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Approaches to assessing effective improvement of safety culture

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Summary

In this report we examined the effectiveness assessment of safety culture improvement from a systemic, multilevel perspective. Two complementary approaches were identified. A phenomenon-based approach viewed safety culture improvement from the perspective of cultural dimensions or manifestations, and how they interrelate with each other and with other sociotechnical elements of the organization. A process-based approach viewed safety culture improvement as an organizational function that involves a process dedicated to safety culture improvement, as well as specific activities that aim to improve safety culture.

Four practical tools were developed to illustrate the practical application of these two approaches. Two tools illustrated the phenomenon-based approach and aimed at modelling specific safety culture attributes—raising concerns, and procedure compliance. The other two tools illustrated the process-based approach and provided means to evaluate the maturity of the safety culture assessment process and effectiveness of safety culture training. Overall, these two approaches and the four practical tools along with the theoretical and empirical justification behind them serve as a starting point for developing a comprehensive toolbox for assessing the effectiveness of safety culture improvement.

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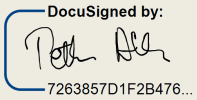
Signature:	
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1. Introduction

Safety culture has been an essential concept in the nuclear industry bringing attention to the social and organizational factors that relate to nuclear safety since its initial introduction in late 1980s and 1990s. Nowadays, safety culture is deeply integrated into the nuclear industry international standards (e.g. IAEA, 2006b, 2016a), and national legislation (e.g. Finnish regulation, STUK, 2018, 2019; European harmonization, WENRA, 2021). The expectation is not only for nuclear organizations to have a good safety culture, but also to formally implement activities focussing on continual improvement to improve safety culture (IAEA, 2006b, 2016a). This includes both general organizational development, but also specific safety culture activities such as safety culture self-assessments and training on safety culture (Viitanen et al., 2022).

When systematically striving towards improving safety culture, it is not sufficient to merely implement the required or recommended activities. It is essential to ensure that the activities are **effective** for their purpose—positively influencing safety culture and ultimately creating better preconditions for ensuring nuclear safety. This involves establishing, for example, what characterizes effective safety culture improvement, what tools or methods can be used to assess their effectiveness, and how the insights concerning effectiveness can be used for continual improvement of the safety culture improvement process.

In this report, we present two approaches to **effectiveness assessment** concerning safety culture improvement and illustrate them with four practical tools. We apply a systemic and multi-level perspective (sociotechnically, Rasmussen, 1997; and culturally, Schein, 1985) to safety culture improvement. This perspective acknowledges that safety culture improvement initiatives can influence phenomena at different levels of culture (e.g. artefacts, behaviour, attitudes, norms, basic assumptions), and at different levels of the sociotechnical system (e.g. organizational, social, individual, or technological levels). We refer to “effectiveness” as the realization of activities and the achievement of results (cf. ISO, 2015a), where activities include general and specific organizational development programmes and activities, and results include positive, safety-related impacts on one or many levels of the organizational culture, and on one or many levels of the sociotechnical system.

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2. Approaches to assessing the effectiveness of safety culture improvement

Systematic safety culture improvement aims to improve a nuclear organization’s ability to maintain and improve nuclear safety in an effective way. However, due to the complex sociotechnical interdependencies between (technical) nuclear safety, human and organizational factors, safety culture and leadership, and organizational development and management, there is not likely to be a simple, end-all solution for effectiveness assessment for safety culture improvement. Consequently, in this report we present various considerations and approaches for effectiveness assessment. These can then be used to assess the effectiveness of safety culture improvement from certain perspectives, depending on the demands of the particular situation.

Organizational culture is usually conceptualized as a multi-level phenomenon (e.g. Guldenmund, 2000; Schein, 1985). Schein's (1985) model of organizational culture is perhaps the most commonly accepted in academia and in practice. It defines three levels of culture:

1. Artifacts
2. Beliefs, norms, and values
3. Basic assumptions

An organizational culture which prioritizes safety is referred to as a **safety culture**.[1] In the nuclear industry, artifacts include structures (e.g. the nuclear technology and the design solutions used, physical environment, integrated management system, organizational structures, and procedures), behaviours and decisions of leaders and other organizational members, as well as organizational performance outcomes, such as safety-related events or incidents and accidents (or their lack) (see, e.g. IAEA, 2016b). Safety-related shared beliefs, norms, and values are the drivers of behaviour and ways of thinking. At the deepest and most implicit level of culture are the shared basic assumptions, which are typically taken for granted and considered self-evident by the organizational members. In the nuclear industry, examples of basic assumptions include how nuclear safety is understood, what kinds of hazards can, cannot, or could exist, how the hazards can be identified or mitigated, what the accepted models of accident causation and human error are, etc.

Organizational culture **develops** over a period of time as the organization solves the problems it faces and teaches the solutions to new organizational members as the "correct" way to perceive, think and feel concerning the problems (Schein, 2010). These problems may relate to external demands (e.g. survival, growth, or adaptation to environment), or internal integration. The iterative nature of how culture forms has been further summarized by Reiman and Rollenhagen (2018), who propose that culture (expectations, beliefs, conceptions and values) influences behaviour, which respectively creates and changes culture; structures (e.g. organizational structure, management system) that store culture, but also influence behaviour and are created and changed by behaviour. A systems-oriented view on safety further proposes that organizational culture represents a category of elements that interact within the sociotechnical system, and creates the preconditions for safety operations (Rasmussen, 1997; Reiman & Rollenhagen, 2014). Safety culture, therefore, is created in the interaction of various phenomena and rooted in relatively stable basic assumptions, beliefs, values, and attitudes that drive behaviour, and ultimately result in safety outcomes. This means that effectiveness assessment should be informed by a **systemic model or understanding of cultural dynamics**. This involves establishing how elements such as basic assumptions, beliefs, values and attitudes, structures and behaviour, as well as improvement initiatives, interact and create culture, and subsequently affect nuclear safety (Viitanen, Gotcheva, et al., 2018; Viitanen, Reiman, et al., 2018).

Extrapolating from Schein's model (Schein, 1985), **organizational culture can be considered to be effective when it is well-adapted** to the external and internal demands that the organization faces, or when it is supporting the fulfilment of the organizational core task (Reiman & Oedewald, 2002, 2006). In the nuclear industry, what it means to have a "well-adapted organizational culture" has been explicated in safety culture models that describe the characteristics of an ideal safety culture. Safety culture models in the nuclear industry are relatively well in line with each other and contain similar dimensions. They include, for example, safety leadership, procedure adherence, open reporting and information flows, a questioning attitude and continuous improvement (see, e.g. IAEA, 2006a, 2020; WANO, 2013). Overall, this emphasizes that a safety culture is a normative phenomenon, and that the norms are defined either

[1] In the nuclear industry, the formal definition of safety culture is: "The assembly of characteristics and attitudes in organizations and individuals which establishes that, as an overriding priority, protection and safety issues receive the attention warranted by their significance." (IAEA, 2018)

generally (“well-adapted”), or in detail (safety culture models). Assessing the effectiveness of safety culture improvement should therefore be informed by this **normativity**. This includes establishing the purpose of safety culture improvement, how the improvement activities contribute to the normative characteristics of safety culture, and what type of cultural phenomena are targeted (e.g. behaviour, values, beliefs, attitudes, or basic assumptions) (Viitanen, Gotcheva, et al., 2018; Viitanen, Reiman, et al., 2018).

Systematic safety culture improvement consists of a variety of processes and activities that maintain and develop organizational activities (based Viitanen et al., 2017, 2022):

- **Daily work and processes**: Activities that the whole organization performs as part of its daily routine (e.g. continuous improvement, conservative decision-making, procedure adherence, human performance tools, questioning attitude, raising safety concerns, or making initiatives)
- **Leadership**: Activities of those who are in positions of formal or informal power (e.g. strategic decision-making, management-in-the-field, leading with example)
- **Safety culture organizational function**: The formal structures and processes that explicitly define activities aiming to improve safety culture (e.g. safety culture programmes and improvement plans)
- **Safety culture activities**: The implementation of activities that explicitly aim to improve safety culture (e.g. safety culture self-assessments, training on safety culture topics, providing safety expertise to support others)

Safety culture improvement involves activities that aim to achieve some operational or managerial goal but also influence safety culture, and activities that are specifically intended to assess or influence safety culture. Usually managers, supervisors and operational staff perform the former group of activities, while safety culture experts implement the latter. It is worth noting that even if there are organizational activities aimed specifically at improving safety culture, their actual influence on culture is indirect: they may affect the behaviour of organizational members, organizational structures, or leadership activities, but their impact on culture emerges only when the implications of the changed behaviour, structures or leadership activities become rooted as shared beliefs, values, attitudes or basic assumptions (Reiman & Rollenhagen, 2018). This means that effectiveness assessment should be informed by an **understanding of how safety culture improvement activities function and how they influence culture** (Viitanen, Gotcheva, et al., 2018; Viitanen, Reiman, et al., 2018).

Summarizing these viewpoints, we propose **two general approaches** for assessing the effectiveness of safety culture improvement: a phenomenon-based approach and a process-based approach.

The **phenomenon-based approach** views safety culture improvement from the perspective of cultural dimensions or manifestations, and how they interrelate with each other and with other sociotechnical elements of the organization (e.g. technology, individual perceptions, values and attitudes, organizational functions, etc.). From this perspective, safety culture improvement is seen as a complex, systemic activity. Explicating the system elements and their interrelations can help identify indicators that can be used for effectiveness assessment, as well as for finding leverage points for improvement. The phenomenon-based approach can answer questions such as: What sociotechnical phenomena influence procedure adherence and how can change in the influence be measured?

The **process-based approach** views safety culture improvement as an organizational function that involves, for example, a process dedicated to safety culture improvement, as well as specific activities that aim to improve safety culture. Effectiveness assessment is seen both as verifying that the process and the related activities are implemented, that the implementation is sufficiently comprehensive, and validating that the process and the related activities have a positive impact on safety culture. The process-based approach can answer questions such as: What constitutes an effective safety culture self-assessment process, and how can it be measured?

It is important to note that the phenomenon-based approach and process-based approach are not exclusive and should be used in a complementary manner. For example, the understanding created as part of the phenomenon-based approach is essential when applying the process-based approach. Respectively, the process-based approach is useful when assessing the effectiveness of specific safety culture activities (possibly) identified as leverage points in the phenomenon-based approach.

In the following two chapters of the report, we present case studies, models and tools that illustrate how the two approaches can be applied in practice to evaluate the effectiveness of safety culture assessment.

3. The phenomenon-based approach

3.1 Introduction

The phenomenon-based approach to assessing the effectiveness of safety culture improvement aims to gain a systemic understanding of cultural dynamics. One way of achieving this goal is to explicate these dynamics through **modelling**.

The **safety culture models** currently used in the nuclear industry can be characterized as “dimension models”. They elaborate detailed lists of dimensions, characteristics and attributes of phenomena that relate to safety culture. Well-known examples of such models include the IAEA 5-characteristic safety culture model (IAEA, 2006a), IAEA Harmonized safety culture model (IAEA, 2020), and WANO safety culture model (WANO, 2013). One limitation of dimension models is that they provide limited understanding of the systemic and sociotechnical nature of safety. That is, they do not explain how the identified phenomena influence each other, and how they are connected to other safety-related phenomena at different levels of the sociotechnical system (e.g. technology, behaviour, administrative systems, culture, external factors, etc.).

Recognizing these systemic interconnections can serve as one step towards creating a valid and practical method for assessing the effectiveness of safety culture improvement activities. For this purpose, we designed a **model development process** that aimed to identify the interconnections of a selected safety culture attribute between various related phenomena. The expected outcome was to reveal the systemic nature of the attribute, and to identify potential effectiveness assessment indicators and intervention strategies.

The model development process draws inspiration from causal modelling methods, such as the AcciMap (Rasmussen, 1997; Rasmussen & Svedung, 2000; Salmon et al., 2020) approach and bowtie (de Ruijter & Guldenmund, 2016) method, that are used in incident and accident analysis. The characteristics of analyses resulting from these methods include identification of causal relationships (both AcciMap and bowtie), phenomena located in different levels of the sociotechnical system (specifically AcciMap), and the existence of a “focal point” that serves as the starting point for the analysis (“top event” in AcciMap and bowtie). In the variation used here, the selected safety culture attribute is in the central “top event” position, and its antecedents and consequences are modelled (Table 1).

The safety culture attribute model development process starts with **selecting a safety culture attribute** for further elaboration. Two safety culture attributes were selected for piloting the modelling approach.

Raising concerns was selected as the first attribute by the research team. This attribute has been widely scientifically studied, which provided a good starting point for analysis. It is also an important aspect of safety culture and is present in all comprehensive safety culture models (e.g. dimension RC in the IAEA Harmonized safety culture model, IAEA, 2020), and its improvement and assessment was considered a challenge in previous data collection within the SAFIR2022 EPIC project (Viitanen et al., 2022).

The **procedure compliance** attribute was suggested by industry practitioners during a joint workshop. Procedure compliance is also an essential aspect of safety culture, and is present in all comprehensive safety culture models (e.g. dimension IR in the IAEA Harmonized safety culture model, IAEA, 2020).

The next steps involve the **identification of the network of antecedents and outcomes** that are associated with the selected safety culture attribute. This step was done by conducting a limited literature review on the attribute and integrating the findings in researcher workshops. This resulted in a draft version of the model, and a **visual representation** of the draft model was prepared.

The visualized draft models were then discussed in a **co-creation workshop** with safety culture experts from nuclear power companies. In the workshops, the validity and relevance of the model was discussed. In addition, the safety culture experts were asked to identify existing and potential assessment and improvement methods for each element in the model. Based on the feedback and additional insights, the researchers **further refined** the model.

