What Do You Mean, Safety Culture?

Contemporary Understandings with Historical Roots

Sara Lind | LUND UNIVERSITY

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Abstract
It has been close to 40 years since the Chernobyl accident and the introduction of 'safety culture', but still there is no consensus on its meaning. This thesis aims at exploring what meanings the Swedish nuclear industry has created out of 'safety culture' by situating the construct both contemporarily and historically, using a methodology inspired by phenomenology. The results show that the Swedish safety professionals believe in an approach based on understanding how structures and prerequisites shape culture(s) and that culture manifests through various patterns over time. The interviewees differentiate between safety and culture while also recognising the relationship between them, where culture can favour or disfavour safety. There is, however, a gap in mental models and language between the safety professionals and engineers working in the industry making it difficult to convey these created meanings. There are also signs of external power, trapping the safety professionals between staying true to their own beliefs and forced simplifications.

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Abbreviations

B2	Barsebäck NPP, unit 2
BWR	Boiling Water Reactor
CNS	Convention on Nuclear Safety
F1	Forsmark NPP, unit 1
GS-G	IAEA Safety Guides
GS-R	IAEA Safety Requirements
HUSC	Human Performance and Safety Culture
IAEA	International Atomic Energy Agency
INSAG	International Nuclear Safety Advisory Group
MTO/HTO	Människa/Man-Technology-Organisation/Human-Technology-Organisation
NEA	Nuclear Energy Agency
NPP	Nuclear Power Plant
O3	Oskarshamn NPP, unit 3
OECD	Organisation for Economic Co-operation and Development
OKG	Oskarshamns Kraftgrupp
PWR	Pressurized Water Reactor
SF-1	IAEA Fundamental Safety Principles
SKISOS	Svenska Kärnkraftsindustrins Samverkansorgan för Säkerhet, [the Swedish Nuclear Industry's Safety Coordination Body]
SSM	Strålsäkerhetsmyndigheten, [the Swedish Radiation Safety Authority]
TMI	Three Mile Island
WANO	World Association of Nuclear Operators

Introduction

'Safety culture' as a construct was first introduced in the International Nuclear Safety Advisory Group's (INSAG) report on the Chernobyl accident in 1986 (INSAG, 1986). Five years later, the International Atomic Energy Agency (IAEA) released INSAG-4 (INSAG, 1991) providing further explanation on what they meant by 'safety culture'. In the years that followed, more elaborated models describing the 'safety culture' construct emerged within the industry and in the academic literature, some even questioning its use (Hopkins, 2016; Sherratt et al., 2025).

Despite the ongoing academic debate on whether or not 'safety culture' is a validated construct (Cox & Flin, 1998), or even something that should exist in the safety science lexicon (Sherratt et al., 2025), the Swedish regulator requires the licensees to put in place a management system that supports a 'culture for safety' (Swedish Radiation Safety Authority, 2018). Thus, the Swedish nuclear power plants (NPP) cannot escape the fact that 'safety culture' is something they need to consider.

This thesis aims at exploring the meanings of safety culture within the Swedish nuclear context, starting 40 years ago. A deep dive into a situational and temporal context might shed some light on how the Swedish nuclear industry has created meanings and purpose from something born out of a political need to explain accidents (Henriqson et al., 2014) and defined in a normative manner.

The Swedish Nuclear Industry

The Swedish nuclear industry was born in the 1950's with its roots in the Swedish workshop industries, power companies and research traditions (SKISOS, 1994). The first two reactors were research reactors, one located at the Royal Institute of Technology in Stockholm (called R1) and the other in Studsvik (R2). In 1957, an order was placed for the first commercial nuclear reactor in Ågesta (R3/"Adam") which provided southern Stockholm with district heating and electricity between 1964-1974. Ågesta was described as a demonstration reactor which was to be followed by a prototype reactor placed in Marviken (R4/"Eva") (Vattenfall, n.d.). In 1960, Vattenfall applied for construction, but the R4 project was abandoned when the reactor could not meet safety requirements (SKISOS, 1994). Instead, it was Oskarshamn Kraftgrupp's (OKG) application to build a light-water reactor at Simpevarp peninsula

that paved the way for the first large commercial nuclear reactor (O1) to be commissioned in 1971[1] (OKG, n.d.).

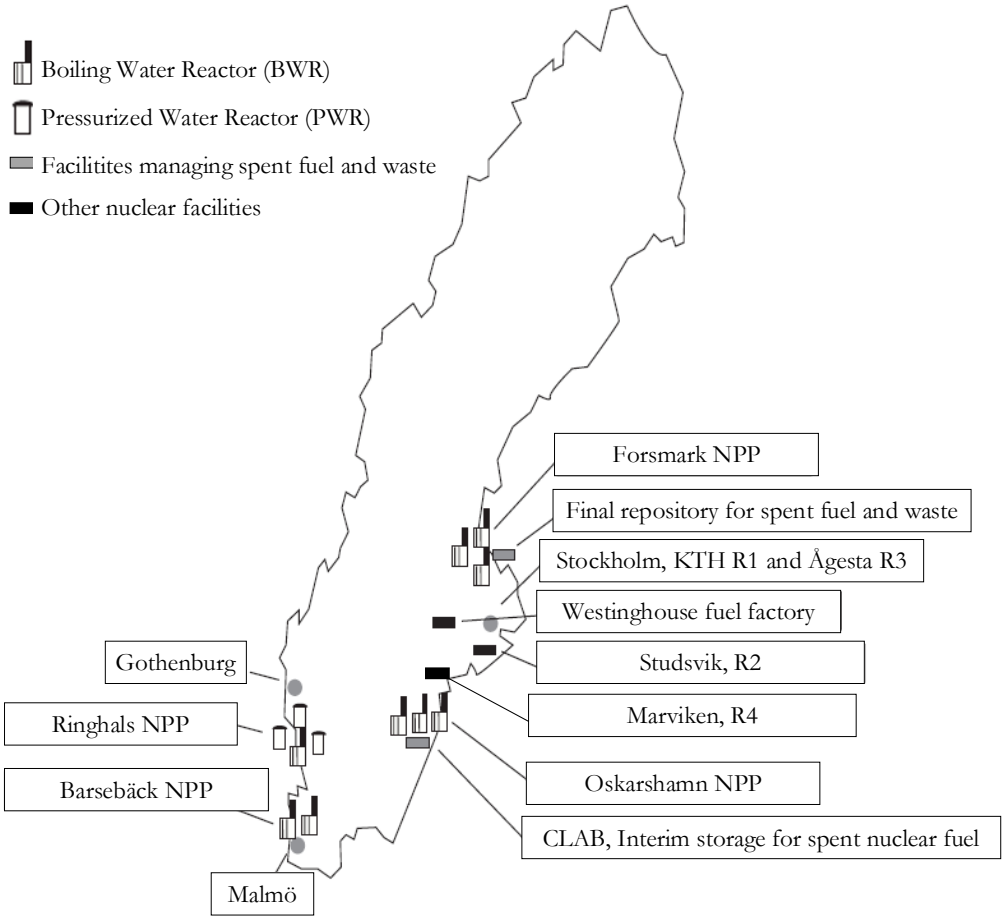
The pioneering work of constructing the first Swedish reactors required high technical competence and an interactive process between the owners, suppliers, and the regulator (SKISOS, 1994). The industry mixed research traditions with industry knowledge, adopting a professional accountability that made the license holders responsible for operation and safety of the power plants. The regulator's role was, and still is, to make sure that the licensees take their responsibility while not interfering in, or regulating, details of daily operations. This is the so called 'Swedish Model' that formed the foundation for the openness and consensus on safety throughout the industry and that is seen as key for a good 'safety culture' within the Swedish context (SKISOS, 1994).

Today, the Swedish nuclear industry contains 12 reactors (see Figure 1). Six reactors are still in operation while the other six are being decommissioned. The industry also includes various institutions and companies which contribute to a working industry, for example the regulator, training provider, fuel and waste management, and fuel manufacturer. There are also many smaller contractors, entrepreneurs and consultants who provide varying services as well as educational centres, such as universities, providing nuclear specific education.

[1] Officially opened by His Majesty King Gustaf VI Adolf in 1972.

Figure 1

The location of nuclear facilities in Sweden (adapted from Ministry of the Environment, 1998).



Research Question

This thesis examines the research question: "What meanings has the Swedish nuclear industry created out of the 'safety culture' construct since the release of the INSAG-1 report in 1986?"

Limitations

The thesis is limited to the licensees still having operating units, together with the Swedish regulator. Interviewees consisted of people who have worked with, or are still working with, the 'safety culture' construct, thus the industry's created meanings will be based on their perception.

Reading Guide

A combined narrative and systematic literature review was performed and synthesised in a separate chapter to indicate it being part of results rather than solely functioning as background.

The research design explains, in depth, the chosen methodology due to its central role in this study. Interpretive phenomenology guided the approach to used methods and subsequent analysis.

This thesis separates findings from analysis. The Findings chapter is presented in a factual, and temporal, manner to visualise a historical perspective on 'safety culture'. The focus is to present what happened to the construct within the Swedish nuclear industry while also including international influences. The Analysis chapter presents the created meanings attached to the construct, reflecting the lived experience of the interviewees.

The Discussions chapter contains the author's reflections on the analysis, used methodology, and methods, as well as closing remarks and important take-aways.

