tendency to delegate decision making to those who have the most expertise, irrespective of their position or hierarchical status.
- **Open minded to debate.** Steep hierarchies in organisations often lead to bureaucratic management (Dekker, 2014). This situation favours the emergence of a single, not to say over simple, official 'view of the world'. Yet, organisations are generally heterogeneous entities, and not monolithic wholes (Dien, 2014). The usual situation, especially on issues of process safety, is for the coexistence of several opinions and views of a situation. Since safety is not only a matter of rule compliance, but is also a matter of debate, every opinion must be expressed, irrespective of the hierarchical position it comes from. Diverse and dissenting voices must be taken into account, although not necessarily agreed with. They must be listened-to without a defensive attitude. The ability to give room to debates (about safety) and welcome 'bad news' is a positive organisational factor for safety. This is notably true in crisis situations, where as well as pre-planned emergency actions, some time will be spent sharing information and interpretations—sometimes through sensemaking confrontations—to inform decisions about what needs to be done.
- **Reluctance to simplify**. Industrial facilities are usually manifest as complex systems. In order to be able to handle the whole process, organisations are tempted to simplify interactions between some subsystems and to exclude some others from serious study. An example of this is modelling, which even when detailed still represents a simplification of an even more complex reality. By putting aside what they consider to be outliers, organisations take risks. Treating outliers in this way creates blind spots over the corresponding zones of the process, so creating the scope for unanticipated and unwanted situations to occur. So, simplification creates a wrong picture of the real situation. The 'devil' as the saying has it, 'is in the details'. To put it another way, 'situational awareness' demands a questioning attitude, one which avoids easy, simplistic explanations and shortcuts in assumptions. Rather than those that simplify at every turn, it is organisations willing to grapple with the complexity of their processes that stay able to avoid major surprises.

These positive factors, it is contended, act in combination. The more of these and other positive factors are present within an organisation, the better safety is positively ensured with safety margins.

Other positive organisational factors are those which allow facilities to remain resilient. As proposed by the resilience engineering school of thought (Hollnagel et al., 2006), the four resilience features are: the ability to respond, the ability to monitor, the ability to learn, and the ability to anticipate. Hollnagel (2009) proposed a matrix which provides a measurement of the resilience level of an organisation according to the score it obtains for each ability.

8.5 Bridging the operational gap: from current 'part one' to future 'part two'

8.5.1 Synthesis of 'part one': A road map towards an OF's framework for guiding and questioning Foresight in Safety

By looking at the literature on major accidents and several accident theories and at our own investigating experiences (in nuclear and chemical industries) we have shown (section 8.2) that it has been known for more than twenty years that OFs affect risk prevention heavily. However, they remain underused by industry and regulators.

In addition to the general definitions of technical and human influence factors that are widely accepted in the safety community, we have proposed three levels of organisational factors: management system failures, organisational dysfunctionalities, and regulation dysfunctionalities.

Exploring our past experiences together with our ideas about hindsight, insight and foresight permitted us (section 8.3) to link different activities (such as investigations, audits, and organisational diagnoses) to different temporal phases (past/hindsight: investigating accidents and incidents; present/insight: auditing and diagnosis; future/foresight: proactive management). The practical examples in this section gave us some ideas about how to improve foresight by combining these different 'sights'.

After research of the literature, we were able to define the three organisational situations leading to three safety states (dysfunctional, normal, and resilient defined in table 3 in section 8.4).

To get a view on which organisational factors are relevant, we reviewed several lists of OFs. Although in the safety literature, there exist several lists of OFs[36], they are scattered and many of them have a limited scope. Moreover, a global and coherent view is lacking and support for a thorough coherent organisational diagnosis remains limited.

The result is that organisational factors remain vague, opaque and, relative to their importance, barely visible as latent causes of accidents or levers for risk prevention. Therefore, there is a need for a framework that enables practitioners and researchers to more readily use these OF constructs in the search for weaknesses/threats and strengths/opportunities in organisations. The use of the framework would be not only backward looking (hindsight) and present (insight) but also for the future (foresight).

8.5.2 Future work for 'part two'

This section describes the work that we plan to do in the future.[37] We identify two tools to be developed.

As result of the above (section 8.5.1), the first step in our plan is to develop a framework that practitioners can use as a tool to help them find significant organisational safety weaknesses and strengths.