Table 1. Model development process

Step	**Method**
1. Selection of one safety culture attribute as a "focal point" for elaboration	Joint agreement (researchers with practitioners)
2. Identification of a network of factors that contribute to the attribute	Literature review, modelling in researcher workshops
3. Identification of outcomes of the attribute	Literature review, modelling in researcher workshops
4. Creating a visual representation of a draft model	Visualization using a general-purpose diagramming software
5. Identification of existing and potential assessment and improvement methods	Co-creation workshop with practitioners and researchers
6. Further development of the model	Revision based on feedback from practitioners

3.2 Modelling the raising concerns attribute

3.2.1 Background

The focal point of the model development was **raising concerns behaviour**. The first group of influencing factors were labelled "enablers" which are the immediate contributors to raising concerns behaviour. They are psychological (psychological safety, motivation, understanding) and organizational (opportunity) in nature. The model development was inspired by an influence diagram on incident reporting behaviour proposed by Shorrock (2021), which was supplemented by a literature review. The literature review included articles from safety-critical industries (e.g. aviation and healthcare) on topics such as speaking up, safety voice, and safety communication. In addition, the factors were classified, and colour coded by contextual factors, values and attitudes, organisational function/process, knowledge, individual perceptions, and organizational outcomes. The draft model and methods to assess and improve raising concerns behaviour were discussed in a workshop with nuclear industry practitioners (safety culture experts from Finnish nuclear power companies) and iterated by the researchers. In general, the suggested methods to assess and improve raising concerns behaviour included audits, event investigations, peer

reviews and safety culture assessments. A simplified illustration of the model is presented in Figure 1 and the full set of identified influencing factors is presented in Attachment A (Figure A1).

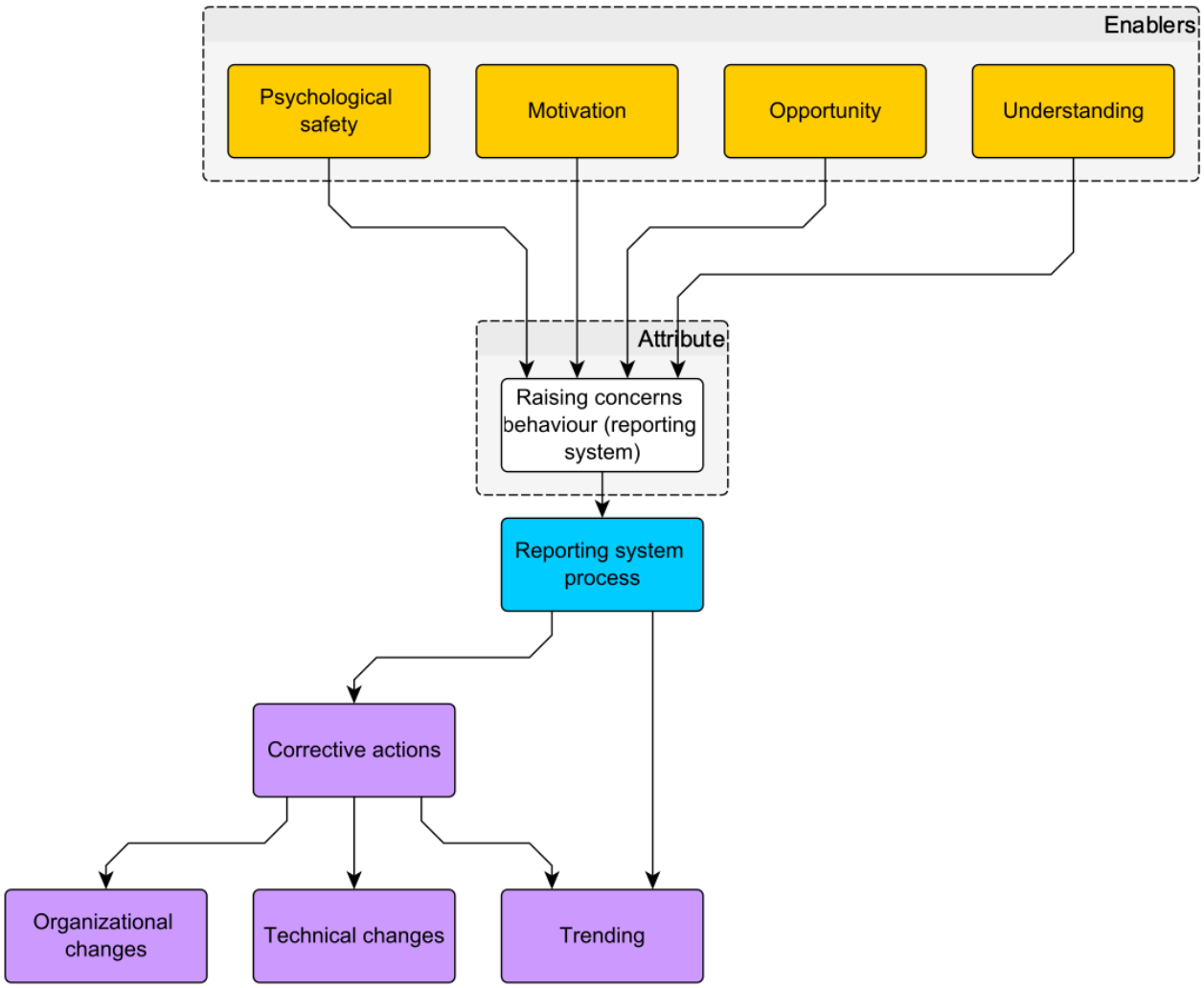

Figure 1. Simplified illustration of the raising concerns behaviour model

In the following subchapter, we describe our model of raising concerns behaviour in further detail and elaborate the insights for assessment and improvement that emerged during the workshop with nuclear industry experts.

3.2.2 Definitions of the enablers and means to assess and improve them

Psychological safety refers to a shared belief amongst employees that their colleagues will not reject them for saying what they think, respect each other's competence, are interested in each other as people, have positive intentions towards one another, are able engage in constructive conflict or confrontation, and feel trust between team members (Edmondson, 1999; Newman et al., 2017). Psychological safety is influenced, for example, by leadership behaviour, work design characteristics, and a supportive work context (e.g. Aranzamendez et al., 2015; Frazier et al., 2017).

Insights for assessment and improvement:

- When there are signs in the organisation that the total level and coverage of reporting is low, a qualitative analysis is recommended to investigate the root-cause reasons behind it. This may reveal whether the personnel feel that it is safe enough to report things and potential challenges can be addressed.

- Analysing the number of people reporting anonymously versus reporting using their own name. It was noted that in more turbulent times the personnel may report more anonymously. A high number of anonymous reports may indicate a lack of psychological safety.

The **motivation** to report means that the personnel want to report issues (cf. Schwappach & Gehring, 2014). We identified the following potential influencing factors regarding motivation: perceptions of responsibility, peer group values and attitudes, perceptions of negative or positive personal consequences, expectation of feedback, company-level learning and change following reporting, previous experience of reporting (first or second hand), perception of confidentiality, ease of reporting, and management values and attitudes.

Insights for assessment and improvement:

- Raised concerns need to be addressed in a timely manner. If concerns are not addressed, the motivation to report in the future declines.

- Substance knowledge is needed to ensure that the personnel are aware and have the feeling that something is significant enough to report.

- Event investigation backlogs may help reveal signs of cynical behaviour and learned helplessness that relate to lack of motivation.

- Giving positive feedback and rewarding reporting. In general, enhancing nuclear professional behaviour by appropriate rewards was noted.

- Surveys that include topics measuring the observation system and how personnel feel about it.

- Open fields in safety culture self-assessment surveys provide the opportunity to gain more qualitative feedback about the observation system and motivation.

Understanding category refers to the personnel's knowledge about their work, its safety significance, work related requirements and procedures as well as various reporting systems of the organisation. The personnel need to know what, when and how they should report matters. This is affected by the sensemaking process, which is a process of social construction that occurs when discrepant cues interrupt individuals' ongoing activities; it involves the retrospective development of plausible meanings that rationalize what people are doing (Weick, 1995).

Insights for assessment and improvement:

- Substance competence is usually self-evident and taken for granted in nuclear power plants. It is important to assess if the personnel really understand what they should do and establish whether the safety significance is really understood.

The **opportunity to report** matters or concerns refers to whether the personnel has time and facilities available for reporting (cf. Martowirono et al., 2012). The opportunity to report concerns is negatively affected if the employee's workload is constantly high and reporting must be done during breaks or in free time, or if the reporting systems are not accurate and easy to use due to their design or other features. This is also affected by company policies as well as regulatory requirements.

Insights for assessment and improvement:

- Organisations have multiple reporting systems (technical, non-technical, safety culture, OHS, corporate systems, other systems with different access rights) which impact the motivation and opportunity to report concerns when personnel need to decide what type of safety concern they wish to report.
- The ease of reporting can be measured by how long it takes to fill in a form.
- In more turbulent times or in a project environment, the time for reporting may cause bias: personnel who are overloaded with work might not have the opportunity to report their concerns and personnel with lower workloads may report very minor issues.

Feedback from the workshop indicated that the system visualization describing how different factors might affect each other is valuable because it makes them visible and possible to discuss. It makes it easier to communicate in the organization and analyse and reflect on the underlying targets. It was noted that visualisation could be a tool for reflective discussions within the organization on various levels when you want to develop something specific and address risk areas related to silos.

Based on the workshop and feedback, the researchers made a practical tool for assessing reporting behaviour in NPPs (Attachment A).

3.3 Modelling the procedure compliance attribute

3.3.1 Background

In general, **two paradigms** of procedure compliance have been identified (Hale & Borys, 2013). The first is a top-down, classical, and rational approach in which rules are seen as static, comprehensive limits for freedom of choice, imposed on users at the sharp end. Deviations from rules are seen as negative behaviour to be suppressed. The second paradigm is a bottom-up, constructivist view where rules are seen as dynamic, local, and situated constructions of users as experts. Competence is seen to a great extent as the ability to adapt rules to the diversity of reality. These paradigms are also reflected in Hollnagel's Safety-1 – reactive and constraining, and Safety-2 – proactive and enabling approaches to safety management (Hollnagel, 2014). Both paradigms have strengths and weaknesses (Hale & Borys, 2013), which makes the procedure compliance attribute complex and even contradictory.

A distinction can be made between **deep and surface level compliance** (Hu et al., 2020). Deep compliance means that employees engage with the intention to maintain workplace safety, and invest the effort required to enacting risk management strategies which are expected to accomplish organizationally desired safety outcomes (Hu et al., 2020). Surface compliance means that employees engage with the intention to meet organizational requirements, and direct their effort and attention towards demonstrating compliance (Hu et al., 2020).

Procedures in nuclear organisations are described in an integrated management system, for example, manuals, and work procedures and instructions. Adherence to procedures is a recurring topic in nuclear industry expectations for a good safety culture (e.g. IAEA, 2006b, 2016a, 2020; WANO, 2013). In the nuclear industry, Stop, Think, Act and Review (STAR) principle and a questioning attitude are expected to manage situations where the rules do not apply or are not safe (e.g. DoE, 2009; INPO, 2006).

In our model of procedure compliance, we included procedure attributes, individual perceptions and factors, organizational factors and leadership, as well as values and attitudes as influencing factors (cf. Kanse et al., 2018). We see procedures as attempting to create an explicit model of safe work (or what the organization perceives and expects safe work to be). This is then communicated to workers using

various document management systems. It is worth noting that the reality of safe work and what the organization assumes it to be may differ (cf. “work-as-done” vs. “work-as-imagined”, Dekker, 2006; Hollnagel, 2015). Figure 2 illustrates the procedure compliance model, and it is further detailed in Figure B1.

In the following subchapters, we review each part of the model in detail and describe insights from a workshop held with nuclear industry practitioners.

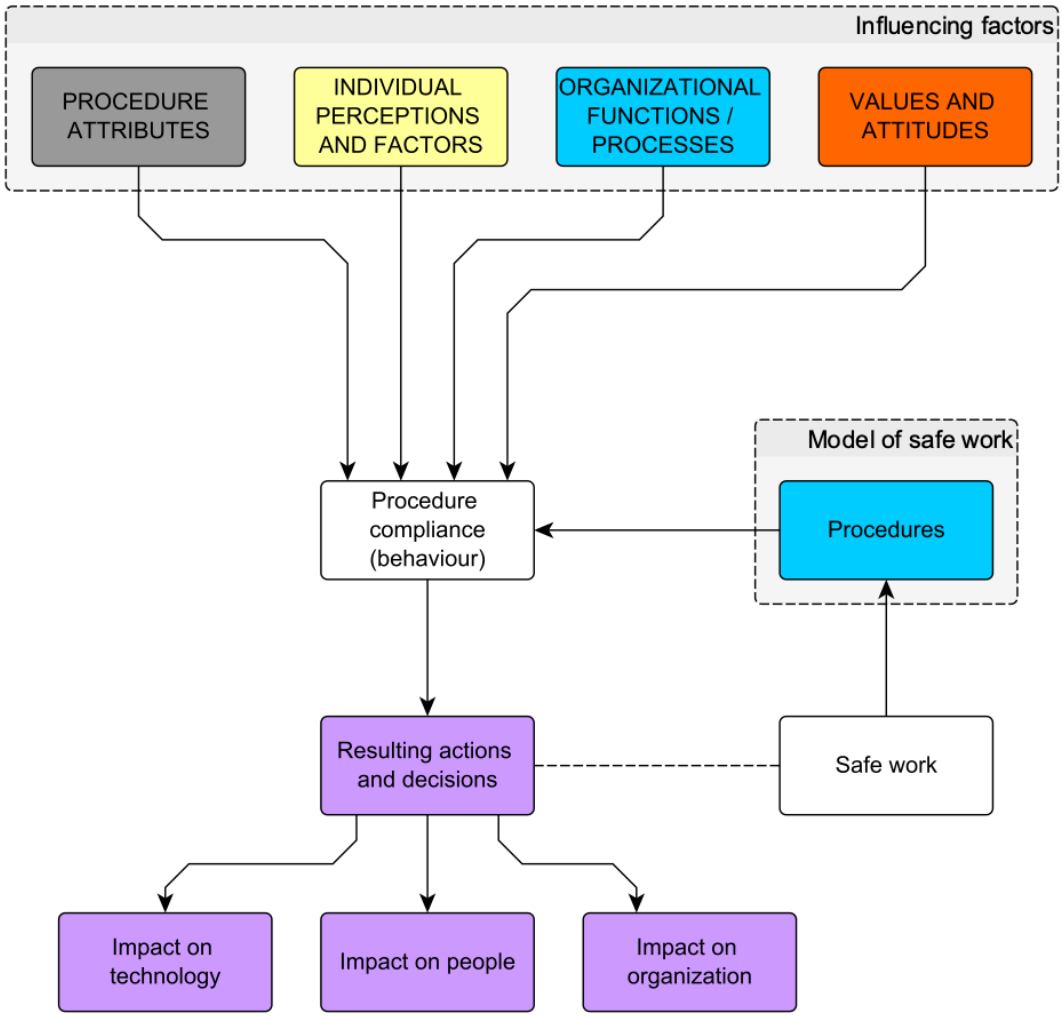

Figure 2. Simplified illustration of procedure compliance

3.3.2 Organizational factors and leadership attitudes

There are three different approaches to compliance management (Kanse et al., 2018). The **punitive approach** involves management responding to non-compliance with sanctions and assigning blame. The **learning approach** is when management responds to non-compliance through open communication and sees it as an opportunity for change. The **involvement approach** refers to the management including employees in the design and implementation of procedures.