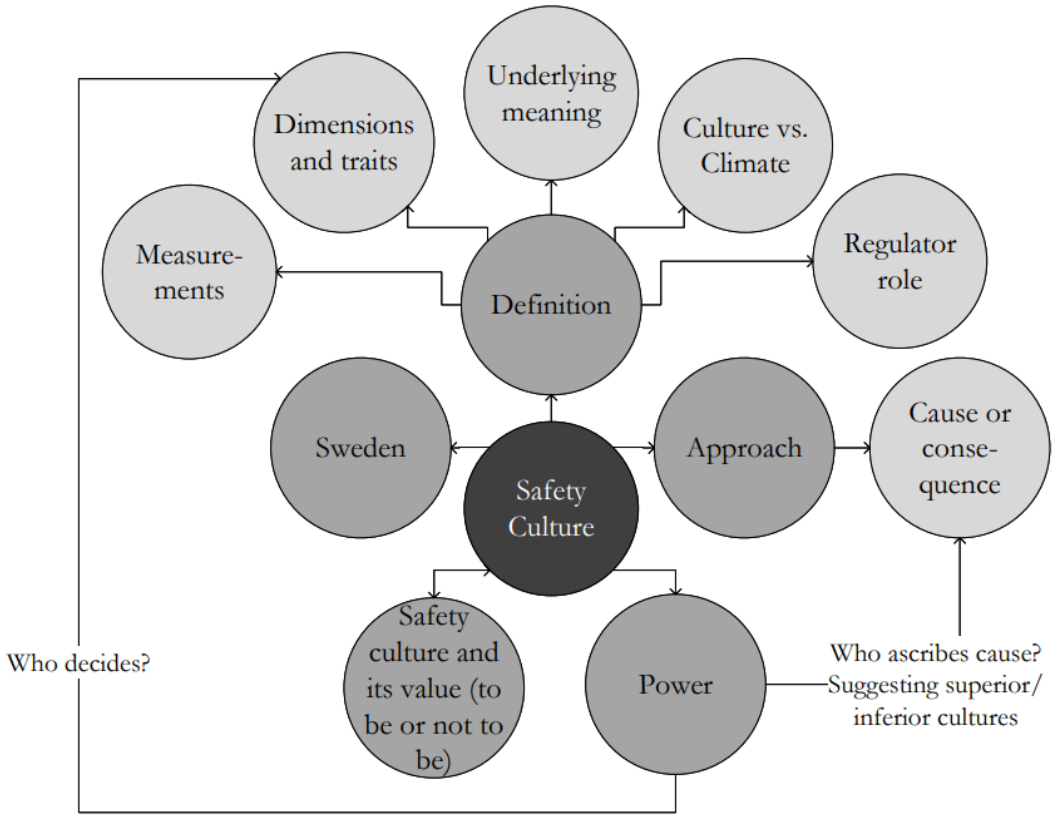
Literature Review

Narrative and systematic literature reviews were performed (see Appendix A), exploring the 'safety culture' construct that was introduced after the Chernobyl accident (Choudhry et al., 2007; Cox & Flin, 1998; Glendon & Stanton, 2000; Pidgeon, 1991). Much research has been undertaken in attempts to better understand the meaning behind the construct, and "it has become the 'motherhood and apple-pie' of safety management that organizations should establish 'excellent safety cultures'" (Cox & Flin, 1998, p. 189). Still, there is no consensus on the meaning of 'safety culture' (Antonsen, 2009a; Choudhry et al., 2007; Guldenmund, 2000; Hopkins, 2006; Sherratt et al., 2025).

Patterns, or general themes, emerged from the literature which the synthesis of the literature will follow (see Figure 2).

Figure 2

Literature Map.



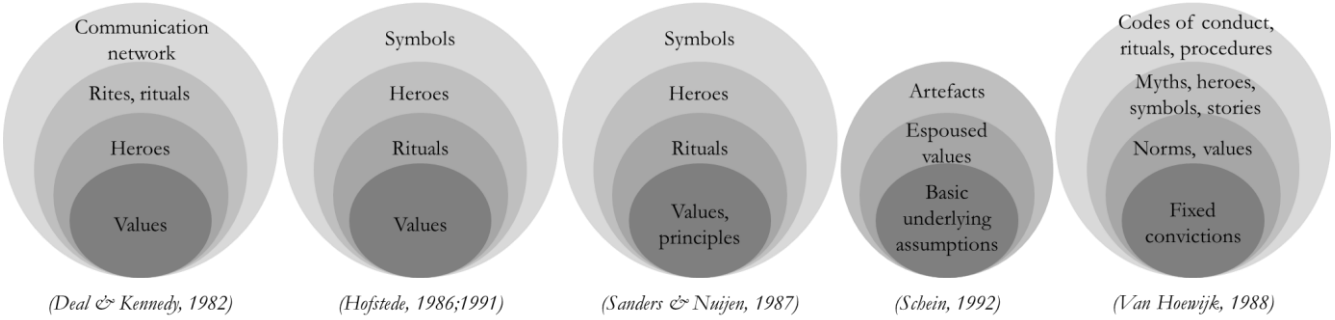
Definition

IAEA (2022) defines 'safety culture' as "the assembly of characteristics and attitudes in organisations and individuals which establishes that, as an overriding priority, protection and safety issues receive the attention warranted by their significance" (p. 190). This definition is prominent within the nuclear industry even though more exist (see for example Cooper, 2000; Guldenmund, 2000). The ambiguity of the concept warrants further elaboration.

According to Guldenmund (2018), culture exists between people and enables us to make sense of our world. It is a complex construct with multiple dimensions, layers, and practices shared among a group of people (Guldenmund, 2000). What these dimensions and layers constitute differs between various researchers (see Figure 3).

Figure 3

Levels of Culture (interpretation of Guldenmund, 2000).

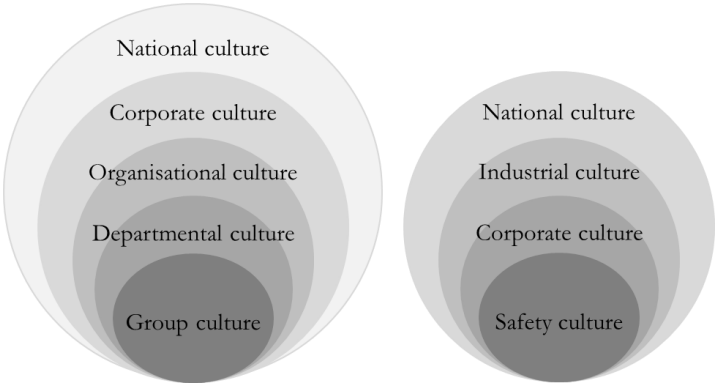


Cooper (2000) presents a critical stance towards cultural models, including the kind of layered models presented by Guldenmund (2000). He discusses two in particular and says: "As currently conceptualised, however, neither model appears to account for the dynamic nature of culture" (p. 122).

Simultaneously, people are part of multiple groups (see Figure 4) which, according to Guldenmund (2000), opens for the notion of sub-cultures and a possibility to talk about culture in terms of small groups of workers, departments, organisations etc. that are overlapping, even nested within each other (Pidgeon, 1991). This nestedness is not reflected in Figure 4 which shows clear boundaries between varying sub-cultures.

Figure 4

Examples of Sub-Cultures and Nested Groupings (interpretation of Guldenmund, 2000).



Because culture is socially constructed, it is unlikely that the culture will look the same in various parts of an organisation, and it is not necessarily homogeneous and free from conflict (Antonsen, 2009a). People bring various assumptions and mental models to different contexts (Guldenmund, 2018). Therefore, rather than studying homogenous local cultures, competing interests as part of the process in creating culture need exploring (Silbey, 2009).

Underlying Meaning

Many definitions on 'safety culture' are derived from organisational culture and the social and management sciences (Cox & Flin, 1998), but there is no agreed-upon definition (Choudhry et al., 2007; Hopkins, 2006; Sherratt et al., 2025) and the validity of the concept is to a great extent unproven (Cox & Flin, 1998). The literature is filled with competing models, various analysis types, measurements and instruments with unreliable instruction or guidance (Silbey, 2009), and existing models often combine multiple components connected to safety, collectively labelling them 'safety culture' (Sherratt et al., 2025).

Cooper (2000) argues that depending on the definition, the purpose of 'safety culture' might vary but the general goal is everybody's commitment to give the highest priority to safety. However, efforts to specify 'safety culture' in terms of individuals' attitudes and commitments illustrate that 'safety culture' could become a form of responsibilisation of the work force (Silbey, 2009) in which individuals are given greater responsibilities and held accountable when something happens (Gray, 2009).

It is not only the definition of culture that gives rise to ambiguity, but also the definition of safety (even different safeties. See for example Reiman & Rollenhagen, 2014; Rollenhagen & Westerlund, 2007; Grote & Weichbrodt, 2013). Safety is an emergent property within an organisation, which highlights its dynamic and abstract nature (Oedewald et al., 2011) and "combining two difficult to define terms into a new one has spurred imagination, but has also provided an easy way out as a catch-all construct" (Grote & Weichbrodt, 2013, p. 226).

Commonly Used Dimensions or Traits

One often hears that 'safety culture', or organisational culture, is more than the sum of its parts (Cooper, 2000; Guldenmund, 2000). This is an expression of the complexity of the construct, highlighting that not only is there a need to define each part, but also what binds them all together. Also, many commonly used traits or dimensions often consist of a mix between something abstract (commitment, learning) and something concrete (rules, staffing) (Reiman & Rollenhagen, 2014).

Reason (1997, 1998) proposes a model in which an informed culture *is* a 'safety culture' that contains four sub-cultures: reporting culture, just culture, flexible culture, and learning culture. Other models include a variety of traits, or attributes, and some ascribe up to 130-140 attributes to the overall construct (Breakwell, 2007; Choudhry et al., 2007; Cox & Flin, 1998).

The rationale for including certain attributes or traits is rarely explained (Cox & Flin, 1998) and the large number of varying dimensions or traits is unhelpful regarding scientific exploration and evaluation (Sherratt et al., 2025). Also, an emergent property (like 'safety culture') cannot be found in its constituent parts (Leveson, 2011).

Culture vs. Climate

There is extensive literature on the difference between culture and climate. Zohar (1980) defined organisational climate as employees' shared perceptions about their working environment as a frame of reference for behaviour. Climate and culture are often used interchangeably (Choudhry et al., 2007; Cox & Flin, 1998; Glendon & Stanton, 2000; Hopkins, 2006) and safety climate is sometimes used as a surrogate measure to 'safety culture' (Cooper, 2000).