The value of the framework to the practitioner will be to guide a systematic search for relevant OFs. We see it as assisting, not replacing, practitioners' existing fieldwork processes. For example, if a practitioner finds that an OF in the framework to be relevant in a particular audit or investigation, they would gather more data using their existing skills and practices to evaluate the relevance and potency of that OF on the organisation's safety.

The framework will permit people acting as investigator (of accidents), auditor, organisational analyst to look from the starting OF to the surrounding, (neighbouring or adjacent) organisational factors so those factors can be investigated and assessed in turn for their impact on safety. Consequently, the "spreading" of the negative or positive impact inside the organisational framework can be made more obvious. In this way, new foresight is created.

Although one must be careful not to overcomplicate the framework—usability is crucial— the possible connections and plausible links between organisational factors could be mapped and will be part of the interpretative framework. For example, too many organisational changes in a short notice might be linked to production pressures or a misperception of the effects of changes, for instance on roles and responsibilities.

On the other side when practitioners find plenty of evidence for a particular OF, they will be very tempted to close too soon the analysis. This is contrary to the

[36] *We studied 26 lists from authors of different competences and skills (safety, engineering, sociology, psychology and management)*

[37] *Any volunteering is welcome! Contact frank.verschueren@werk.belgie.be or nicolas.dechy@irsn.fr*

principle of thorough inspection and investigation. Our aim is that the future framework will support the questioning and prevent the premature stop of an analysis.

The second step in 'part two' will be a set of "assessment questions". Ideally, each component of the framework will have questions to help the practitioner assess the quality of impact (positive or negative) and its level (weak or strong impact). However, although safety issues evolve in general ways, (e.g. ageing, digital transformation, etc.) they manifest uniquely in every specific organisation. Mindful of this interplay between general and specific, when applying them, practitioners will always need to adapt the framework and the set of questions.

Our approach implies to look for the effects, observable outcomes of the combination of OFs in some specific normal functioning situations of the system, activities or events inside the organisation.

In contrast with the classic basic audit which delivers an instantaneous picture of the present situation and performance, we see an approach that is more extended over time, and dynamic in what it focuses on and the temporal perspective taken.

If time is a limiting factor, this kind of organisational diagnosis (audit, inspection, investigation) can be performed on specific topics rather than the whole management of safety. To avoid staying at the surface of the organisation and the 'speeches of the front stage', we recommend a tighter focus: selecting a few sub-topics to be questioned, such as those revealed by previous audits or investigations, or areas that the organisation is changing.

By assessing organisational factors, which we see as characteristics of the organisation that are critical for safety, we can identify weaknesses. Some weaknesses will require urgent remedy, but others allow a more gradual approach to improvement. Similarly, by referring to positive factors, we can detect areas for consolidation.

To summarise, we propose these as relevant objects for study and intervention:

- Historical vulnerabilities
  => to be found especially in the past

- EWS, symptoms of dysfunctionality, drift and changes
  => to be searched for in the past and in the present situation;

- New threats to consider and opportunities for improvement
  => to be looked for in future potential situations.

As we aim to support practitioners to find these objects and to assist them in verifying and proving that they identified the correct former vulnerabilities, the right present or past EWS and the relevant future threats (we cannot imagine now), we propose development of:

1. A framework to help practitioners detect and characterise if the set of organisational factors (the factors that are essential characteristics of the safe functioning of the organisation) are dysfunctional, normal or resilient and are producing observable effects (symptoms and EWS);
2. A set of questions that practitioners can ask as part of their exploration of organisational factors in a given investigation, audit or assessment;
3. An assessment method to foresee the future effects—whether positive, negative or neutral — of organisational factors on safety in a given organisational setting. This will be a kind of SWOT analysis (Strengths, Weaknesses, Opportunities and Threats);
4. A protocol for collective and debated judgment of the overall safety state: stable, improving or degrading.

All this will be further developed and finalised in our future part two, where in addition we would like to see development of the following capacities:

- Guiding Hindsight, Insight but specially Foresight in Safety by the ("guided") search of other plausible EWS starting from a detected and confirmed EWS;
- Enhancing Insight and Oversight on the safety performance of an organisation;
- Questioning Foresight in Safety by assessing the impact of present and future decisions and behaviours of all levels, but in particular those of the Board and senior management.

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