Based on a further literature review, the following organizational factors were identified as contributing to procedure compliance (Bensonch et al., 2022; Dekker, 2003; Hu et al., 2016, 2018; Kanse et al., 2018):

- Work design and planning (e.g. time pressure, overoptimization, work overload, conflicting demands, integrating workers into organizational activities)
- Design, quality, and usability of the procedures (e.g. too many rules, user-friendliness, access, inflexibility, complex, or unclear, and/or inadequate content, lack of real-world relevance)
- Training
- Leaders' attitude and supervision (e.g. expectation of having to bend rules to get work done, supervisors could facilitate the perceived usefulness of procedures and employees' job self-efficacy by helping employees to achieve their job goals, poor supervisor-worker collaboration)
- Users' involvement in procedure development (e.g. voicing users' thoughts and opinions about the procedures they use)

3.3.3 Individual perceptions, factors, and procedure attributes

Users' perceptions and individual factors predicting **compliance** with procedures include (Bensonch et al., 2022; Dekker, 2003; Hu et al., 2016, 2018; Kanse et al., 2018):

- Procedures perceived as, logical, to the point, at the right technical level, and user-friendly
- Safety motivation, commitment, and job satisfaction
- Attitudes toward procedure compliance, procedure utility, and fewer years of experience
- Perception of high procedure quality

Users' perceptions and individual factors predicting or affecting **noncompliance** include (Bensonch et al., 2022; Dekker, 2003; Hu et al., 2016, 2018; Kanse et al., 2018):

- Procedures perceived as time consuming, unnecessary, out of date, or too numerous
- Tiredness, or seeing ways to make shortcuts
- Intention, attitude, and habits of non-compliance
- Perceived low risk
- The personality trait of "outward irritability"
- Self-image and status among peers that favours risk and violation
- Previous accident involvement
- Low level of training
- Low level of competences and planning

3.3.4 Procedure compliance (behaviour)

The behaviour related to procedure compliance can be classified along a continuum of intentionality, for example, according to a culpability decision tree (Reason, 1997). Reason classifies unsafe acts as clear cases that are intentional (e.g. sabotage, or substance abuse), violations (e.g. reckless

noncompliance with procedures, negligence, or system-induced violation resulting from lack of proper procedures), and blameless non-compliance (e.g. system-induced errors resulting from deficiencies in training, experience, or personnel selection, or blameless errors of individuals without any history of unsafe acts) (Reason, 1997). Violations can be further classified as routine (as normal and accepted ways of working in a group), situational (happening only in specific context when the rule seem not to be relevant), exceptional (in a unique situation one time only), and optimizing (solving trade-offs of safety with other objectives such as production pressure) (Hale & Borys, 2013). Identifying the type of noncompliance with procedures should inform the consequences or corrective actions resulting from it: whether punishment, training, learning, procedure update or other organizational change is the appropriate action.

3.3.5 Insights for assessing and improving procedure compliance

According to the **workshop discussions,** the general workplace culture, atmosphere, and peer pressure can affect compliance positively or negatively: it can change a newcomer to adopt the ways of the organization, regardless of whether the newcomer was initially reckless or pedantic. The workshop participants found that old attitudes emphasizing "*if you need to read the instructions – you are in the wrong place*" are fading away in the nuclear industry. They also felt that recognizing the importance of instructions and the correct level at which they are written (not too detailed, not too vague) are important factors in their proper use in nuclear power plants.

In nuclear power plants, **factors affecting procedure compliance** are addressed in internal and external safety culture assessments and in audits to some extent. Involving users in procedure writing was considered an important factor towards improving the quality of the procedures and employee commitment to them.

When discussing the **safety-significance** of different types of procedures, the nuclear industry practitioners felt that in general, upper-level guidelines are more policy-like and lower-level guidelines define prioritization in a more concrete manner. The procedures identified as the most safety-significant were related to operational limits and conditions (OLC), operational decision-making, emergency and incident management, and main control room operations.

Based on the workshop discussions, **assessing and improving procedure compliance** should strive to improve understanding of the importance of the instruction/procedure and on what level it needs to be applied. This requires sensemaking abilities from the person, workgroup, and the whole organization to continuously reason how to act in certain situations. The workshop participants felt that non-compliance in nuclear power plants is rarely an intentional violation or a conscious decision but is the result of a joint sense-making. The following insights emerged:

- Ensuring a systematic, traceable, and transparent system for procedure development initiatives.
- Categorizing what instructions need to be followed and in what situation.
- Informing the personnel when updating instructions.
- Finding new ways to distribute updated instructions.
- Ensuring that plant suppliers' improvement suggestions are systematically addressed and considered in the development of procedures.
- Training and guiding supervisors and subcontractors to ensure the compliance and continual development of instructions and procedures.
- Systematically and at regular intervals reviewing different level and types of procedures and assessing whether there are blind spots and contradictions.

- Emphasizing compliance with procedures also in other safety-significant areas (e.g. occupational safety in heavy lifting), not just in the most nuclear safety-significant operations (e.g. main control room).

- Systematic master-apprentice model for pairing experienced and new employees to ensure the adoption of good working practices.

Feedback from the workshop indicated the importance and complexity of the topic. In addition, a need was identified to examine procedure compliance based on cutting-edge research results from outside safety science, such as cognitive and psychological sciences.

4. The process-based approach

4.1 Introduction

To illustrate the process-based approach, two most commonly applied and required safety-culture-specific subprocesses of safety culture improvement were chosen: safety culture assessment and safety culture training. The next two chapters describe the best practices concerning these two activities and describe the reasoning behind tools that can be used to evaluate the effectiveness of these activities. The proposed tools are described in Attachments C and D.

4.2 Subprocess: safety culture assessment

4.2.1 Background

Implementing a safety culture assessment process is among the first and most important specific activities for safety culture improvement that safety-critical organizations carry out. It serves as the input for the continual organizational development cycle. In the nuclear industry, a safety culture assessment is required and expected in international standards and in national legislation.

The IAEA requires the implementation of regular assessments of leadership for safety and of safety culture[2], including safety culture self-assessments[3,4,5,6] and independent safety culture assessments[7,8]. IAEA GS-G-3.1 (2006a) and IAEA GS-G-3.5 (2009) make a distinction between self-assessment by senior management and self-assessment by individual and managers (other than senior management). Self-assessment by senior management explicitly includes safety culture as a topic. A management review is another assessment type and includes evaluating the effectiveness of the management system (which is expected to be applied to foster strong safety culture[9], but does not explicitly refer to a safety culture assessment. IAEA SRS-83 (IAEA, 2016b) provides detailed guidance on how the IAEA expects a safety culture self-assessment should be performed.

The Finnish regulatory framework contains the same elements as the IAEA requirements. References are made to the assessment of the management system[10,11], generally being aware of the status of safety

[2] IAEA GSR Part 2 Requirement 14: Measurement, assessment and improvement of leadership for safety and of safety culture. Senior management shall regularly commission assessments of leadership for safety and of safety culture in its own organization. (IAEA, 2016a)

[3] IAEA GSR Part 2. 6.9. Senior management shall ensure that self-assessment of leadership for safety and of safety culture includes assessment at all organizational levels and for all functions in the organization. Senior management shall ensure that such self-assessment makes use of recognized experts in the assessment of leadership and of safety culture. (IAEA, 2016a)

[4] IAEA GS-G-3.1 6.7. Effective self-assessment by senior management should evaluate such conditions as: the state of the knowledge, motivation and morale of individuals; safety culture; the amount of mutual trust and communication among individuals; the existence of an atmosphere of creativity and improvement; and the adequacy of human and material resources. (IAEA, 2006a)

[5] IAEA GS-G-3.5 6.6. The input to self-assessment by senior management should include information on: (a) Safety related results and trends and performance indicators; (b) Overall performance, including safety, health, environmental, security, quality and economic considerations; (c) Analysis of current performance, such as feedback from peer evaluations, surveillance and results of technical reviews; (d) Adequacy of the management system of the organization; (e) Effectiveness of management procedures and work instructions; (f) Organizational issues, such as levels of authority and responsibility, interfaces, communications and policies for recruitment, training and promotion; (g) Results of staff surveys and assessments of safety culture; (h) Effect of regulatory and statutory requirements and any changes to them; (i) Strategic planning, the purpose or 'mission' of the organization and the safety objective; (j) Feedback from experience. (IAEA, 2009)

[6] IAEA GS-G-3.5 6.35. The self-assessment of safety culture should include the entire organization. Several different self-assessment tools should be used to determine the status of the safety culture of the organization. Possible self-assessment tools include interviews, focus groups, questionnaires, observations and document reviews. The safety culture should be assessed on the basis of its characteristics (see paras 2.14—2.21) and attributes (see Appendix I). These characteristics and attributes should all be covered when developing interview questions, items for inclusion in a questionnaire or issues for discussion in focus groups. (IAEA, 2009)

[7] IAEA GSR Part 2 6.10. Senior management shall ensure that an independent assessment of leadership for safety and of safety culture is conducted for enhancement of the organizational culture for safety (i.e. the organizational culture as it relates to safety and as it fosters a strong safety culture in the organization). (IAEA, 2016a)

[8] IAEA GS-G-3.5 6.38. The independent assessment of safety culture should follow a similar approach to that used for the self-assessment and should also include all characteristics (see paras 2.14—2.21) and attributes (see Appendix I) of safety culture. The independence and qualification of the members of the assessment team should be considered crucial for the success of the assessment. The team should be staffed with sufficient diversity of experience and should include specialists in behavioural science, with knowledge of statistical methods of analysis. (IAEA, 2009)

[9] IAEA GSR Part 2 4.9. The management system shall be applied to achieve goals safely, to enhance safety and to foster a strong safety culture by: (a) Bringing together in a coherent manner all the necessary elements for safely managing the organization and its activities; (b) Describing the arrangements made for management of the organization and its activities; (c) Describing the planned and systematic actions necessary to provide confidence that all requirements are met; (d) Ensuring that safety is taken into account in decision making and is not compromised by any decisions taken. (IAEA, 2016a)

[10] STUK Y/1/2018 Section 25. 2. Organisations participating in the design, construction, operation and decommissioning of a nuclear facility shall employ a management system for ensuring safety and the management of quality. The objective of such a management system shall be to ensure that safety is prioritised without exception, and that quality management requirements correspond to the safety significance of the activity and function. The management system shall be systematically assessed and further developed. (STUK, 2018)

[11] YVL A.3 716. The management shall conduct a review of the management system at regular intervals in order to ensure the management system's applicability and effectiveness. The reviews shall include the objectives of the management system, including the safety and quality policy, that pertain to nuclear and radiation safety and quality as well as an assessment of opportunities for improvement and needs for change. As input data for the reviews, the following shall be used: the results of independent audits, process assessments, realisation of safety and quality objectives, status of corrective and preventive action, follow-up measures taken after previous management reviews, suggestions for improvement, and changes that could affect the management system. [2019-03-15] (STUK, 2019)

culture[12], and conducting safety culture self-assessments[13,14], as well as independent safety culture assessments[15]. Finnish regulations also explicitly require licensees to assess (and ensure) the safety culture in the supply chain[16].

Process **maturity models** are a commonly used method for structuring the evaluation of the degree of formality and level of development of business processes. For example, the Capability Maturity Model identifies five levels of maturity: initial, repeatable, defined, managed and optimized (Paulk et al., 1993). This model has also been used as a basis for creating safety culture assessment models, often adapting alternative level descriptions: emerging, managing, involving, cooperating and continually improving (Goncalves Filho & Waterson, 2018). In Attachment C, we propose a maturity evaluation model and tool for safety culture assessment process. The tool was developed by integrating the best practices described in the following subchapters and extrapolating them in accordance with a process maturity model using expert judgement. The tool describes safety culture assessment process evaluation criteria and how they manifest at four levels of maturity. The maturity levels include lack of achieving the evaluation criteria (i.e. non-conformance), as well as basic, advanced, and best practice levels. These maturity levels differ from the Capability Maturity Model by explicitly including the lowest, non-conformance level; however, the other three levels largely correspond to the extremes of the Capability Maturity Model. Note that unlike safety culture (status) maturity levels, the approach described in Attachment C aims to structure the maturity evaluation of the safety culture assessment process, rather than the culture itself.

Below we summarize a set of **best practice** considerations that were used to formulate the maturity evaluation tool. The best practices were identified based on nuclear industry standards (the requirements and recommendations described above, as well as IAEA SRS-83, IAEA, 2016b), previous research of safety culture expert work done within SAFIR2022 EPIC (Viitanen et al., 2022), and a cursory selection of other literature. An overview of the safety culture assessment process and list of key evaluation criteria is described in Figure 3. It is worth noting that the existing organizational culture and organizational context affect how the organization understands the safety culture assessment process and consequently what elements it sees as relevant to implement and at what level of maturity.