Measurements

Organisational culture is usually measured using qualitative methods such as interviews and observations, complemented with surveys, questionnaires, and document analysis (Antonsen, 2009b; Choudhry et al., 2007; Oedewald et al., 2011). Ethnographic approaches tend to be expensive and time consuming, so organisations might, therefore, choose a more pragmatic way forward, for example the one presented by Oedewald et al. (2011) based on a qualitative approach combining document analysis, interviews, surveys, and, if possible, observations.

Regulator Role

Sherratt et al. (2025) say it is problematic to include requirements on 'safety culture' in regulations when there is no agreed upon definition. Regulatory requirements and industry guidance make it *look like* such a definition exists accompanied with tools and measurements which could give rise to a kind of false sense of safety, or confidence. Regulations on 'safety culture' requires guesswork and should instead focus on prescribing, monitoring, and enforcing safety management (Grote & Weichbrodt, 2013). Le Coze & Wiig (2013) present an opposing view writing that introducing an ambiguous concept such as 'safety culture' into regulations could push organisations to explore issues that they otherwise would not.

Approaches to 'Safety Culture'

According to Guldenmund (2000), there tend to be two different approaches to 'safety culture': "(1) normative or prescriptive models, which seek to describe and specify safety climate or culture per se; and (2) descriptive or empirical models, which attempt to summarise findings from one or several organisations studied" (p. 238). The literature additionally describes a functionalist and an interpretivist approach (Glendon & Stanton, 2000; Reiman & Rollenhagen, 2014), stemming from the 1980's discussion whether organisations 'have' or 'are' culture (Guldenmund, 2018). The functionalist approach assumes that there is an ideal to aspire to (Glendon & Stanton, 2000) viewing culture as a variable and something the organisation has created for itself (Reiman & Rollenhagen, 2014). The interpretivist approach, on the other hand, assumes that culture is an emergent, complex phenomenon that exists in social groups (Glendon & Stanton, 2000). Culture is considered to be embedded in social processes and practices, thus

it cannot be analysed or evaluated independently of the context since culture *is* the context (Reiman & Rollenhagen, 2014).

The original use of the term was normative in the way that it separated good and poor 'safety culture' (Pidgeon, 1991), and contemporary definitions and models often treat 'safety culture' as a thing, or tool, that can be used to reduce, or prevent, accidents and incidents (Choudhry et al., 2007; Silbey, 2009; Cooper, 2000). Antonsen (2009b), however, argues that "in order to understand the way culture influences safety, it is not sufficient to address cultural issues alone. Rather, one should employ a more holistic perspective, emphasizing the interplay between cultural, structural and interactional aspects of work" (p. 1127).

'Safety Culture' as Cause or Consequence

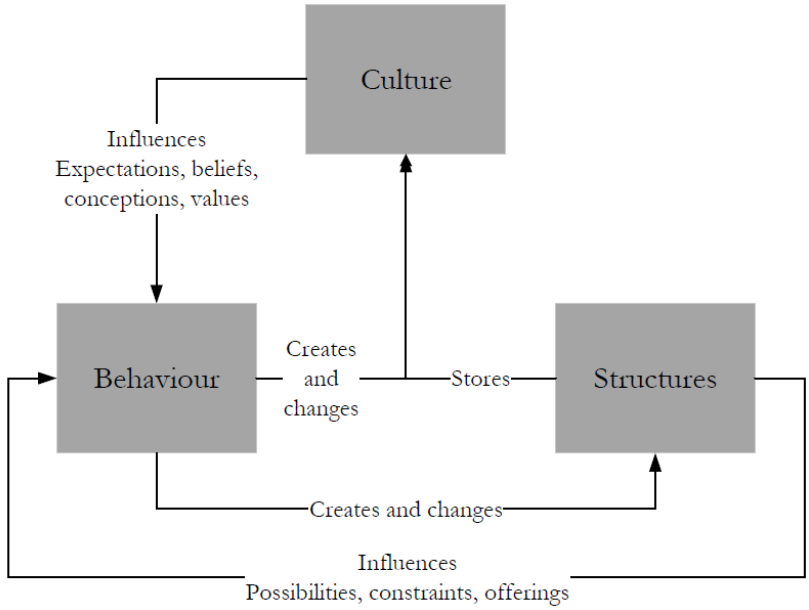
Inadequate 'safety culture' was reported to be a contributing cause to the Chernobyl accident (INSAG, 1986), and 'safety culture' has been ascribed as a cause after other accidents as well (Breakwell, 2007; Henriqson et al., 2014; Silbey, 2009). Antonsen (2009a) has additionally seen it described as a proactive way to support organisations' safety management.

On the other hand, 'safety culture' could be seen as a consequence, constantly redefined and recreated following contextual changes (Antonsen, 2009a; Choudhry et al., 2007). Culture emerges from social and contextual interactions, thus constructed through complex social processes (Antonsen, 2009a; Guldenmund, 2018; Silbey, 2009). Reiman & Rollenhagen (2014) argue anthropological and sociological studies (e.g. Vaughan, 1996) have empirically shown how features of work and organisations, including safety, are socially constructed in our daily work.

A reciprocal relationship between various factors is suggested by Cooper (2000) which is supported by Antonsen (2009a) and Silbey (2009) who argue that most researchers now see culture as both a product and a process. Behaviour creates and changes culture while culture in return influences our behaviour (see Figure 5) (Reiman & Rollenhagen, 2018).

Figure 5

The Iterative Nature of Culture (adapted from Reiman & Rollenhagen, 2018).



The Interaction Between huMan, Technology and Organisation (MTO) or Systemic View

The concept of huMan-Technology-Organisation (MTO)[2] is well-established in the Swedish nuclear industry (Karltun et al., 2017). The concept is based on a systems view where interactions and interdependencies between the three elements are emphasised.

When adopting a systems view, one tries to understand the whole system and the interactions between the parts rather than the parts in isolation (Reiman & Rollenhagen, 2014). The 'safety culture' construct, according to Reiman & Rollenhagen, gives the impression of also being systemic, but traditional approaches to 'safety culture' focus on the dimensions comprising the concept while the systemic approach has been largely lost.

Goh et al. (2010) suggest that it is 'the way things are done' (i.e. culture, originally from Deal & Kennedy, 1982, as cited in Hopkins, 2006) or behavioural patterns that trigger major incidents. They

[2] The Swedish word for 'Human' is *Människa.* The acronym MTO is strongly established in the Swedish nuclear industry and will therefore be used in the thesis.

propose the use "of systems thinking concepts to achieve a clearer understanding of how underlying systemic structures create and sustain poor safety culture" (p. 302). Instead of targeting 'safety culture', it would be wiser to address what Grote & Weichbrodt (2013) call 'manifest problems' more directly, or to adopt a more holistic perspective examining the interplay between cultural, structural and interactional aspects of work (Antonsen, 2009b).

Power

At the time of the Chernobyl accident, the 'safety culture' construct fulfilled a political demand to explain large organisational accidents (Henriqson et al., 2014). Using 'safety culture' as a cause was not just political, it also showed signs of power. Busch (2021) writes that "in the Chernobyl case, the 'culture card' was played in a political way to deflect critical questions about Western nuclear installations. In that sense, it is a power move" (p. 42).

Silbey (2009) made a similar observation. Following the accident in Bhopal in 1984, subsequent discussions claimed that nations vary in their respect for safety and that "the Indian partners in the Union Carbide plant did not share the American culture (which implicitly valued safety), [and] they were, by inference, responsible for the accident" (Silbey, 2009, p. 349). These examples show that "cause is a political construct, and scapegoating a play of power" (Dekker & Nyce, 2014, p. 46). Reiman & Rollenhagen (2014) have additionally noticed an ethical undertone to the 'safety culture' discourse where signs of a weak 'safety culture' might be interpreted implicitly as a deficient morality among the employees or managers resulting in an organisation being perceived as bad or even evil.

"We miss a great deal when we substitute culture for power" (Perrow, 1999, p. 380), but power is something rarely addressed in 'safety culture', or safety science research (Antonsen, 2009a; Dekker & Nyce, 2014). A power-oriented approach to 'safety culture' could help question some underlying theoretical frameworks and philosophical assumptions built on compliance, rules, and procedures (Antonsen, 2009a).

To Be or Not To Be

Many authors are questioning the relevance of the 'safety culture' construct (Antonsen, 2009b). Hopkins (2016) says "the term safety culture is so confusing that we should abandon it" (p. 91). Sherratt et al. (2025) additionally argue for its removal from the safety science lexicon, saying the construct has become a sort of truism, that when something is said to be everything, it is nothing. Instead, they suggest further research on the separate dimensions, attributes or traits and their relationship to safety performance "rather than seeking the holy grail" (Sherratt et al., 2025, p. 2).

This argument is reminiscent of Dekker & Hollnagel's (2004) description of folk models, i.e. concepts that at first glance seem meaningful, but the value "hinges on their common-sense appeal rather than their substance" (p. 80). Folk models can be recognised by defining the core construct by substitution for another construct that needs equal explanation. Similar to Sherratt et al.'s (2025) conclusion, Dekker & Hollnagel (2004) propose to "focus on the characteristics of performance rather than on inferred and uncertain states of the mind" (p. 85). According to Antonsen (2009b) "the term safety culture is not strictly necessary other than as a conceptual label denoting the relationship between culture and safety" (p. 1119).

Reiman & Rollenhagen (2014) critique the 'safety culture' construct but highlight the practical impact in various industries. The authors argue that the construct has made managers and workers think about a soft side of safety and therefore the construct has been beneficial. Busch (2021) also recognises the positive aspects a construct like 'safety culture' bring to the discussion about safety, but critiques the way it has been over-used and abused, hence saying it would be best not to talk about it.

'Safety Culture' in the Swedish Nuclear Industry

An early, informal collaboration between the regulator and the nuclear organisations was initiated after Chernobyl to discuss the definition and scope of INSAG-4 (Rollenhagen, 2021). Many of the attributes associated with 'safety culture' today were recognised back then, making the 'safety culture' construct rather stable. In the years following this early initiative, several formal and informal networks have been set up with the aim of strengthening 'safety culture' at the Swedish NPPs.