[12] YVL A.3 318. The management system shall contain procedures to make the management aware of the situation of the safety culture in their organisation, changes to it and, in particular, the potential deterioration of the safety culture. [2019-03-15] (STUK, 2019)
[13] YVL A.3 709. The management and all organisational levels shall carry out regular self-assessment of their own work performances against pre-defined criteria. Experts in the topic shall be utilised in self-assessment of safety culture and leadership. [2019-03-15] (STUK, 2019)
[14] YVL A.3 710. The organisation shall have in place a procedure for measuring the personnel's awareness of the significance and importance of their duties and of how the individuals affect the achievement of safety and quality objectives. [2013-11-15] (STUK, 2019)
[15] YVL A.3 712. The management system shall include the requirements and procedures for regular, independent assessment of the system's conformity, performance, and effectiveness. Areas to be assessed in particular shall include the effectiveness of processes as regards the achievement of objectives and the realisation of the strategies and plans, the results of work performances and leadership, the organisation's safety culture, and the quality of products. [2019-03-15] (STUK, 2019)
[16] YVL A.3 318a. The licensee's management system shall contain procedures to ensure the good safety culture of safety-significant suppliers, to assess the safety culture and to respond to its development needs. [2019-03-15] (STUK, 2019)

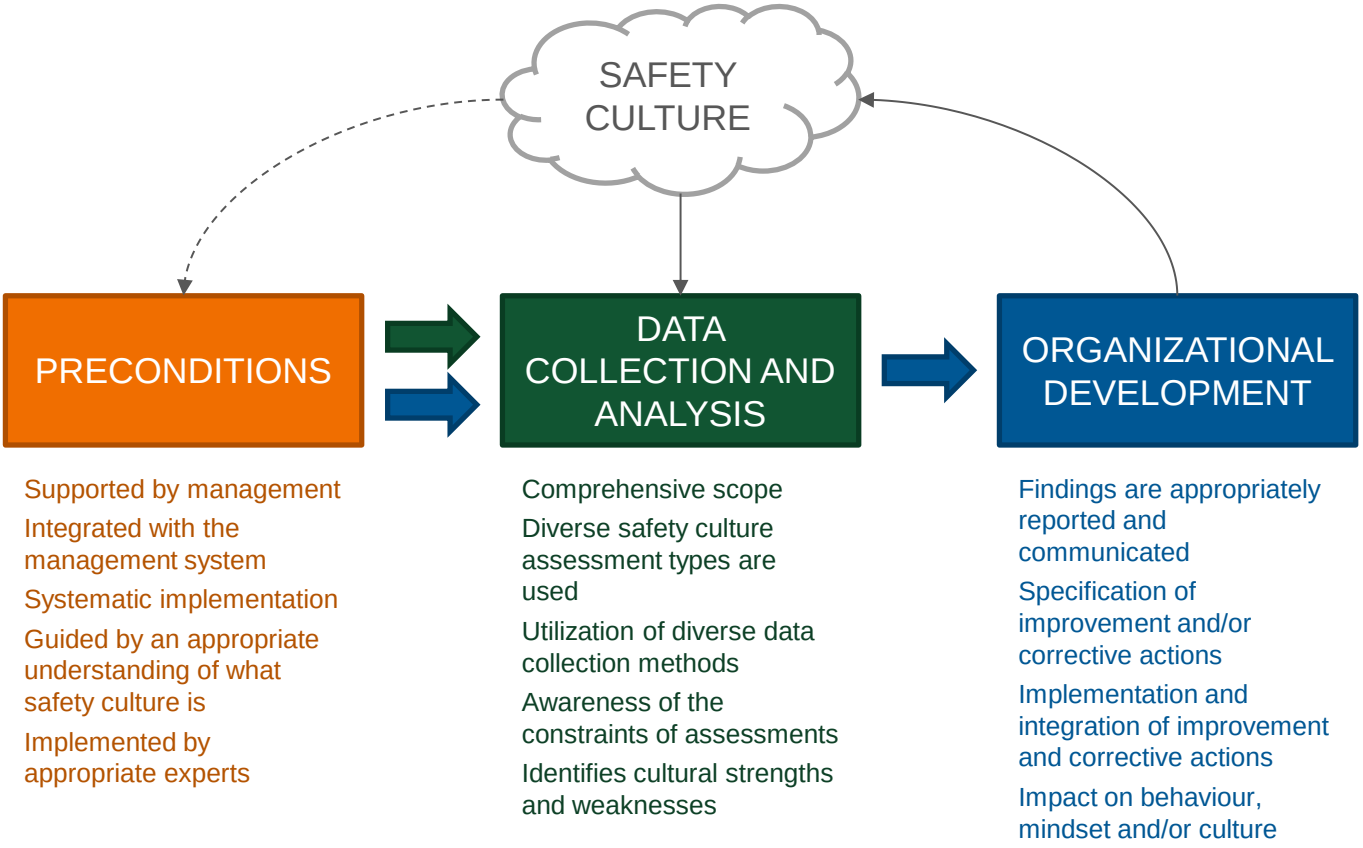

Figure 3. Overview of safety the culture assessment process and list of key evaluation topics

4.2.2 Preconditions

Management support is an essential precondition for implementing a safety culture assessment process, as is the case with most organizational development activities (cf. ISO, 2015b), including safety culture improvement (e.g. Antonsen, 2009; Cooper, 1998; Hale et al., 2010; Mengolini & Debarberis, 2007). Management's role includes providing time and resources (IAEA, 2016b; Viitanen et al., 2022), providing a mandate for the experts (e.g. access to organizational functions, Viitanen et al., 2022), as well as supporting and championing the assessment process (IAEA, 2016b). The management should also provide the group implementing the safety culture assessment process with sufficient independence and encourage them to question or highlight problems if necessary (Viitanen et al., 2022). At lower process maturity levels, management support does not exist or hinders the implementation of safety culture assessments. The risk of low maturity of this criterium is that the safety culture assessment process is not implemented at all, or the lack of resources or mandate makes the safety culture assessment activities too limited or unreliable to be useful for organizational development.

Management system integration of the safety culture assessment process involves preparation of appropriate written documentation (e.g. procedures and/or instructions), preparation of binding and approved implementation plans, as well as identifying how the process interfaces with other business processes of the organization (Viitanen et al., 2022). At lower process maturity levels, the process has not been formally described and/or only exists in the (informal) practices of individuals that implement it. Low maturity levels make it more difficult to ensure the allocation of responsibilities for the process, to validate the quality of methods applied, and that the activity continues at a sufficiently high level even if there is turnover of staff that implements the assessment.

Systematic implementation of a safety culture assessment process involves ensuring its periodic implementation (according to defined procedures), as well as systematic development based on own experiences, or external insights (Viitanen et al., 2022). At lower process maturity levels, safety culture assessment activities are conducted on an ad hoc basis and without periodicity. The risks of low maturity levels include long gaps between assessments, that the unsystematic assessment practices do not ensure results that are useful for organizational development or for trending over time, and that the assessment process becomes stagnant in relation to the organization's development level, new industry standards, or research and development on safety culture assessment practices.

The safety culture assessment process should be **guided by an appropriate understanding of what a safety culture is** (e.g. Guldenmund, 2000, 2010; IAEA, 2009, 2016b; Viitanen et al., 2022). This means not only applying suitable industry standard safety culture models, but also appreciating the concept of organizational culture (e.g. Schein, 1985), sociotechnical system view of safety (e.g. Leveson, 2011; Rasmussen, 1997) and the mechanisms through which cultural phenomena influence nuclear safety. At lower process maturity levels, safety culture assessment is guided by a superficial or incorrect understanding of culture (e.g. perceiving it only as the behaviour of individuals, or as the implementation of specific safety culture activities required in the regulations). The risks of such an understanding of a safety culture are that the assessment process is not designed in a manner that enables the identification of cultural phenomena and improvement needs, and that the results produce a misleading or invalid overview of existing safety culture.

There should be **appropriate group of experts** implementing a safety culture assessment process (IAEA, 2009, 2016b, 2016a; Oedewald et al., 2011; Viitanen et al., 2022). From expertise perspective, safety culture assessment requires many types of expertise and benefits from formal education and experience in human and social sciences, quantitative and qualitative methods, knowledge in nuclear industry and nuclear safety, as well as experience in organizational assessment and development. Safety culture expert tasks (generally, and as part of the overall safety culture assessment process) can be quite fragmented (Viitanen et al., 2022), which means that the group responsible for the practical implementation of the safety culture assessment process should also have readiness to continuously adopt new competences. At lower process maturity levels, the group has is no or little expertise in non-technical nuclear safety matters. This can have an adverse impact, for example, on how and what methods are used for the assessment and what conclusions are made based on them.

4.2.3 Data collection and analysis

Safety is an emergent phenomenon that results from complex sociotechnical interactions (e.g. Dekker, 2011; Hollnagel, 2014; Rasmussen, 1997). All organizational functions and activities (in accordance with a graded approach) either directly or indirectly influence nuclear safety. This means that ideally, the **scope** of the safety culture assessment process should include the whole nuclear organization, both divisionally (internal organizational units, functions and divisions; as well as the supply chain), hierarchically (from top management to operative staff), and culturally (structures, behaviour, attitudes, values, norms, basic assumptions) (cf. IAEA, 2016b; Oedewald et al., 2011). At lower process maturity levels, the safety culture assessment either explicitly excludes certain aspects of the organization or its culture, or implicitly due to methodological limitations. It is worth noting that the scope in cultural terms should be in line with the safety culture assessment process and its capability. For instance, a process that is implemented in a lightweight manner (e.g. using only surveys) and that has not been active for a long period of time, is not likely to have the capability to reveal deep cultural phenomena, and trying to make conclusions of deep cultural phenomena may risk unreliable or invalid results (Viitanen et al., 2022).

The safety culture can be assessed at different frequencies, with some assessment types being continuous and others project based. In our empirical study of safety culture expert's work in the Finnish

nuclear industry, we observed that the following **safety culture assessment types** were used (Viitanen et al., 2022):

- **Fast-cycle monitoring**: performed continuously, e.g., operational events and screening meetings, safety concern review meetings, safety walks, tours, and inspections, KPIs.
- **Annual summarization**: performed annually, e.g., annual summary report on safety culture status or safety culture chapter in a management review.
- **Slow-cycle assessments**: performed every 2–4 years, e.g., safety culture self-assessments or safety culture questionnaires.
- **On-demand or opportunity-based assessments**: not performed periodically, e.g., independent safety culture assessments or investigations.

Each safety culture assessment type serves a different **purpose** and contributes to the overall aim of gaining awareness of the status of the safety culture in the organization. For example: fast-cycle monitoring helps identify grass-roots manifestations of the safety culture and issues that require a quick response; annual summaries provide an overview of the safety culture status for the management based on existing assessments and data, as well as follow-up of safety culture improvement activities; slow-cycle assessments provide insights into deeper cultural phenomena by applying special data collection and analysis methods; and on-demand or opportunity-based assessments enable deeper analysis of specific or acute safety culture issues, or may utilize findings from safety culture-related assessments conducted by third parties (Viitanen et al., 2022). These four types of assessments complement each other and over time they help build a comprehensive view of safety culture status. At lower maturity levels, safety culture assessments might only be seen as the implementation of a safety culture self-assessment project or a safety climate questionnaire. The risk of such an approach is that the organization does not fully utilize the available information for safety culture assessment, which ultimately may result in a limited view of culture.

Data collection methods should be diverse to achieve sufficient reliability. Data collection methods should apply both quantitative and qualitative methods, and interactive methods to complement non-interactive methods (e.g. Oedewald et al., 2011; Schöbel et al., 2017). Typically, five data collection methods are referred to in industry recommendations: interviews, focus groups, surveys, document reviews and observations (IAEA, 2002, 2009, 2016b). These methods should be designed and used in a way that enables revealing cultural phenomena. At lower process maturity levels, no safety culture specific data collection methods are used, or only single (safety culture-specific) methods are used. Typically, if an organization only uses a single method for its safety culture assessment, it is a safety climate questionnaire. The risk of low maturity levels is that an unreliable or inadequate overview may be obtained of the safety culture due to the lack of triangulation.

Due to the qualitative and intangible nature of safety culture assessments, it is important that those responsible for their implementation have **awareness of the constraints** of the assessments done as part of the process. This includes awareness of the reliability, quality and strength of the data, analysis results and conclusions (Oedewald et al., 2011; Viitanen et al., 2022). At lower process maturity levels, there is a lack of a questioning attitude and a non-critical approach concerning the assessments. This may result in, for example, accepting results without corroborating data or meaningful justification as facts.

The safety culture assessment process should result in the **identification of cultural strengths and weaknesses** (IAEA, 2016b). This means that the results should capture, for example, how observed culture deviates from ideal culture (see descriptive and normative approaches described in IAEA, 2016b), and/or the identification of deeper levels of culture such as values, norms, or basic assumptions and how they deviate from the organization's core task demands (Reiman & Oedewald, 2007). At lower process maturity levels, the assessment process might only result in descriptions of raw data, or analysis results that do not relate to the status of the safety culture.

4.2.4 Organizational development

Appropriate **communication and reporting** are important success factors in ensuring that the safety culture assessment process actually results in improvement, and to ensure management support and acceptance among the staff (IAEA, 2016b; Oedewald et al., 2011; Viitanen et al., 2022). It is important to identify the orientation of the management and the organization to establish the right level and style of communication. One which is not too complex or not too simple for the audience in question (Viitanen et al., 2022). At lower process maturity levels, findings are either not reported or reviewed at all, or only communicated to the immediate customer (e.g. top management or oversight function), rather than the overall organization. This risks the safety culture assessment process becoming detached from the organizational reality and daily work—at levels where the safety culture ultimately manifests.