Other initiatives are also present in the Swedish nuclear industry (Rollenhagen, 2021). Rollenhagen gives an example from the Oskarshamn NPP which developed a 'safety culture' programme in 2004. In 2015, that programme was developed further with a strategy to improve 'safety culture' support based on the departments' various needs, moving away from generic activities. This reflects Antonsen (2009a), saying a top-down approach to 'safety culture' could be harmful in a Scandinavian context with strong union traditions and participative management with a low degree of power distance.

Rollenhagen (2021) also describes the result of a study performed in Sweden that showed the presence of robust sub-cultures. Another study aimed at understanding the current status of identified 'safety culture' elements to be able to enhance 'safety culture' within the industry (Lowe & Hayward, 2006).

Research–Practice Gap

There exists a research–practice gap in safety science partly due to that published research has limited relevance to practitioners and is often deemed impractical (Shorrock, 2020). The practitioners' context introduces several kinds of dilemmas and difficulties, such as involving operational staff, communicating with other parties, getting management on board and compliance with regulations, thus having different goals and incentives compared to safety research.

Le Coze (2024; Le Coze et al., 2025) investigates another aspect of the gap between contemporary research and industries that base their safety approach on flawed ideas, and even myths. Le Coze (2024) & Le Coze et al. (2025) refer to this as the 'the blues of safety professionals', calling out the safety profession's dysfunctions. They describe how the safety profession is not respected, but that some safety professionals contribute to this by adopting irrelevant practices due to an inability to update basic philosophies (Le Coze, 2024).

Research Design

This study focuses on exploring the lived experience within the Swedish nuclear industry regarding interpretations and created meanings of 'safety culture'.

Epistemology and Philosophical Position

'Safety culture' is considered a constructed (Guldenmund, 2000; Henriqson et al., 2014; Pidgeon, 1991), artificial object, rather than an objective fact. It emerged in a historical context, merging that time's management and organisational research together with a political need to explain accidents (Henriqson et al., 2014).

Based on the belief that 'safety culture' is a construct, the epistemology adopted in this study is that of constructionism and the philosophical position is guided by interpretivism in which reality and the meaning of the world is constructed by us humans as we engage with it (Crotty, 1998). Interpretivism tries to situate various interpretations of the world both culturally and historically as the same phenomenon can generate vastly different meanings depending on the context.

To situate the 'safety culture' construct, the aim of this thesis is to understand 'safety culture' as a construct in the Swedish nuclear industry, tracing it back to 1986, and how the underlying meanings of the construct has changed over the course of 40 years. Given this aim, the research methodology for this thesis is based on phenomenology.

Phenomenology

Phenomenology tries to gain a deeper understanding of real life and the meaning of experience connected to a phenomenon (Beck, 2021). A key factor is 'essence' because "essence is what makes a phenomenon what it is, and without it, it would not be that phenomenon" (p. 11). We tend to see our surroundings as natural, habitually attributing meaning to various phenomena, but according to phenomenology, we need to uncover the underlying meaning by putting a phenomenon within brackets as a way of helping us question what the pure and underlying meaning really is.

Interpretive Phenomenology

The focus in this study was interpretive phenomenology. This type of phenomenology is interested in the nature of *being* and aims at understanding the underlying meaning of a phenomenon by relating it to varying contexts (Beck, 2021). The chosen methodology was inspired by Dahlberg, Dahlberg & Nyström (2008) and their 'reflective lifeworld research' and hermeneutic interpretive approach to phenomenology. It suited this study because of its flexible approach and the way it iterates between a holistic view and studying details to uncover hidden meanings.

Methods

Because some interpretations and meanings can be found written down in multiple documents, while others are highly personal, the chosen methods for this study were document review and interviews.

Review of Industry Documents

A document review was performed to identify the written meanings of the 'safety culture' construct within the nuclear industry. To identify relevant documents, the IAEA, the Swedish Radiation Safety Authority's, and the World Association of Nuclear Operators' (WANO) publications databases were searched. Selection of the documents to be included in the review was based on identifying the core documents, such as IAEA Safety Fundamentals (International Atomic Energy Agency, 2006a), Safety Requirements (International Atomic Energy Agency, 2006b, 2016), Safety Guides (International Atomic Energy Agency, 2006c, 2009), regulatory requirements (Swedish Radiation Safety Authority, 2018a, 2018b) and industry guidance, such as WANO's 10 traits (WANO, 2013). For the full list of documents included, see Appendix B.

All information regarding 'safety culture' in these documents was first summarised individually followed by a comprehensive summary. The comprehensive summary is presented in Appendix B accompanied with a visual timeline (see Figure B7) while a shorter version is presented in section 'Findings – Review of Industry Documents'. These documents provided definitions on what 'safety culture' is and specified various attributes and traits. The purpose with the review was to gain an initial

understanding of the construct through the industry's eyes as a preparation, or background, before the interviews.

Interview Study

Being a safety professional within the industry, using a network of connections, made it possible to contact people working with 'safety culture' 35-40 years ago. A total of 11 interviewees from the power companies and the Swedish regulator participated in the study. The interviewees consisted of six females and five males with experience ranging from 3 to 41 years (average 18,6 years). Together they represent the Swedish nuclear industry, 1984 to present day. They are in this thesis collectively named 'Safety Professionals'. Informed consent was obtained before the interviews (see Appendix C).

Semi-structured interviews were conducted and recorded using Microsoft Teams. The length of the interviews ranged between 1h 9min up to 1h 43min (average 1h 22 min, σ 11min 44sek). The interviews followed pre-defined questions while simultaneously giving room for follow-up questions based on the course of dialogue. This interview set-up gave an opportunity to explore the 'safety culture' construct temporally, situationally, and with depth. Depth in this case equalled putting 'safety culture' in brackets to begin uncovering the underlying meaning and lived experience of each interviewee. Each interview was later transcribed using BuzzAI (v1.2.0).

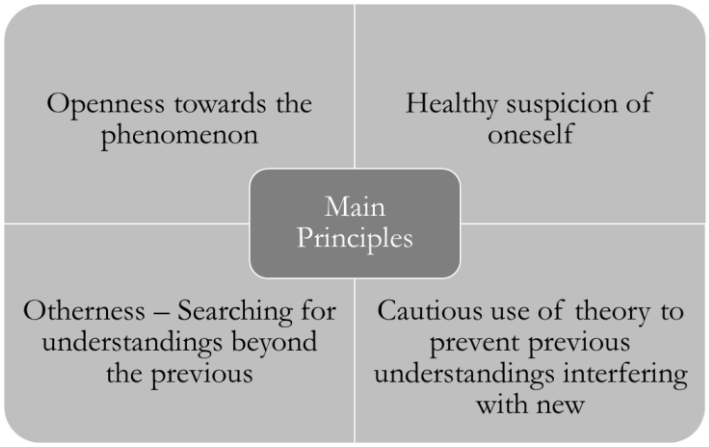
According to Dahlberg et al. (2008), data saturation is not achievable when examining a phenomenon because there are countless different meanings attached to it. The number of interviews was therefore not fixed beforehand. The goal was rather to attain a rich variation in data as 'safety culture' is complex and several contexts needed to be examined.

Data Analysis and Synthesis

Reflective lifeworld research includes a hermeneutic interpretive analysis which contains some main principles (see Figure 6) that need to be adhered to (Dahlberg et al., 2008).

Figure 6

Main principles for interpretive analysis (adapted from Dahlberg et al., 2008).

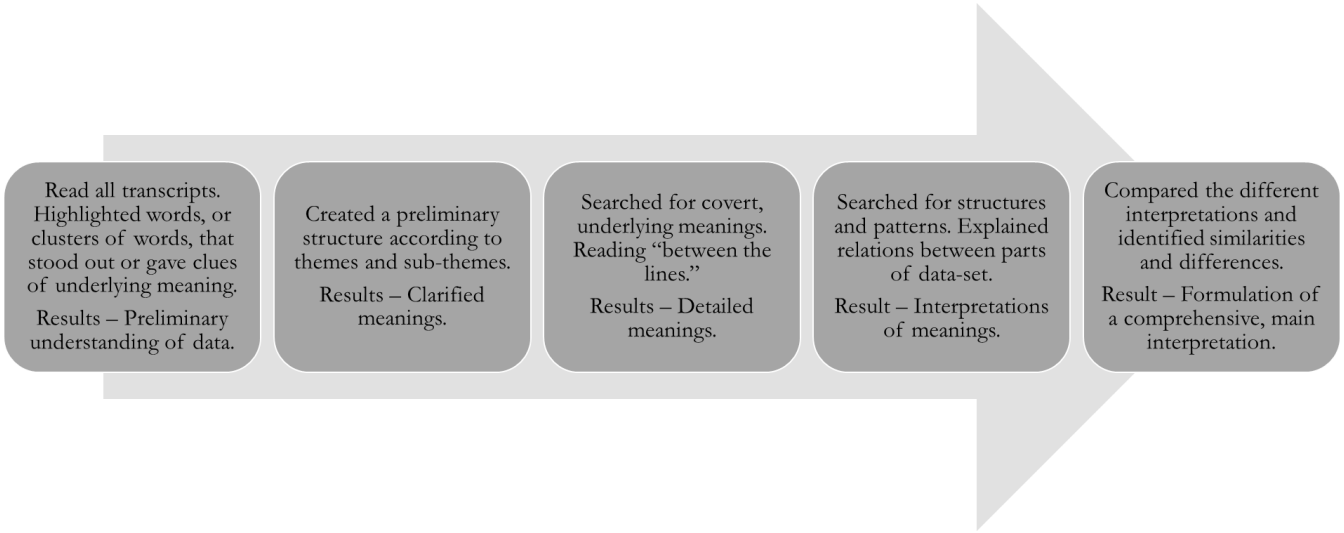


Dahlberg et al. (2008) argue that the analysis builds on a dialogue with the text (transcriptions, documents, etc.) and that it is imperative to move between the whole and the parts as the parts need to be understood in terms of the whole and vice versa. This is the hermeneutic circle, or spiral, that guides the researcher's understanding.

The analysis in this study followed a strategy (see Figure 7) based on an initial reading of all interview transcripts to get a preliminary understanding of the phenomenon before engaging in more detailed reading, uncovering hidden meanings. In the first reading, words or words clusters that stood out were highlighted and listed in Excel together with the word's surrounding context. The obtained information was then structured in preliminary themes and sub-themes, providing clarification of meanings (Dahlberg et al., 2008). Another review of the themes and sub-themes resulted in smaller adjustments and detailed meanings. Following the formation of themes and sub-themes was a written text summarising what each theme contained.

Figure 7

Analysis process (inspired by Dahlberg et al., 2008).



Based on the initial text, the formation of tentative interpretations followed which needed to be understood within the context of the whole. After exploring underlying meanings and tentative interpretations, a new whole was put together. The analysis includes a comprehensive understanding and main interpretation of the phenomenon.

The analysis of the comprehensive document summary was inspired by Dahlberg et al. (2008), keeping the analysis at a holistic level while only touching on some of the details.

Research Ethics

The research was heavily reliant on the interviewees' personal reflections and their disclosed information was recorded and transcribed. The data is stored in a digital folder that is accessible only by the author to guarantee data security, and the raw data (recordings) will be deleted upon approval of the thesis whereas the anonymised transcripts will be saved. All participants were sent a copy of their transcript to review to ensure it captured their intention accurately.

Because the author is part of this limited population mentioned above, already existing relationships are present between the author and some of the interviewees. This was considered when performing the interviews to maintain a high level of professionalism (Blaxter et al., 2010).

The research study did not collect personal information. It did not entail any physical interventions, collection of biological material, nor methods affecting the participants' physical or mental health. Thus, this study did not require ethical review or permission from the Swedish Ethical Review Authority (2023).

Findings

Review of Industry Documents

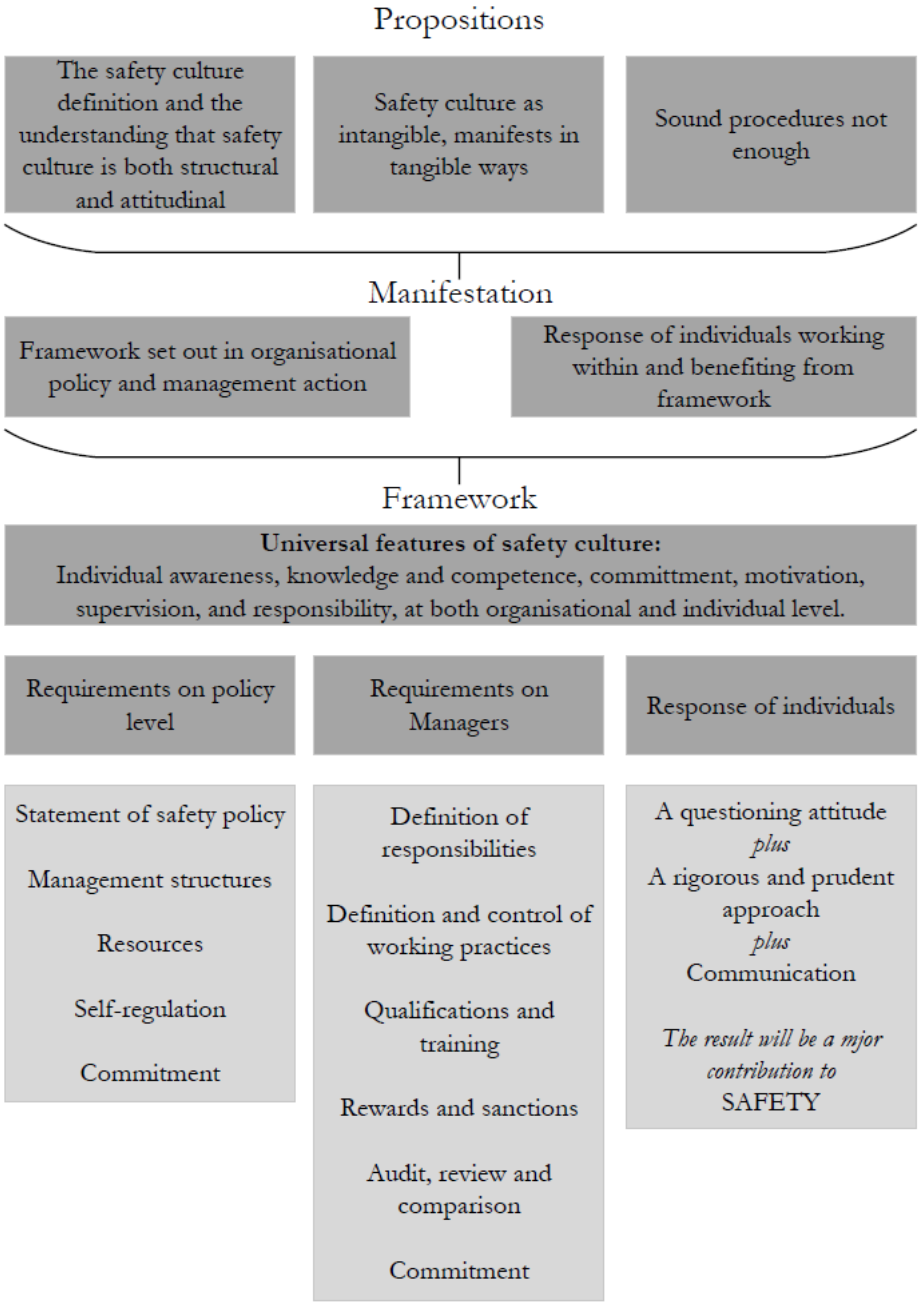
Following the Chernobyl accident in 1986, the International Nuclear Safety Advisory Group (INSAG) released a summary report, INSAG-1 (1986), on the post-accident review meeting held in Vienna. The report gave a first introduction to 'safety culture' stating that "there is a need for a 'nuclear safety culture' in all operating nuclear power plants" (p. 76).

Two years later, INSAG released a new report, INSAG-3 (1988), stating "an established safety culture governs the actions and interactions of all individuals and organizations engaged in activities related to nuclear power" (p. 10). In INSAG-3, 'safety culture' was for the first time mentioned as being part of defence-in-depth.

In 1991, the IAEA's Director General remarked in the foreword of INSAG-4 that "the meaning of the term was left open to interpretation and guidance was lacking on how safety culture could be assessed" (INSAG, 1991, Foreword section, para. 2). The INSAG-4 provides the first version of the 'safety culture' definition: "safety culture is that assembly of characteristics and attitudes in organizations and individuals which establishes that, as an overriding priority, nuclear plant safety issues receive the attention warranted by their significance" (p.1). INSAG-4 (1991) additionally presents three propositions describing 'safety culture' together with two major manifestations as well as a framework including universal features of 'safety culture' (see Figure 8).

Figure 8

Illustration of the presentation of 'safety culture' in INSAG-4 (adapted from INSAG, 1991).



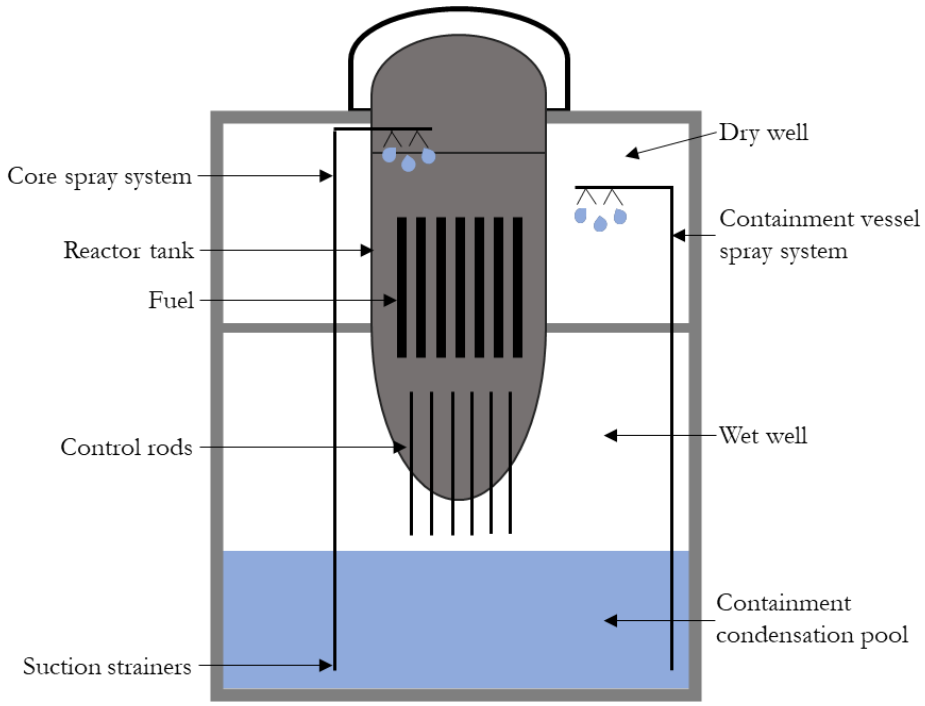
In 1992, INSAG-7 (INSAG, 1992) was released, presenting an update of the original INSAG-1 report. Due to new information coming out of the Soviet Union regarding what happened at Chernobyl, parts of the INSAG-1 report needed revision. The conclusions from INSAG-1 were not affected, but the balance of factors contributing to the accident shifted and the role of the operators eased (INSAG, 1992).