The safety culture assessment process should be closely connected to organizational development (IAEA, 2016b; Viitanen et al., 2022). This includes both **specification and implementation of improvement and/or corrective actions**. The integration of overall organizational development and establishing how the safety culture assessment process is positioned within this is essential to ensure that safety culture activities do not become detached (perceived as add-on) or overlap with other development programmes or activities (Viitanen et al., 2022). For example, in Finnish power companies, various multidisciplinary groups or task forces are used to coordinate these efforts (Viitanen et al., 2022). At lower process maturity levels, improvement and/or corrective actions are not specified or implemented at all, or they are treated as a specific task for safety culture experts, rather than a task for the line organization whose implementation the safety culture experts facilitate or support.

Ultimately, the safety culture assessment process should be able to drive the organizational development in a way that results in **impacts on the safety culture** and its constituent elements (structures, behaviour, attitudes, values, norms, and basic assumptions). At lower process maturity levels, even if the safety culture assessment process is implemented, the same (cultural) problems still reoccur, and positive development is not evident, suggesting that the process is not effective. This can be due to not achieving one or many of the best practices described in this chapter.

4.3 Subprocess: training on safety culture

Training on safety culture is one of the most common specific activities that aims to improve safety culture. It is also required or expected in nuclear industry standards or regulations. The IAEA sets many recommendations related to training on safety culture issues, but most of the recommendations do not explicitly state that one should carry out safety culture training. Instead, the IAEA recommends creating a common understanding about safety culture concept[17,18], understanding of the safety significance of own

[17] IAEA GS-G-3.1 4.12. To achieve quality and to maintain safety, individuals should be capable of performing their assigned tasks. Training should emphasize the correct performance of work and should provide an understanding of: — The principles of the management system and the relevant management processes and procedures; — Accountabilities and responsibilities in the organization; — Individual and organizational values and behavioural standards; — The relationship between the management system and the development of a strong safety culture; — Key characteristics and attributes of safety culture; — The importance of involving interested parties and how to best involve them. (IAEA, 2006a)

[18] IAEA GS-G-3.5 2.19. A common understanding of what is meant by safety culture should be established. Training is one of the means by which individuals can achieve this understanding. Such training should not be considered a 'one-off' event but should be provided regularly to all individuals, including senior management. (IAEA, 2009)

tasks[19], and the importance of safety[20]. Finnish regulations also contain requirements for training on safety culture. The licensee's own personnel[21] and suppliers[22] are distinguished in the regulatory framework. It is implied that these groups have slightly different training objectives: own personnel are expected to understand the features of good safety culture, while suppliers are expected to understand the requirements and the safety-significance of their own work and have the skills needed to deal with deviations.

Training on safety culture can be organized in many ways. A common practice is to arrange classroom training, but complementary activities such as theme days, events, mock-up sessions, or one-off lectures can also be used (Viitanen et al., 2022). In addition, due to its cross-cutting nature, safety culture topics can be integrated into almost any training that concerns human work or human interaction with technology.

In nuclear industry practice, the content of safety culture training has become somewhat established. Typical contents of safety culture training include at least the following elements (Viitanen et al., 2022):

- **Terminology and background**: descriptions of legislative, regulatory and requirements and industry standards, definitions of safety culture, theoretical justification.
- **Experiences**: descriptions of failures, accidents, successes, near-misses, or operating experiences, and how safety culture was a contributing factor.
- **Expectations concerning safety culture**: descriptions of positive (and negative) characteristics safety culture, often in relation to one of the industry standards safety culture models or in relation to company's own safety culture principles.
- **Descriptions of safety culture processes and practices**: how safety-culture assessments are conducted, and who are safety culture experts and what they do.
- **Facilitation**: discussion on a safety culture topic, its safety significance, or how safety culture manifests in the personnel's own work.
- **Concrete actions**: recommendations on how to act in accordance with a good safety culture, or how to promote it in daily work, including descriptions of general principles such as the STAR principle, how and when to use the reporting system, or when to stop work.

Safety culture training involves elements that are **motivational, informational, and practical**. Motivational elements aim to build a safety-conscious mindset (e.g. through descriptions of case studies or experiences). Informational elements aim to provide organizational members with the information about what is meant by safety culture and what type of mindset and behaviour the company and the industry expects. The practical elements aim to provide the participants with behavioural guidance on what to do

[19] IAEA GSR Part 2 4.26. All individuals in the organization shall be trained in the relevant requirements of the management system. Such training shall be conducted to ensure that individuals are knowledgeable of the relevance and the importance of their activities and of how their activities contribute to ensuring safety in the achievement of the organization's goals. (IAEA, 2016a)

[20] IAEA GS-G-3.1 4.8. In planning for education and training needs, account should be taken of changes caused by the nature of the organization's processes, the competence levels of individuals and the culture of the organization. The objective should be to provide individuals with knowledge and skills that, together with attitudes and experience, will enhance their competence. In education and training, emphasis should be placed on the importance of safety, of meeting requirements and of the needs and expectations of interested parties. Training should also cover awareness of the consequences for the organization and individuals of failing to meet the requirements. (IAEA, 2006a)

[21] YVL A.3 311. The personnel shall be provided training to support the understanding of the features of good safety culture. [2019-03-15] (STUK, 2019)

[22] YVL A.3 311a. Training shall be provided for the personnel of safety-significant suppliers in order to support a person's awareness and understanding of the nuclear and radiation safety requirements of his or her work and their safety significance and provide the skills to act in the right manner when detecting a deviation. [2019-03-15] (STUK, 2019)

in their daily work. When assessing the effectiveness of the safety culture training subprocess, the extent to which these elements are achieved should be considered.

In a safety culture improvement context, training can also have other purposes than unidirectionally influencing the learners. Participatory methods such as group discussions and interactive sessions can also provide information about the **state of the safety culture** in the company. For example, group discussions structured around reflecting on the safety-significance of the participants' own work may reveal structures, practices, or cultural characteristics that either hinder or facilitate nuclear safety. Such insights provide useful information for safety culture assessment which can be utilized as part of continuous improvement and learning.

The uniformity and practical relevance of safety culture promotion are important in terms of creating an effective safety culture training process (Viitanen et al., 2022). If the messages from different sources or from different levels of the organization contradict each other, they may cancel each other out or confuse the organizational members. This may be the case if there are multiple competing or overlapping safety campaigns, or if the ideals presented in safety culture training events do not align with the realities of daily work. In the latter case, safety culture training may be perceived as detached from the staff's own work and not considered relevant. Therefore, one aspect of assessing the effectiveness of safety culture training involves positioning the training in the overall framework of safety communication of the organization, including other safety (culture) promotion activities, as well as the leadership activities of managers and supervisors.

Research indicates that various safety-related training events or training programmes can have an **impact on the safety culture and on safety outcomes**. For example, a safety culture training programme (Xie et al., 2017), training on human factors training (Ansari et al., 2020), teamwork training (Alsabri et al., 2022; Jones et al., 2013; Picard et al., 2022; Schmidt et al., 2021), and Crew Resource Management (Man et al., 2020; Marquardt et al., 2021) have been reported to have positive impacts on safety culture. In some research papers, a positive impact on safety outcomes has been reported as well. Most of the research on this topic seems to have originated from healthcare. In healthcare, a common study design for evaluating the training impact on the safety culture is to use a before-after design with a questionnaire (Alsabri et al., 2022).

In nuclear power companies, a commonly used method for assessing the effectiveness of safety culture training (and other training as well) are **feedback forms** (Viitanen et al., 2022). However, feedback forms are largely perceived as useful for gaining information on practical issues (e.g. perceived usefulness, quality of materials, etc.), rather than evaluating the training impact on culture or nuclear safety. Some companies also conduct before and after tests assessing the change in knowledge.

Kirkpatrick's model (Kirkpatrick, 1994) is a simple, widely applied model and analysis tool for evaluating the effectiveness of training programmes in organizations. It provides a vocabulary and taxonomy for training evaluation criteria (Alliger & Janak, 1989). The model consists of four subsequent, causally linked levels: reaction, learning, behaviour, and results (Kirkpatrick & Kirkpatrick, 2005). Reaction is the initial level and indicates whether the participants feel interested in the training session or perceive it as relevant. This level also indicates the "customer satisfaction" of the participants. The learning level refers to whether the content that has been taught has been understood, whether new skills have been developed or acquired, or whether attitudes have changed. The behaviour level refers to whether on-the-job behaviour has changed after the training programme. The results level refers to whether positive organizational outcomes have been achieved. The first two levels (reaction and learning) can be considered to be within the control of the trainers, while the latter two levels (behaviour and results) can only be indirectly influenced by trainers as they occur outside of the actual training session (Kirkpatrick & Kirkpatrick, 2005).

The **existing safety culture and leadership** affect what the organizational members consider valuable, relevant, and useful. Consequently, this may influence the outcomes of safety culture training at each of the four levels. For example, from the perspective of the "reaction" level, an organizational culture that does not consider non-technical issues to be relevant to nuclear safety may reduce training participants'

motivation and interest. An organizational culture that discourages development or learning may negatively impact the “learning” level. At the “behaviour” level, the training content gets integrated into daily actions and decisions. If the surrounding organizational culture is at odds with what the safety culture training promotes, the training might not have any influence over things in practice. Similarly, as the organizational results (e.g. safety and quality outcomes) are created by complex sociotechnical interactions, this means that the “results” level is clouded by a multitude of factors other than the safety culture training itself. Overall, this means that a part of creating effective safety culture training programmes, is also facilitating a “learning culture” (Kirkpatrick & Kirkpatrick, 2005; Reason, 1997) by means of leadership and safety culture promotion aligned with the same ideals that are taught in the safety culture training.

Indeed, the purpose of safety culture training is to influence the existing culture. This means that an effective safety culture training programme can create a **feedback loop** back to the existing organizational culture. As its implementation proceeds and the organizational members are influenced by its content, the organizational culture should ideally change to be more receptive to the safety culture training. This further suggests that effective safety culture training should be continuously revised to best meet what the organization (and its culture) is able and expects to receive.

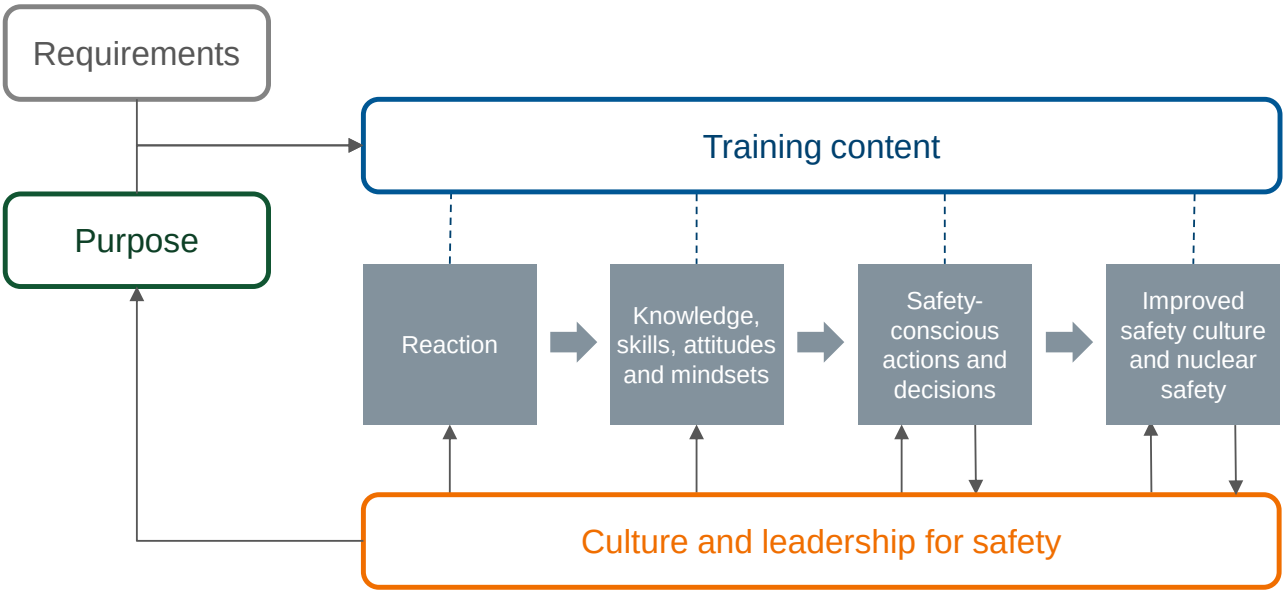

Figure 4. Model describing the taxonomy for assessing the effectiveness of safety culture training (grey boxes) along with influencing factors (white boxes)

Figure 4 summarizes the four-level taxonomy for assessing the effectiveness of safety culture training and how the essential influencing factors (requirements, existing culture and leadership, purpose definition and training content) are connected to four levels. In Attachment D, we propose a tool for assessing the effectiveness of safety culture training in the nuclear industry. The approach details how each of the four levels of Kirkpatrick’s model may manifest in the context of safety culture training and what questions could be reviewed as part of effectiveness assessment of safety culture training. The approach was developed by adapting the elements of the Kirkpatrick model, and integrating insights from a cursory literature review on safety (culture) training, and empirical findings concerning safety culture expert work (Viitanen et al., 2022) in a researcher workshop.

5. Conclusions

5.1 Summary

In this report we examined the effectiveness assessment of safety culture improvement from a systemic, multilevel perspective. Two complementary approaches were identified. A phenomenon-based approach viewed the improvement of safety culture from the perspective of cultural dimensions or manifestations, and how they interrelate with each other and with other sociotechnical elements of the organization. A process-based approach viewed the improvement of safety culture as an organizational function that involves a process dedicated to safety culture improvement, as well as specific activities that aim to improve safety culture.

Four practical tools were developed to illustrate the practical application of these two approaches. Two tools illustrated the phenomenon-based approach and aimed to model specific safety culture attributes—raising concerns, and procedure compliance. The other two tools illustrated the process-based approach and provided means to evaluate the maturity of the safety culture assessment process and the effectiveness of safety culture training. Overall, these two approaches and the four practical tools along with the theoretical and empirical justification behind them serve as a starting point for developing a comprehensive toolbox for assessing the effectiveness of safety culture improvement.