Sweden Awakens

When restarting Barsebäck unit 2 (B2) (see Figure 9) after the yearly outage in 1992, a rupture-disc opened at high pressure inside the containment (Wahlström & Gunsell, 1998). The steam release caused pipe insulation to be ripped off and large amounts of mineral wool insulation were transported down to the containment condensation pool blocking the emergency core cooling suction strainers in the pump inlet to the containment vessel spray system and the core spray system. Wahlström & Gunsell (1998) argue that international events, such as Chernobyl and Three Mile Island (TMI) had cultural roots, and that the B2 event was the most prominent event with roots in the Swedish culture up to that point in time.

Figure 9

Boiling water reactor, containment.

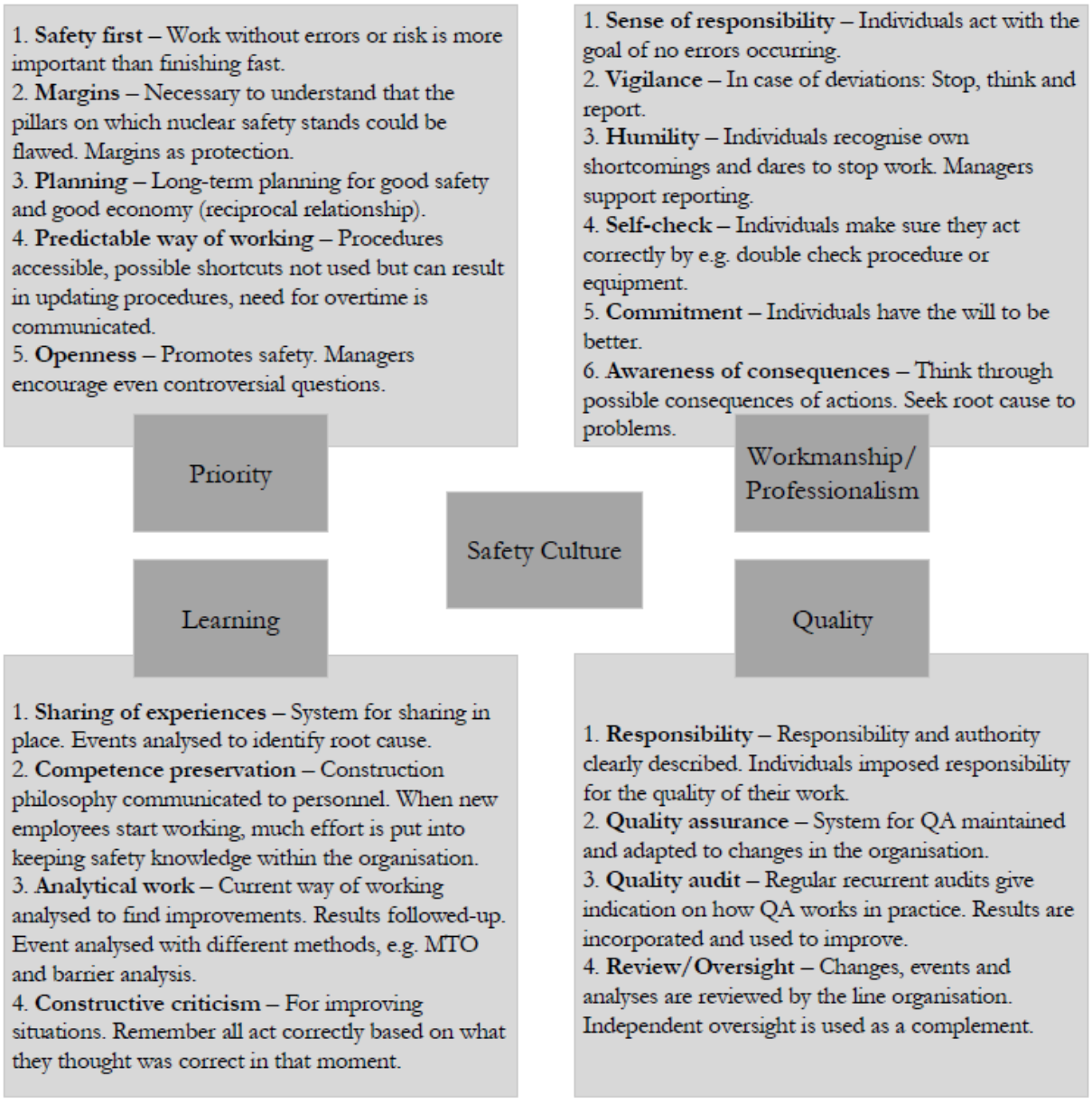


From the documentation, it is unclear how much the B2 event impacted the industry regarding 'safety culture', but Ringhals NPP started their 'safety culture' work in 1991-1992 and between 1995-1996 'safety culture' was a prioritised area of focus in their business plan (Swedish Nuclear Inspectorate, 2004c). At Sydkraft group, owner of Oskarshamn NPP, a 'safety culture' assessment was performed in 1993 and the result showed that a more structured approach towards safety work was desirable (Swedish Nuclear Inspectorate, 2004b).

In 1994, the Swedish Nuclear Industry's Safety Coordination Body (SKISOS) wrote a report on the Swedish interpretation of INSAG-4, presenting several traits adapted to Swedish values (SKISOS, 1994) (see Figure 10).

Figure 10

SKISOS adaptation of INSAG-4 (summary based on SKISOS, 1994).



In 1995, Sweden signed the Convention on Nuclear Safety which says that all contracting parties shall promote an effective nuclear 'safety culture' (IAEA, 1994). The Ministry of the Environment has since sent in reports to IAEA every three years, describing actions to fulfil the convention.

In 2002, fluctuations in the water flow at Barsebäck unit 2 (B2) were assumed to be caused by an already known problem, so no further analysis was initiated (Kärnsäkerhetsutredningen, 2003). In the beginning of 2003, it was discovered that damaged piping partly blocked the water flow. This event had little impact on safety, but, according to Kärnsäkerhetsutredningen, showed a lacking 'safety culture'. The inspectorate (2004d) wrote that 2003 in general showed the importance of working with 'safety culture'.

In 2007, the Ministry of the Environment (2007) reported an event at Forsmark unit 1 (F1) on the 25 July 2006. According to the Ministry, it was a "complicated electrical event…resulting in loss of power supply to two out of four redundant safety trains during 22 minutes" (p. 21) where half of the instrumentation in the main control room went dark (Sanne, 2012). The operators did not know whether the control rods had been inserted into the reactor core, or the reactor water level or pressure, but managed to figure out what happened and manually connected the unit to the grid. According to the Ministry (2007), this event together with others indicated deficiencies in safety management and 'safety culture'.

In the same report it was written that both Ringhals NPP and Oskarshamn NPP had put in place 'safety culture' programmes while Forsmark NPP had a so-called 'safety culture' initiative (Ministry of the Environment, 2007). In general, these included training, workshops, analyses, evaluations, and research initiatives, seemingly with the aim of creating awareness of 'safety culture' throughout the organisations. The 'safety culture' work up until 2015 followed the programmes and planned activities as described earlier, but in 2015, Forsmark and Ringhals merged their 'safety culture' programmes and expertise (Ministry of the Environment, 2016). At the same time, Oskarshamn analysed their 'safety culture' programme and realised their approach was not effective, as described earlier by Rollenhagen (2021).

The regulator also began reflecting on their role in the wider national safety infrastructure (Ministry of the Environment, 2019). As a result, the regulator incorporated five principles presented by the Nuclear Energy Agency (NEA) (2016) into their management system (Ministry of the Environment, 2022). The regulator together with WANO and OECD/NEA held a country-specific 'safety culture' forum in 2018, aiming at "providing an arena to explore the impact of the national context on nuclear

safety and derive approaches to sustain and improve nuclear safety culture" (Nuclear Energy Agency, 2018, p. 11).

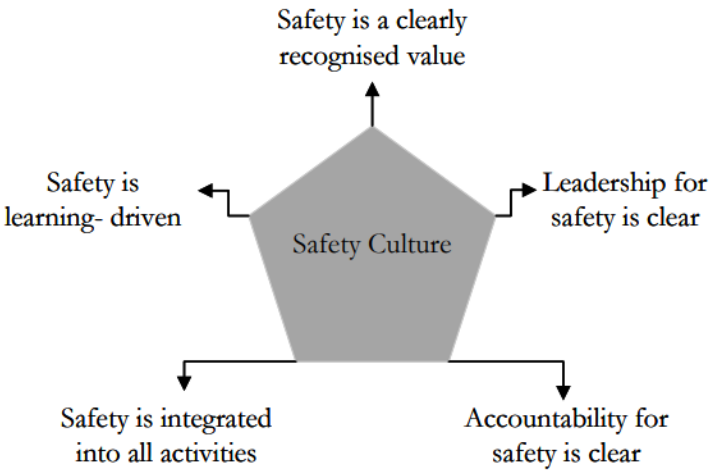
Requirements and Regulations

In 1998 the Swedish Nuclear Power Inspectorate (1998) put 'safety culture' explicitly in their general guidance regarding the application of the regulations, saying it was part of upholding an effective defence-in-depth. In the updated regulations set in place in 2004, 'safety culture' assessment was introduced in the general guidance concerning evaluation of plant safety (Swedish Nuclear Power Inspectorate, 2004a).

In 2006, IAEA published their Safety Standard series (IAEA, 2006a, b, c). In the Fundamental Safety Principles (SF-1), principle 3 specifically targets 'safety culture' (IAEA, 2006a) which is then elaborated on in the Safety Requirements describing the management system for facilities and activities (GS-R-3) (IAEA, 2006b). The Safety Guides (GS-G-3.1 and GS-G-3.5) add yet another level of detail, presenting important attributes for a strong 'safety culture' (see Figure 11) (IAEA, 2006c, 2009). 10 years after the publication of SF-1, IAEA (2016) released new Safety Requirements regarding leadership and management for safety (GSR part 2).

Figure 11

Important attributes of a strong safety culture (adapted from IAEA, 2006c, 2009).