5.2 Practical implications

The proposed effectiveness assessment tools (Attachments A, B, C, and D) were developed to be readily applicable for nuclear industry end-users, including managers and supervisors, as well as experts responsible for organizational development, safety culture, and leadership. The tools can be utilized as such in nuclear licensee organizations as part of continual improvement of their safety culture, and by nuclear regulators as part of their oversight activities. With appropriate contextual considerations, the tools may also be applicable outside the nuclear industry.

During the practical application of the effectiveness assessment tools, a graded approach may be desirable. For example, Attachments A and B present practical assessment tools resulting from modelling individual safety culture attributes and these two tools are applicable as such. However, there are a multitude of other attributes identified in industry standard safety culture models that are also important for nuclear safety. Modelling all attributes may be an excessively resource-demanding effort. The organizations and experts aiming to use the tools or create their own variations (of different attributes) should therefore make informed decisions on which attribute to choose for modelling. Strengths, weaknesses, threats, or opportunities identified as part of the safety culture assessment process may support this decision-making. Similarly, the application of the maturity evaluation tool concerning the safety culture assessment process would benefit from a strategic approach from the company, including what maturity level profile the company aims to achieve, the advantages and disadvantages of this choice, and the long-term roadmap to achieve it. For example, companies just introducing their safety culture assessment process might benefit from gradual introduction of some elements to avoid becoming overwhelmed with the implementation.

5.3 Limitations and future research needs

In this report we attempted to decompose the complex safety culture phenomena into more manageable descriptions of factors influencing their manifestation. This served as a starting point for co-creation workshops and for creating effectiveness assessment tools. However, the approaches described in the report still present safety culture attributes and improvement methods as relatively separate from one another. In terms of systems thinking, this does not fully represent the reality of organizational development

where system elements are likely to be much more interconnected. A future scientific research need is therefore the further application of a systemic approach and sociotechnical systems thinking to link the different (cultural) phenomena and organizational development activities holistically.

The proposed effectiveness assessment tools (Attachments A, B, C, and D) were developed based on empirical case studies, literature reviews, co-creation workshops with nuclear industry practitioners and the expert judgement of the researchers. However, the final versions of the tools have not yet been tested in a practical context. A future practical research need is therefore to test the methods for practical effectiveness assessment purposes. Topics to be reviewed as part of this testing include reviewing the quality and clarity of the proposed assessment processes, validity and comprehensiveness of the topics covered, and the ability of the tools to measure or provide novel insights regarding the effectiveness of safety culture improvement.

The report is based mainly on data collection and analysis made from Finnish perspective: the case studies and co-creation workshops that formed the empirical part of the study were conducted with Finnish nuclear power companies. Even though the studied topics are quite universal in nature, there may be factors that limit the generalizability or applicability of the findings and recommendations for nuclear organizations that operate in significantly different environments, or that have core tasks which significantly differ from traditional nuclear power plants in the operating phase. For example, country-specific limitations may emerge from different national cultures, nuclear industry practices, or national legislation and regulatory frameworks. A future research need thus includes international application and validation of the recommendations and tools proposed in the report.

References

Alliger, G., & Janak, E. (1989). Kirkpatrick's Levels of Training Criteria: Thirty Years Later. Personnel Psychology 42: 331–342. http://doi.org/10.1111/j.1744-6570.1989.tb00661.x

Alsabri, M., Boudi, Z., Lauque, D., Dias, R. D., Whelan, J. S., Östlundh, L., … Bellou, A. (2022). Impact of Teamwork and Communication Training Interventions on Safety Culture and Patient Safety in Emergency Departments: A Systematic Review. Journal of Patient Safety 18: E351–E361. http://doi.org/10.1097/PTS.0000000000000782

Ansari, S. P., Rayfield, M. E., Wallis, V. A., Jardine, J. E., Morris, E. P., & Prosser-Snelling, E. (2020). A Safety Evaluation of the Impact of Maternity-Orientated Human Factors Training on Safety Culture in a Tertiary Maternity Unit. Journal of Patient Safety 16: E359–E366. http://doi.org/10.1097/PTS.0000000000000609

Antonsen, S. (2009). Safety culture: theory, method and improvement. Farnham, England: Ashgate.

Aranzamendez, G., James, D., & Toms, R. (2015). Finding Antecedents of Psychological Safety: A Step Toward Quality Improvement. Nursing Forum 50: 171–178. http://doi.org/10.1111/nuf.12084

Bensonch, C., Argyropoulos, C. D., Dimopoulos, C., Varianou Mikellidou, C., & Boustras, G. (2022). Analysis of safety climate factors and safety compliance relationships in the oil and gas industry. Safety Science 151: 105744. http://doi.org/10.1016/j.ssci.2022.105744

Cooper, M. D. (1998). Improving Safety Culture: A Practical Guide. Chichester: John Wiley & Sons.

de Ruijter, A., & Guldenmund, F. (2016). The bowtie method: A review. Safety Science 88: 211–218. http://doi.org/10.1016/j.ssci.2016.03.001

Dekker, S. (2003). Failure to adapt or adaptations that fail: contrasting models on procedures and safety. Applied Ergonomics 34: 233–238. http://doi.org/10.1016/S0003-6870(03)00031-0

Dekker, S. (2006). Resilience engineering: Chronicling the emergence of confused consensus. In E. Hollnagel, D. D. Woods, & N. Leveson (Eds.), Resilience engineering: Concepts and precepts. UK: Ashgate.

Dekker, S. (2011). Drift into failure: from hunting broken components to understanding complex systems. Farnham; Burlington, VT: Ashgate.

DoE. (2009). Human Performance Improvement Handbook Volume 2, Human Performance Tools for Individuals, Work Teams, and Management (No. DOE-HDBK-1028-2009). Washington, D.C.: U.S. Department of Energy.

Edmondson, A. (1999). Psychological Safety and Learning Behavior in Work Teams. Administrative Science Quarterly 44: 350–383. http://doi.org/10.2307/2666999

Frazier, M. L., Fainshmidt, S., Klinger, R. L., Pezeshkan, A., & Vracheva, V. (2017). Psychological Safety: A Meta-Analytic Review and Extension. Personnel Psychology 70: 113–165. http://doi.org/10.1111/peps.12183

Goncalves Filho, A. P., & Waterson, P. (2018). Maturity models and safety culture: A critical review. Safety Science 105: 192–211. http://doi.org/10.1016/j.ssci.2018.02.017

Guldenmund, F. W. (2000). The nature of safety culture: a review of theory and research. Safety Science 34: 215–257. http://doi.org/10.1016/S0925-7535(00)00014-X

Guldenmund, F. W. (2010). (Mis)understanding Safety Culture and Its Relationship to Safety Management: Perspective. Risk Analysis 30: 1466–1480. http://doi.org/10.1111/j.1539-6924.2010.01452.x

Hale, A. R., & Borys, D. (2013). Working to rule, or working safely? Part 1: A state of the art review. Safety Science 55: 207–221. http://doi.org/10.1016/j.ssci.2012.05.011

Hale, A. R., Guldenmund, F. W., van Loenhout, P. L. C. H., & Oh, J. I. H. (2010). Evaluating safety management and culture interventions to improve safety: Effective intervention strategies. Safety Science 48: 1026–1035. http://doi.org/10.1016/j.ssci.2009.05.006

Hollnagel, E. (2014). Safety-I and Safety–II: The Past and Future of Safety Management. Farnham, Surrey: Ashgate Publishing, Ltd.

Hollnagel, E. (2015). Why is Work-as-Imagined Different from Work-as-Done? In R. L. Wears, E. Hollnagel, & J. Braithwaite (Eds.), Resilient Health Care, Volume 2 The Resilience of Everyday Clinical Work. pp. 249–264. Farnham, Surrey, UK: Ashgate Publishing, Ltd.

Hu, X., Griffin, M. A., & Bertuleit, M. (2016). Modelling antecedents of safety compliance: Incorporating theory from the technological acceptance model. Safety Science 87: 292–298. http://doi.org/10.1016/j.ssci.2015.12.018

Hu, X., Griffin, M., Yeo, G., Kanse, L., Hodkiewicz, M., & Parkes, K. (2018). A new look at compliance with work procedures: An engagement perspective. Safety Science 105: 46–54. http://doi.org/10.1016/j.ssci.2018.01.019

Hu, X., Yeo, G., & Griffin, M. (2020). More to safety compliance than meets the eye: Differentiating deep compliance from surface compliance. Safety Science 130: 104852. http://doi.org/10.1016/j.ssci.2020.104852

IAEA. (2002). Self-assessment of safety culture in nuclear installations: highlights and good practices. Vienna, Austria: International Atomic Energy Agency.

IAEA. (2006a). Application of the Management System for Facilities and Activities (Safety Guide No. GS-G-3.1). Vienna, Austria: International Atomic Energy Agency.

IAEA. (2006b). Fundamental safety principles (Safety Fundamentals No. SF-1). Vienna, Austria: International Atomic Energy Agency.

IAEA. (2009). The Management System for Nuclear Installations (Safety Guide No. GS-G-3.5). Vienna, Austria: International Atomic Energy Agency.

IAEA. (2016a). Leadership and Management for Safety (No. GSR Part 2). Vienna, Austria: International Atomic Energy Agency.

IAEA. (2016b). Performing Safety Culture Self-Assessments (No. Safety Reports Series No. 83). Vienna, Austria: International Atomic Energy Agency.

IAEA. (2018). IAEA Safety Glossary. Terminology Used in Nuclear Safety and Radiation Protection. 2018 Edition. Vienna, Austria: International Atomic Energy Agency.

IAEA. (2020). A Harmonized Safety Culture Model (IAEA Working Document). Retrieved from https://www.iaea.org/sites/default/files/20/05/harmonization_05_05_2020-final_002.pdf

INPO. (2006). Human Performance Reference Manual (No. 06–003). Institute of Nuclear Power Operations.

ISO. (2015a). ISO 9000: 2015 - Quality Management Systems. Fundamentals and Vocabulary. International Organization for Standardization.

ISO. (2015b). ISO 9001: 2015 - Quality Management Systems - Requirements. International Organization for Standardization.

Jones, K. J., Skinner, A. M., High, R., & Reiter-Palmon, R. (2013). A theory-driven, longitudinal evaluation of the impact of team training on safety culture in 24 hospitals. BMJ Quality and Safety 22: 394–404. http://doi.org/10.1136/bmjqs-2012-000939

Kanse, L., Parkes, K., Hodkiewicz, M., Hu, X., & Griffin, M. (2018). Are you sure you want me to follow this? A study of procedure management, user perceptions and compliance behaviour. Safety Science 101: 19–32. http://doi.org/10.1016/j.ssci.2017.08.003

Kirkpatrick, D. L. (1994). Evaluating Training Programs: The Four Levels. San Francisco : Emeryville, CA: McGraw-Hill Ryerson.

Kirkpatrick, D. L., & Kirkpatrick, J. D. (2005). Transferring learning to behavior: using the four levels to improve performance. 1st ed. San Francisco, CA: Berrett-Koehler Publishers.

Leveson, N. (2011). Engineering a safer world: systems thinking applied to safety. Cambridge, Mass: MIT Press.

Man, A. P. N., Lam, C. K. M., Cheng, B. C. P., Tang, K.-S., & Tang, P.-F. (2020). Impact of Locally Adopted Simulation-Based Crew Resource Management Training on Patient Safety Culture: Comparison Between Operating Room Personnel and General Health Care Populations Pre and Post Course. American Journal of Medical Quality 35: 79–88. http://doi.org/10.1177/1062860618824863

Marquardt, N., Hoebel, M., & Lud, D. (2021). Safety culture transformation—The impact of training on explicit and implicit safety attitudes. Human Factors and Ergonomics In Manufacturing 31: 191–207. http://doi.org/10.1002/hfm.20879

Martowirono, K., Jansma, J. D., Luijk, S. J. van, Wagner, C., & Bijnen, A. B. (2012). Possible solutions for barriers in incident reporting by residents. Journal of Evaluation in Clinical Practice 18: 76–81. http://doi.org/10.1111/j.1365-2753.2010.01544.x

Mengolini, A., & Debarberis, L. (2007). Safety culture enhancement through the implementation of IAEA guidelines. Reliability Engineering & System Safety 92: 520–529. http://doi.org/10.1016/j.ress.2006.01.003

Newman, A., Donohue, R., & Eva, N. (2017). Psychological safety: A systematic review of the literature. Human Resource Management Review 27: 521–535. http://doi.org/10.1016/j.hrmr.2017.01.001

Oedewald, P., Pietikäinen, E., & Reiman, T. (2011). A Guidebook for Evaluating Organizations in the Nuclear Industry – an example of safety culture evaluation (Research No. 2011:20). Stockholm: Stralsakerhetsmyndigheten. Retrieved from http://inis.iaea.org/search/search.aspx?orig_q=RN:43113518

Paulk, M. C., Curtis, B., Chrissis, M. B., & Weber, C. V. (1993). Capability Maturity Model for Software, Version 1.1. Fort Belvoir, VA: Defense Technical Information Center. Retrieved from http://www.dtic.mil/docs/citations/ADA263403

Picard, J., Evain, J.-N., Douron, C., Maussion, É., Stihle, X., Manhes, P., … Albaladejo, P. (2022). Impact of a large interprofessional simulation-based training course on communication, teamwork, and safety culture in the operating theatre: A mixed-methods interventional study. Anaesthesia Critical Care & Pain Medicine 41: 100991. http://doi.org/10.1016/j.accpm.2021.100991

Rasmussen, J. (1997). Risk management in a dynamic society: a modelling problem. Safety Science 27: 183–213. http://doi.org/10.1016/S0925-7535(97)00052-0

Rasmussen, J., & Svedung, I. (2000). Proactive risk management in a dynamic society. Karlstad, Sweden: Swedish Rescue Services A.