In 2008, the merging between the Swedish Nuclear Power Inspectorate and the Swedish Radiation Protection Institute, forming the Swedish Radiation Safety Authority, resulted in new regulations coming into force in 2008. The 2008:1 regulation (Swedish Radiation Safety Authority, 2008) still only covered 'safety culture' in the general guidance. It would take until 2017 for 'safety culture' to be specifically mentioned in a requirement, amending 2008:1.

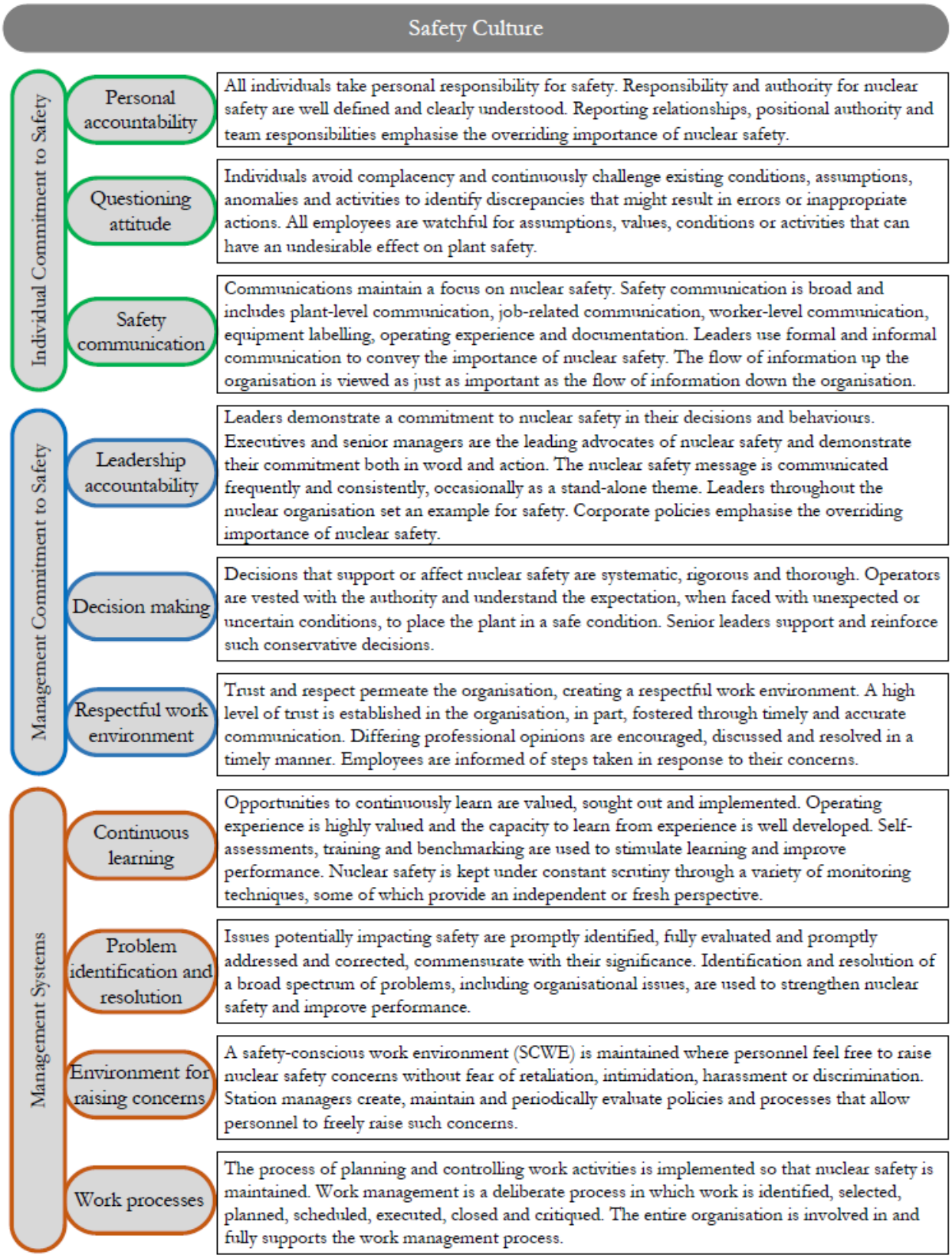
New regulations were released in 2018 which resulted in 'safety culture' getting a stand-alone requirement (chapter 3, paragraph 6) stating that the management system shall support and promote a culture where nuclear safety related questions get the attention warranted by their significance (Swedish Radiation Safety Authority, 2018a). The regulator presents more details on 'safety culture' in their guidance text to chapter 3, paragraph 6 (Swedish Radiation Safety Authority, 2018b).

World Association of Nuclear Operators

In 2006, WANO released their guideline describing eight principles for a strong nuclear safety culture (WANO, 2006). These eight principles were revised in 2013 when WANO published their 10 traits for a healthy nuclear safety culture (see Figure 12) (WANO, 2013). WANO defines a trait as "a pattern of thinking, feeling, and behaving such that safety is emphasised over competing priorities" (p. 4). According to WANO (2013), "experience has shown that the personal and organisational traits described in this document are present in a positive safety culture. Conversely, shortfalls in these traits and attributes are a significant contributor to plant events" (pp. 4-5).

Figure 12

10 traits for a healthy nuclear safety culture (extracted from WANO, 2013, p. 15-35).



Interview Study Findings

This section presents the interviewees' recollections on the introduction of 'safety culture' into the industry and what happened to 'it' while also including specific events that influenced the construct's development in the Swedish context.

'Safety Culture' in the Swedish Nuclear Industry – A Crash Course

After the Three Mile Island accident in 1979, the Swedish inspectorate hired four employees whose job became focused on the interaction between human and machine. One of the interviewees (R08), who came to the inspectorate in 1984, thought that the description of the working unit reflected a too narrow view and re-wrote the description it to include the interaction between huMan, Technology and Organisation (MTO). The inspectorate's safety professionals at the time were met with resistance at the power plants. People were saying that 'a properly designed plant is inherently safe' and that human errors did not pose any risk because of the high degree of automation. At this point in time, 'safety culture' was not an area of focus, but the industry spoke about organizational factors.

The interviewee (R08) remembered that in the end of April 1986 the inspectorate participated in a meeting at Oskarshamn NPP. One of the inspectorate's managers present at the meeting received a call from the Director General who told they had discovered elevated levels of radiation outside of Forsmark NPP. On their way back from lunch, they noticed people taking measurements on the grass outside and the equipment used made crackling sounds. Coming back into the meeting, they had an open telephone line to the Director General who called the Managing Director at Forsmark, thinking the radiation came from there, but the Managing Director said they did not know where it came from. Some heated words were spoken because the Director General thought they were hiding something. The meeting was cancelled and one or two days later, they got the news that the radiation came from the Soviet Union.

In the weeks that followed, an emergency preparedness centre was set up where the interviewee (R08) answered telephone calls from the public which asked questions like 'the milk was cheaper today, is it due to radiation?' The public was very worried. In Sweden at that time, there were only emergency

preparedness plans for the areas close to the power plants, so no fixed measuring stations were set up elsewhere making answering questions about radiation levels in other parts of the country impossible.

Later that year, one of the managers at the inspectorate visited Vienna and when he came back, he showed the interviewee (R08) a draft of the accident report (INSAG-1). The interviewee noticed what they had written about 'safety culture', and was sceptical, thinking this will be a concept very hard to define and people will argue about what it means. The interviewee called one person who was part of INSAG and asked why they introduced this concept, and the answer was simply 'because they had the wrong attitude towards safety' and that the Soviets did not have the right mindset when it came to thinking about safety. According to the interviewee, what was written in the INSAG-1 report, 'lack of safety culture', was hard to relate to because culture is something that is there regardless, but it could probably be lacking in the attitude towards safety. According to some interviewees (R04, R05, R08, R09, R10), Chernobyl helped the industry put focus on organisational issues.

A few years later, in 1991, an international audit was held at Ringhals NPP and, according to an interviewee (R04), one of the auditors asked about the state of their 'safety culture'. The interviewee had never heard of that term before and they started to collect papers and reports that included 'safety culture', gathering them all in a binder. In the beginning of 1992, the Managing Director at Ringhals also came across the term and wanted a presentation of the construct. According to the interviewee, they used the binder of papers and reports and tried to get some sort of structure on all the information before presenting 'safety culture' to the Managing Director and the senior management group.

Not long after this presentation, in April of 1992, the Swedish Nuclear Industry's Safety Coordination Body (SKISOS) held a meeting at Arlanda and the interviewee (R04) was asked to hold the same presentation for the meeting participants. Others held presentations as well, but the overall impression was general confusion. No one really knew anything about 'safety culture', so the presentation given by the interviewee was in these circumstances very concrete. SKISOS decided to form a sub-group to write about 'safety culture', resulting in a yellow booklet called "Safety Culture". The interviewee said the Barsebäck event in 1992 disturbed the work of writing the yellow booklet because the industry put

100% of their focus to solve the issues with the emergency core cooling suction strainers resulting in there being no time to work with 'safety culture'.

According to the interviewee (R04), the yellow booklet was not a translation or interpretation of INSAG-4, but it is rather something that Sweden came up with on their own, basing the structure on the presentation held at Ringhals in early 1992. This yellow booklet was in the industry later preferred over INSAG-4, partly because it was written in Swedish, and partly because INSAG-4 was deemed too abstract for the average person to take to heart. According to another interviewee (R08), 'safety culture' now became a buzzword within the industry.

The first time the inspectorate came close to something involving culture was around this time, in the early 1990s'. Another interviewee (R08), being a smoker, told that they, while present in designated smoking areas, heard about problems coming from various areas at the Barsebäck NPP realising it was not just the employees at the MTO department noticing deviations, but colleagues in other departments as well. This resulted in Barsebäck being the first NPP to be put under special supervision from the inspectorate. When asked whether the Barsebäck event in 1992 affected their decision to put the power plant under special supervision, or if the event had cultural roots, the interviewee said neither because it was caused by design flaws. Regardless, Barsebäck needed to resolve the identified issues and when the time came to release the special supervision, the inspectorate performed a companywide inspection. In preparing for this, the interviewee trained 13 inspectorate employees in how to do interviews to capture 'safety culture' aspects. According to the interviewee, special supervision back then was something the inspectorate applied when they saw 'safety culture' related issues because it involved the whole organisation and its activities.