Reason, J. (1997). Managing the Risks of Organizational Accidents. 1 edition. Aldershot, Hants, England; Brookfield, Vt., USA: Ashgate.

Reiman, T., & Oedewald, P. (2002). Contextual assessment of organisational culture-methodological development in two case studies. Retrieved from http://www.vtt.fi/inf/pdf/tiedotteet/2002/T2164.pdf

Reiman, T., & Oedewald, P. (2006). Assessing the maintenance unit of a nuclear power plant – identifying the cultural conceptions concerning the maintenance work and the maintenance organization. Safety Science 44: 821–850. http://doi.org/10.1016/j.ssci.2006.05.004

Reiman, T., & Oedewald, P. (2007). Assessment of complex sociotechnical systems – Theoretical issues concerning the use of organizational culture and organizational core task concepts. Safety Science 45: 745–768. http://doi.org/10.1016/j.ssci.2006.07.010

Reiman, T., & Rollenhagen, C. (2014). Does the concept of safety culture help or hinder systems thinking in safety? Accident Analysis & Prevention 68: 5–15. http://doi.org/10.1016/j.aap.2013.10.033

Reiman, T., & Rollenhagen, C. (2018). Safety culture. In N. Moller, S. O. Hansson, J.-E. Holmberg, & C. Rollenhagen (Eds.), Handbook of Safety Principles. pp. 647–676. Hoboken: John Wiley & Sons.

Salmon, P. M., Hulme, A., Walker, G. H., Waterson, P., Berber, E., & Stanton, N. A. (2020). The big picture on accident causation: A review, synthesis and meta-analysis of AcciMap studies. Safety Science 126: 104650. http://doi.org/10.1016/j.ssci.2020.104650

Schein, E. H. (1985). Organizational culture and leadership. San Francisco: Jossey-Bass Publishers.

Schein, E. H. (2010). Organizational Culture and Leadership. San Francisco, CA: John Wiley & Sons.

Schmidt, J., Gambashidze, N., Manser, T., Güß, T., Klatthaar, M., Neugebauer, F., & Hammer, A. (2021). Does interprofessional team-training affect nurses' and physicians' perceptions of safety culture and communication practices? Results of a pre-post survey study. BMC Health Services Research 21. http://doi.org/10.1186/s12913-021-06137-5

Schöbel, M., Klostermann, A., Lassalle, R., Beck, J., & Manzey, D. (2017). Digging deeper! Insights from a multi-method assessment of safety culture in nuclear power plants based on Schein's culture model. Safety Science 95: 38–49. http://doi.org/10.1016/j.ssci.2017.01.012

Schwappach, D. L., & Gehring, K. (2014). Trade-offs between voice and silence: a qualitative exploration of oncology staff's decisions to speak up about safety concerns. BMC Health Services Research 14: 303. http://doi.org/10.1186/1472-6963-14-303

Shorrock, S. (2021, April 2). Systems Thinking: Influence Diagrams (HUM-SYS-V-IDA) [Video]. Retrieved December 20, 2022, from https://www.youtube.com/watch?v=QwaFiZPhc6s

STUK. (2018). Radiation and Nuclear Safety Authority Regulation on the Safety of a Nuclear Power Plant. Helsinki, Finland: Säteilyturvakeskus.

STUK. (2019). Guide YVL A.3 Leadership and management for safety. Helsinki, Finland: Säteilyturvakeskus.

Viitanen, K., Airola, M., & Gotcheva, N. (2022). Effective Improvement of Leadership and Safety Culture – Intermediate Report. VTT Technical Research Centre of Finland.

Viitanen, K., Gotcheva, N., & Rollenhagen, C. (2017). Safety Culture Assurance and Improvement Methods in Complex Projects – Intermediate Report from the NKS-R SC_AIM (No. NKS-381). NKS. Retrieved from http://www.nks.org/en/nks_reports/view_document.htm?id=111010214063661

Viitanen, K., Gotcheva, N., Rollenhagen, C., & Reiman, T. (2018). Safety Culture Assurance and Improvement Methods in Complex Projects – Final Report from the NKS-R SC_AIM (No. NKS-405). NKS. Retrieved from http://www.nks.org/en/nks_reports/view_document.htm?id=111010214694225

Viitanen, K., Reiman, T., Rollenhagen, C., & Gotcheva, N. (2018). Mapping methodical change in safety culture. Presented at the Probabilistic Safety Assessment and Management conference, Los Angeles, USA. Retrieved from http://www.scopus.com/inward/record.url?scp=85063125721&partnerID=8YFLogxK

WANO. (2013). Traits of a Healthy Safety Culture (No. PL 2013-01). World Association of Nuclear Operators.

Weick, K. E. (1995). Sensemaking in Organizations. 1st edition. Thousand Oaks, Calif.: SAGE Publications, Inc.

WENRA. (2021). Safety Reference Levels for Existing Reactors 2020. Western European Nuclear Regulators Association.

Xie, J., Ding, S., Zhong, Z., Zeng, S., Qin, C., Yi, Q., … Zhou, J. (2017). A safety culture training program enhanced the perceptions of patient safety culture of nurse managers. Nurse Education in Practice 27: 128–133. http://doi.org/10.1016/j.nepr.2017.08.003

ATTACHMENT A. Practical tool for assessing raising concerns in NPPs

WHO: The tool can be used by managers and supervisors, as well as experts responsible for organizational development, safety culture, and leadership.

WHEN: The tool can be used in case there are signs of challenges in raising concerns, or if you want to assess its status.

WHAT FOR: The tool aims to make the cultural phenomena and their dynamics more visible. The tool can be used to facilitate constructive and comprehensive discussion to identify strengths and weaknesses, and effective ways to improve raising concerns.

HOW: **Preparation phase**

- **Go through the template tool (Figure A1) by yourself**. Estimate the current status of raising concerns, including its strengths and weaknesses. Collect data on indicators that can be used to verify its current status (e.g. safety culture assessments, other surveys and assessments, statistics on reporting system, etc.).
- Decide the relevant **participants** for discussion group.
- Pay attention to **diversity** of the discussion group: participants should be from several hierarchical levels and functions of the organization. If relevant, include other stakeholders such as suppliers.
- **Print** the tool (Figure A1), preferably at least A3 size.

HOW: **Group phase** (workshop)

- Go through enablers one by one. Facilitate the discussion on the **current status** of raising concerns via the enablers.
    - **Psychological safety**: a shared belief amongst employees that their colleagues will not reject them for saying what they think, respect each other's competence, are interested in each other as people, have positive intentions towards one another, are able engage in constructive conflict or confrontation, and feel trust between team members.
    - **Motivation**: the personnel want to raise concerns and feel that reporting will not lead to unwanted consequences.
    - **Understanding**: the personnel's knowledge about their work, its safety significance, work-related requirements and procedures as well as various reporting systems of the organization. Knowing what, when and how to report.
    - **Opportunity**: whether the personnel have time and facilities available for raising their concerns.
- Use the six types of **influencing factors** (contextual factors, individual perceptions, knowledge and understanding, organizational functions and process, values and attitudes, and organizational outcomes) in the above boxes to structure a discussion to see that all the relevant influencing factors are considered. If you come up with new factors, add them in empty boxes. Try to identify interconnections between the enablers and the influencing factors. Note that one influencing factor can have an impact on many enablers or other influencing factors.

- Write down the **strengths and areas of improvement** based on the discussion.
- **Discuss and prioritize improvement actions**. Consider their nuclear safety significance and relevance to the current situation at the plant (e.g. in relation to other development initiatives).

HOW: **Follow-up measures**

- **Prepare a summary** of the assessment results and identified development actions.
- **Communicate the summary to interested parties**, including top management, group phase participants, and other relevant stakeholders.
- **Assess the impact of development actions.** This can be done, for example, in safety culture assessments, reviewing the data collected, and/or by conducting this assessment again.

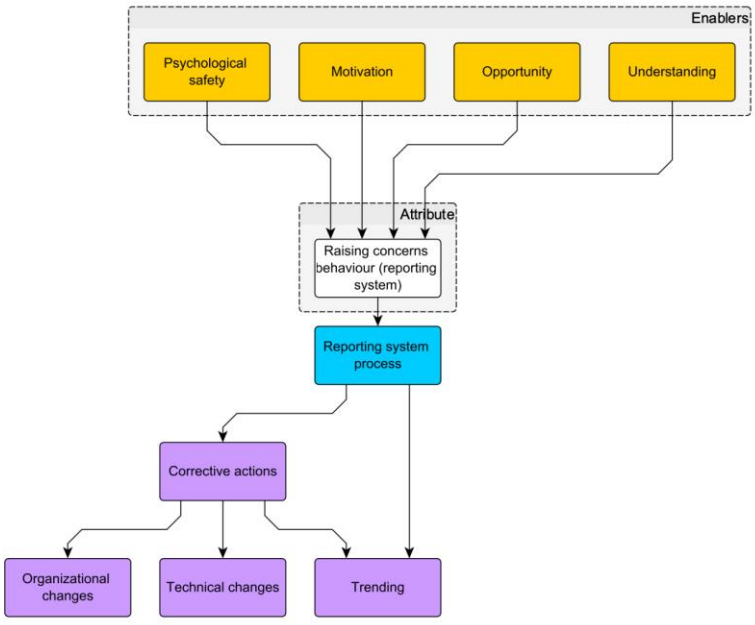

Figure A1. Visualization describing factors influencing raising (safety) concerns

ATTACHMENT B. Practical tool for assessing procedure compliance in NPPs

WHO: The tool can be used by managers and supervisors, as well as experts responsible for organizational development, safety culture, and leadership.

WHEN: The tool can be used in case there are signs of challenges concerning procedure compliance, or if you want to assess the status of this element.

WHAT FOR: The tool aims to make the cultural phenomena and their dynamics more visible. The tool can be used to facilitate constructive and comprehensive discussion to identify strengths and weaknesses, and effective ways to improve procedure compliance.

HOW: **Preparation phase**

- **Select** certain procedure or instruction.
- **Go through the template tool (Figure B1) by yourself**. Estimate the current status of compliance with the **selected procedure/instructions**, including the strengths and weaknesses. Collect data on indicators that can be used to verify the current status (e.g. safety culture assessments, other surveys and assessments, statistics on compliance, etc.). Summarize the data onto a slide to be used to facilitate discussion in a workshop.
- Decide the relevant **participants** for discussion group.
- Pay attention to the **diversity** of the discussion group: participants should be from several hierarchical levels and functions of the organization. If relevant, include other stakeholders such as suppliers.
- **Print** the tool (Figure B1), preferably at least A3 size.

HOW: **Group phase** – two parts (workshop)

First topic of the workshop: **What factors affect compliance with procedures?**

- Go through enablers one by one. Facilitate the discussion on **current status of a selected procedure** via the enablers. Use the collected data to facilitate the discussion.
    - Assess the **quality of the procedure**—how it is written, how does it relate to the real work, is it logical and at the right technical level, etc.? What affects the quality of the procedure? How can it be improved? How often is the procedure updated and how?
    - Discuss how the **users of the procedure perceive the procedures in general.** Are there signs of demotivation, heavy workloads, users not understanding the instructions etc.? Do users consider that there is enough training? What is the general feeling and attitude related to instructions and procedures?
    - Discuss the **organizational issues** related to procedures on a more general level. How is the work designed and planned? Is there enough time for supervision for newcomers? How are the users involved in the procedure writing etc.?
    - Discuss how the leaders and peer group **values and attitudes** affect compliance with procedures. How are the values and attitudes visible in practice? How can values and attitudes be addressed and improved?

- Use the four types of **influencing factors** (procedure attributes, individual perceptions and factors, organizational functions and processes, and values and attitudes) in the above boxes to structure a discussion to check that all the relevant influencing factors are considered. If you come up with new factors, add them to the empty boxes. Try to identify interconnections between the enablers and the influencing factors. Note that one influencing factor may have an impact on many enablers or other influencing factors.
- Write down the **strengths and areas for improvement** based on the discussion.
- **Discuss and prioritize improvement actions**. Consider their nuclear safety significance and relevance to the current situation at the plant (e.g. in relation to other development initiatives).

Second topic of the workshop: **Assessing procedure compliance and organizational response to it**

- Discuss the **outcomes** of the procedure compliance based on themes in the matrix (Figure B2).
    - Are the chosen procedures followed? How do you know if they are followed? How do you gather information about it?
    - If procedures are followed, do they support a safe way of working? How do you assess that?
    - If not, why not? In what ways does the procedure not support a safe way of working? How should the procedure be improved?
    - Is compliance with the procedure rewarded? Should it be rewarded?
    - What are the main reasons for violations of the procedure? How common are the violations? What constitutes a violation?
    - How are the violations addressed and discussed? How should they be addressed?
- **Summarize** the discussion findings and define the areas for improvement.

HOW: **Follow-up measures**

- **Prepare a summary** of the assessment results and identified development actions.
- **Communicate the summary to interested parties**, including top management, group phase participants, and other relevant stakeholders.
- **Assess the impact of development actions.** This can be done, for example, in safety culture assessments, by reviewing the data collected, and/or by conducting this assessment again.

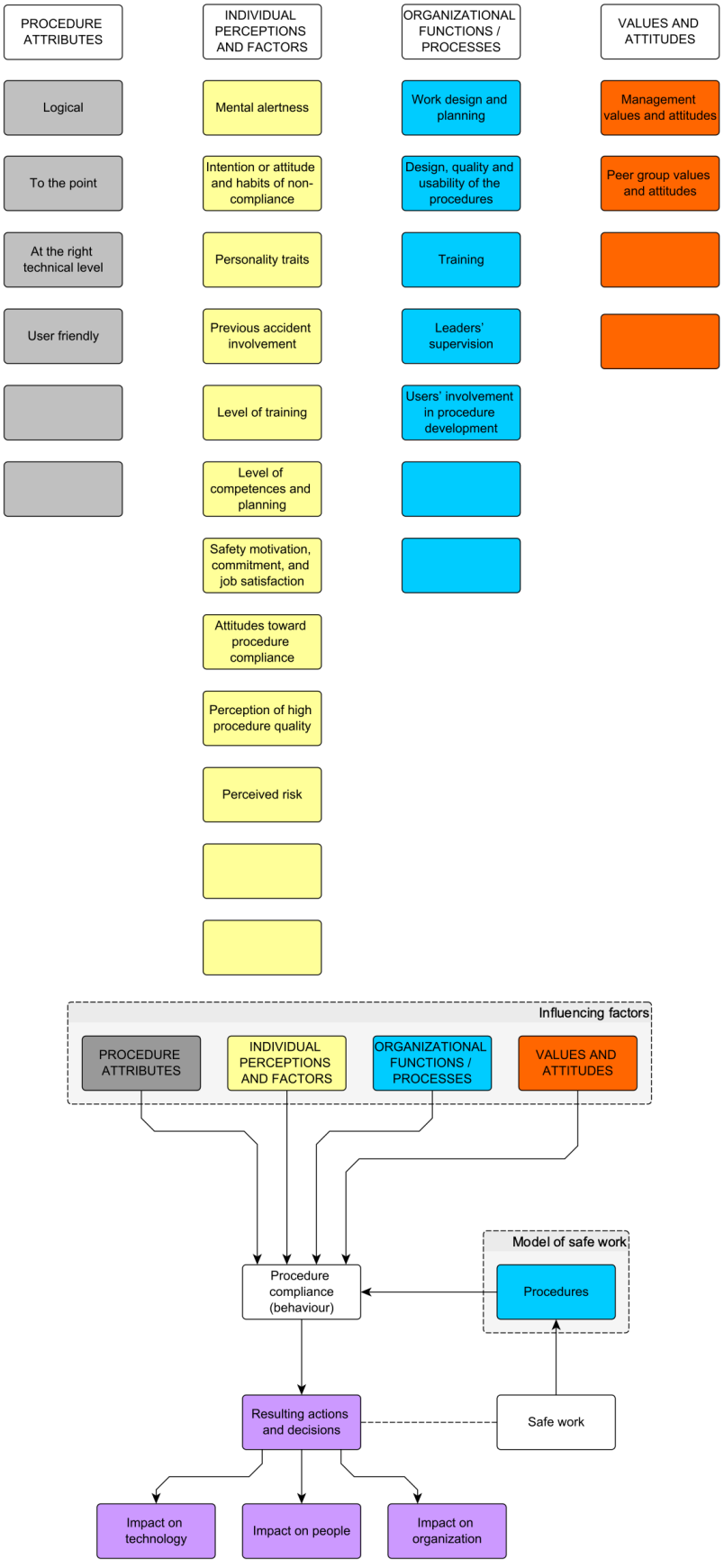

Figure B1. Visualization describing factors influencing procedure compliance

	Procedures support safe and effective work	
	Yes	**No**
Compliance	Ideal state	”Blind compliance” Lack of questioning attitude
Non-compliance	Errors Reckless violations	Gap between work practices and procedures System-induced violations Complacency with low quality of procedures

Figure B2. A matrix describing how the quality of procedures and procedure compliance are linked with examples of possible discussion topics.

ATTACHMENT C. Maturity evaluation tool for safety culture assessment process

WHO: The tool can be applied by managers or experts in licensee organizations. In addition, the tool may be useful for regulatory or supply chain oversight.

WHEN: The tool can be used as part of continuous improvement of safety culture assessment process, or when evaluating the maturity of safety culture assessment processes of third parties.

WHAT FOR: To evaluate the maturity of a safety culture assessment process.

HOW:

- **Familiarize** yourself and the evaluation group with the three tables below. Tables C1, C2 and C3 represent the three general phases of the safety culture assessment process: preconditions, data collection and analysis, and organizational development. For each evaluation criterion, four maturity levels have been defined. Level 0 maturity (does not achieve the evaluation criterion) is negatively worded or describes an undesirable practice. The other three levels gradually describe the maturity development from basic to best practice.
- **Review process documents, records and practices** related to safety culture assessment according to the three tables below.
- **Identify the process maturity level** for each evaluation criterion.
- **Define improvement actions** to achieve the next maturity level for each evaluation criterion.
- If you have determined that the highest level has been achieved for an evaluation criterion, define **actions or conditions that will maintain** the level of maturity.
- Identify **risks that may result in decrease** in achieved maturity level.

Table C1. Preconditions

Evaluation criterion	Level 0: no implementation	Level 1: basic	Level 2: advanced	Level 3: best practice
Supported by management	Resources and access are not provided. Experts are not provided with sufficient independence.	Minimum resources are provided, and assessment is generally permitted by the management.	Sufficient resources and independence are provided, and the management ensures wide access to all organisational functions.	Continuously active management support for the safety culture assessment process (e.g. communication, promotion, etc.).
Integrated with the management system	Safety culture assessment process is not documented, and knowledge of its content is person dependent.	The safety culture assessment process is described in local and unofficial working documents.	The safety culture assessment process is formally described, documented, and approved in the management system. Responsibilities have been assigned.	The safety culture assessment process and its implementation is monitored (e.g. as part of management review) and continually improved.
Systematic implementation	Safety culture assessment activities are performed on an ad hoc basis with no evident process or periodicity.	Safety culture assessment activities are conducted according to established informal practice.	Processes and procedures guide the implementation of safety culture assessment activities.	Safety culture assessment processes and procedures are periodically reviewed and improved. This development is guided by, e.g., experiences from its implementation, benchmarking, industry best practices, and cutting-edge research.
Guided by an appropriate understanding of what safety culture is	The safety culture concept is not used to guide the assessment or it is used incorrectly.	An implicit understanding of safety culture guides the assessment process.	Industry standard safety culture models are used for data collection and normative analyses.	Industry standard views of safety culture are complemented by scientifically accepted concepts of organizational culture and cutting-edge research, and this is evident in the assessment process.
Implemented by appropriate experts	Implemented by people with no expertise on human or social sciences. They are not provided with training on safety culture assessment.	Implemented by people with no formal education on human or social sciences. They are provided basic training on safety culture assessment.	Implemented by experts with formal education or extensive experience in human or social sciences.	Top experts in the field implement the process. They are regularly provided with access to advanced education on safety culture (assessment) with training courses, events, and conferences.

Table C2. Data collection and analysis

Evaluation criteria	Level 0: no implementation	Level 1: basic	Level 2: advanced	Level 3: best practice
Comprehensive scope	The scope definition is imprecise and does not include the safety culture status.	The assessment process focuses only on limited groups of employees (e.g. operative field staff) or limited aspects of safety culture.	The process assesses the status of all dimensions of safety culture and all organizational functions.	All levels of organizational culture (structures, behaviour, attitudes, values, norms, basic assumptions) are assessed, as well as safety culture improvement activities and their impact.
Diverse safety culture assessment types are used	Safety culture assessment is seen only as performing safety culture self-assessments or audits.	In addition to performing safety culture self-assessments, safety culture experts sometimes utilize insights from other assessments.	The safety culture assessment process includes fast-cycle monitoring, annual summarizing, slow-cycle assessments and utilization of on-demand or opportunity-based assessments.	Safety culture insights are continuously sought from many available data sources and assessments. New assessment methods are created when necessary.
Utilization of diverse data collection methods	No safety culture specific data collection methods are used.	Single method application, e.g., using only safety climate surveys for safety culture self-assessment.	Single-method application is occasionally supported by additional methods. Larger assessment projects utilize multiple data collection methods.	Consistently applying multiple, diverse methods (e.g. interactive, and non-interactive, qualitative, and quantitative approaches).
Awareness of the constraints of assessments	Assessment methods and their limitations are not understood. Their results are taken at face value, even if they are only represented by a single number.	Qualitative and quantitative analysis methods are used appropriately. The evidence behind analysis results is sometimes based on single datapoints or data sources.	Experts are cautious in drawing conclusions based on incomplete or non-corroborated data. The reliability or strength of analyses is identified and clearly stated.	Experts have a profound understanding and experience of what kind of data and assessments are required for drawing conclusions at different cultural levels, how to collect or find this data, and how to perform the appropriate assessments.
Identifies cultural strengths and weaknesses	Assessment process produces descriptions of raw data, or analysis results that do not relate to the status of safety culture.	The assessment process identifies some indications of the status of safety culture.	The assessment process systematically reviews how the observed safety culture deviates from the ideal state.	The assessment process can capture and document (at least over longer periods of time) changes in deeper levels of culture (e.g. values, norms, basic assumptions).

Table C3. Organizational development

Evaluation criteria	Level 0: no implementation	Level 1: basic	Level 2: advanced	Level 3: best practice
Findings are appropriately reported and communicated	Findings are not reported at all, or the report is not reviewed by top management.	Findings are only reported to the immediate internal customer (e.g. top management or oversight function).	Findings are widely communicated in the organization, including operative staff. Written safety culture assessment reports are made public in the organization.	Reflective workshops or seminars are arranged in units or divisions to discuss findings. The assessment group is aware of the organization's orientation and adapts the most effective communication style.
Specification of improvement and/or corrective actions	No actions are described.	Improvement and corrective actions are defined primarily by safety culture experts.	Improvement and corrective actions are defined in a dialogic manner with top management. Top management formally approves the actions for implementation.	All involved organizational functions participate in the specification of the improvement and corrective actions. Safety culture experts may facilitate this process.
Implementation and integration of improvement and corrective actions	The organization does not implement the improvement or corrective actions defined by the safety culture assessment process.	Implementing recommended actions is the responsibility of a limited group of safety culture experts.	Recommended actions from the safety culture assessment process are extensively integrated into ongoing development programmes and new ones are initiated if necessary.	The responsibilities for implementing the actions represent many organizational functions and are coordinated. Safety culture experts are seen as being in a supporting or facilitating role, rather than implementing.
Impact on behaviour, mindset and/or culture	The safety culture assessment process has no impact, and the same issues reoccur.	The safety culture assessment process has had some impact on addressing surface-level cultural problems.	The safety culture assessment process has had clear impact on the more surface elements of safety culture, such as structures, behavioural patterns, or attitudes. There is evidence that some cultural problems have been addressed.	The safety culture assessment process has, over time, revealed cultural problems at deeper levels (e.g. values, norms, assumptions), which have subsequently been addressed as part of the continual organizational development process.

ATTACHMENT D. Tool for assessing the effectiveness of safety culture training

WHO: The tool can be used by managers and supervisors, as well as experts responsible for organizational development, safety culture, and leadership.

WHEN: The tool can be used when the nuclear organization wishes to evaluate the effectiveness of safety culture training.

WHAT FOR: The tool elaborates what types of effects safety culture training may have and what assessment measures can be utilized for follow up. The tool can also be used to further develop the content of safety culture training programmes. In addition, the tool can provide insights for safety culture assessment and thus facilitate organizational learning and development.

HOW: Review the questions from the tables below at each of the levels together with those responsible for arranging training with safety culture topics. Collect and utilize information as part of the assessment (right columns of the tables).

Table D1. Reaction and learning levels

Level and its application in safety culture training	Example assessment measures
1. Reaction: *enjoyment, relevance, interest in training* Did the participants perceive the safety culture training as **relevant** for their jobs? How did the participants understand safety culture training as part of ensuring **nuclear safety**? How did the participants perceive the **quality** of materials or presentations? How did the participants perceive the balance of **theoretical and practical** topics? Did the participants perceive their organization's **safety communication** as in line with the safety culture training (e.g. do supervisors and managers promote safety-conscious values and behaviour)? How did the existing **organizational culture and leadership** affect the participants' reaction to the safety culture training (e.g. is safety culture training seen a "tick-in-a-box", or is there is a shared understanding of human and organizational phenomena as important to safety)?	Comments, questions, reactions, and polls during the training Joint feedback reflection at the end of training Feedback forms after training
2. Learning: *gaining new knowledge, skills, or attitudes during training* What was the extent to which the participants acquired new or maintained existing safety culture-related **knowledge** (e.g. understanding the reasoning and significance of safety culture in ensuring nuclear safety, knowing safety culture requirements and expectations, understanding the characteristics of good safety culture and how they manifest in practice, and understanding the safety-significance of their own work)? What was the extent to which the participants acquired new or maintained existing safety-related non-technical **skills** (e.g. identifying and raising safety concerns and deviations, tools or practices that can be used to improve human performance, setting good examples and communicating on safety topics)? What was the extent to which the participants acquired new or maintained existing safety-related **attitudes or mindsets** (e.g. safety motivation, a questioning attitude, vigilance concerning safety issues, procedure use and adherence, etc.)? What was the extent to which the safety culture training contributed to creating a **common understanding** of the safety culture and common (behavioural) expectations? How did the **existing organizational culture and leadership** affect the participants' learning of topics covered by the safety culture training (e.g. is continuous learning and development encouraged, enabled, and considered a self-evident part of work)?	Knowledge tests before and after training Competence assessment programmes and their trends Trends in safety culture assessments

Table D2. Behaviour and results levels

Level and its application in safety culture training	Example assessment measures
3. Behaviour: *changes in on-the job behaviour after training* How have the participants **on-the-job behaviour, practices or decisions** changed since the safety culture training? How have the acquired knowledge, skills, attitudes, or mindsets been evident in **daily work** of the participants? How has the **existing organizational culture and leadership** affected the participants' possibilities to apply what was taught in the safety culture training. What might have promoted or prevented behavior change? (E.g. do the leaders and the work community encourage and enable safety-conscious actions and decision-making?)	Field observations, walkarounds Trends in safety culture assessments
4. Results: *changes in organizational outcomes* How has the safety culture training programme influenced the **safety culture or its individual dimensions**? Also consider what other initiatives have influenced the safety culture at the same time. What **nuclear safety** impacts has the safety culture training program had?	Long-term trends in safety culture assessments Operating experience trends and relating them to safety culture training programme implementation phases Benchmarking companies that have implemented or have not implemented similar safety culture training programmes