According to one interviewee (R04), a common understanding of 'safety culture' within their organisation did not start to emerge until around 1995 when the departments had conference-like meetings to discuss varying topics, including 'safety culture'. They probably did not use INSAG-4 or the yellow booklet, but the interviewee remembered that the meetings varied in how they approached the topic. Another interviewee (R06) remembered 'safety culture' being communicated widely during the 90's

and back then it was tightly coupled to nuclear safety and the importance of being thorough and conservative.

In another interview, the respondent perceived the work following the release of the SKISOS-report as stagnant, but the event at Barsebäck in 2003 changed that. According to the interviewee (R10), *that* event had cultural roots due to the organisation's lack of actions despite knowledge of the problem. The inspectorate saw the plant's lack of a clear stand on their operability during a prolonged period as something serious. Following the event, 'safety culture' was for the first time used in an injunction. The deviations were deemed so severe that the inspectorate also sent it to a prosecutor for indictment. However, the prosecutor did not like the use of 'safety culture' due to the inspectorate not having a formal requirement on the construct at that time. Barsebäck on the other hand accepted the inspectorate's argument of them focusing on production rather than safety, so they put in great efforts to strengthen their 'safety culture'.

Just three years later, in 2006, another event happened at Forsmark. Management had, according to an interviewee (R10), not acted in a 'safety culture'-focused manner, but rather put production first. The event resulted in another injunction that was sent to a prosecutor for indictment. This time, the prosecutor did not have an issue with including 'safety culture' even though there still was no formal requirement on the construct, which according to the interviewee, indicated a development regarding the view of the construct. The Forsmark event was mentioned by several interviewees (R05, R07, R09, R10) as a wake-up call for the Swedish nuclear industry, highlighting the importance of working with 'safety culture'. Not just at the power plants, but at the inspectorate as well.

Following the event at Forsmark, the 'safety culture' related work increased, but the organisations overall focused on production. It took many years to get heard, but slowly the power plants started to shift their perspective and the people working with safety culture involved others to be safety culture coordinators/ambassadors, helping facilitate workshops and trainings. The result was that non-technical traits were being discussed to a greater extent. Today, the industry is not as scared of the construct even though it is still confusing and hard to get heard sometimes.

The Fukushima accident in 2011 changed the perception of the construct. Before the accident, focus had been on the licensees, but the accident highlighted the regulator's role regarding 'safety culture', which resulted in the Swedish regulator starting their own internal 'safety culture' work.

Analysis

The analysis is divided into three main themes with accompanying 11 sub-themes highlighting the diversity and various perspectives on 'safety culture' meanings. The analysis describes core meanings attached to the construct while also including the lived experience through communicative activities and the continuous re-creation of meaning.

Safety Professionals Internally Created Meanings

The first main theme explains which meanings the safety professionals has created out of the 'safety culture' construct.

Overall Development of Created Meanings

The created meanings of 'safety culture' could, based on an overall understanding of the interview data, generally be divided in a 'before' and an 'after' the Forsmark event in 2006. Before, the industry relied on surveys and various kinds of traits. The yellow booklet, for example, highlighted prioritisation, professionalism, learning and quality as traits of a good 'safety culture' in the Swedish context. Both the Barsebäck event in 2003 and the Forsmark event in 2006 put focus on 'safety culture' within the whole industry. One interviewee (R01) said 'safety culture' was seen as something important in 2003 while many interviewees (R05, R07, R09, R10) deem the Forsmark event as an eye-opener. Reflecting on the stories told by the interviewees, the introduction of a more systematic way of working with the construct through various programs and initiatives seemingly led to a divide within the industry. The safety professionals started to develop a greater understanding of the construct reflecting an interpretivist approach while the rest of the industry to a greater extent got stuck in an interpretation reflecting a functionalist approach.

While the previous paragraph reflects a development in created meanings based on a general temporal context, there are also situational contexts for each interviewee. Even though their stories are personal, they share a general pattern. Many remembered the lack of proper introduction to the construct, that the first impression was confusing and "it did not feel obvious what it was" (R02_ID59). Initial meanings were created by adopting various traits, or follow-up on 'safety culture' activities, but they needed to learn through their own experience as well as other colleagues. Gradually, their perception of

the construct changed into something more complex and humbling, where culture is seen as a result, or consequence, of interactions and how the organisation works rather than a 'thing' the organisation has. One interviewee said, "you do something, and culture will follow" (R03_ID127), reflecting arguments provided by Antonsen (2009a) and Silbey (2009), who said 'safety culture' is constructed through complex social processes. The change in understanding was summarised by the interviewee saying "we have changed focus to leadership. Earlier, it was about shoving down traits into people's throats saying 'behave like this, live like this', but it is really about trust, reliability, and faith" (R03_ID125). What the interviewees share are personal experiences of adapting to uncertainties, trying to make sense of something confusing without much support.

Patterns Over Time

'Safety culture' was, by some interviewees, described as a thought system (R01), or a lens through which safety could be interpreted (R06, R07). It was also described by several interviewees (R01, R06, R09, R10) as varying patterns, favouring or disfavouring safety. One interviewee argued "there are so many things that are included in safety culture. It is a part of everything. Small symptoms…not just one error, but patterns" (R09_ID418). Another interviewee (R06), to exemplify, said it is not possible to draw cultural conclusions based on a single decision, but there needs to be repeated decisions over time made in various parts of the organisation to be able to talk about cultural roots. The interviewee highlighted the difficulty with this realisation, saying "If it is a long-lasting phenomenon of the kind we want to call culture, you are probably not aware of it because of the normalisation that occurs. It becomes normal" (R06_ID272). This reflection, again, captures Antonsen (2009a) and Silbey (2009), but also, Reiman & Rollenhagen (2014), who argued Diane Vaughan (1996) showed cultural patterns contributing to the Challenger accident in 1986, where small changes gradually became the norm. So, with culture being a long-lasting phenomenon, it is likely that organisations do not know when culture changes, because it is a continuous, socially constructed, process.

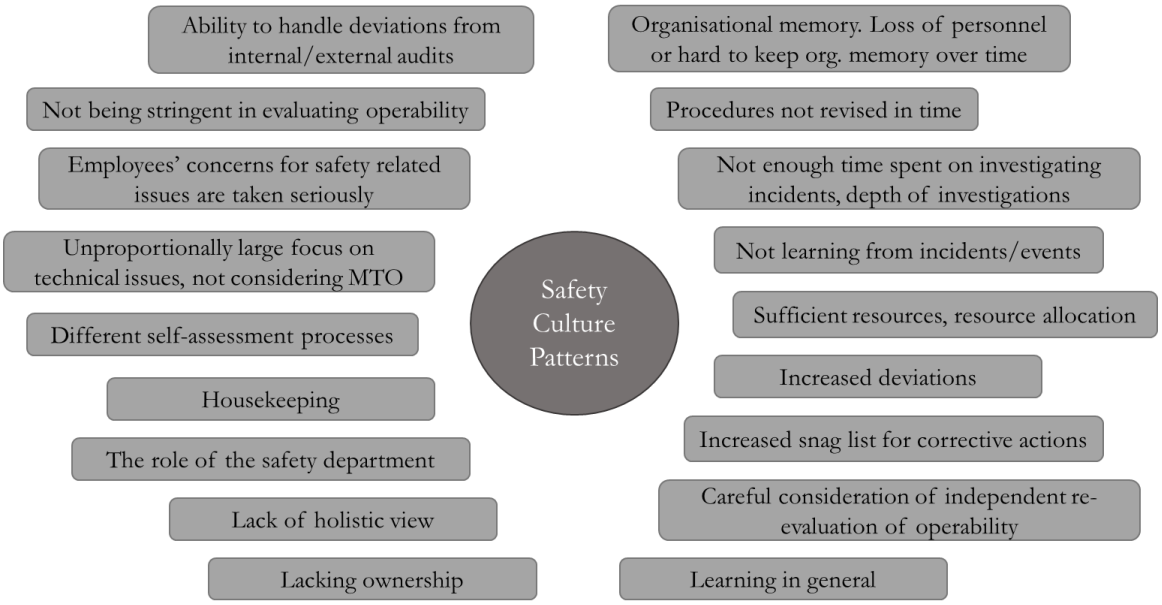
One interviewee (R09) expressed that various symptoms of culture can be identified in everything, and reflecting on that statement makes it clear that it is only the symptoms that are exposed and not culture in itself, which is something that lives, covert, inside the organisation. These symptoms are,

according to the interviewee (R09), collectively called 'safety culture' and using 'safety culture' as a collective term does not take away from the experienced symptoms as long as the symptoms are called by their right name. This statement contradicts Sherratt et al. (2025), writing that when something is said to be everything, it is nothing, suggesting further research on the separate dimensions rather than 'safety culture' as the holy grail. This interviewee, on the other hand, argued that the use of 'safety culture' forces the organisations to think bigger and take holistic ownership of their operation rather than focusing all attention on one symptom.

After the Barsebäck event in 2003, the inspectorate started to reflect on what cultural aspects were present in their observations at the licensees. Collecting these kinds of symptoms was not fully systematic but following the event they started to systematically collect information on various cultural symptoms (see Figure 13). After the Forsmark event in 2006, the inspectorate realised the importance of being present at the power plants to collect cultural symptoms and to be able to build these patterns over time. The inspectorate's intention was to identify possible underlying assumptions in the organisations, and whether social phenomena could explain what they were observing, while simultaneously acknowledging an individual making an error is not culture. One interviewee, employed by the inspectorate at this time, said "it is important not to draw hasty conclusions based on individual errors and call it culture. It is not a catch-all, but it is easy to put that label on it" (R10_ID444). This indicates an awareness within the inspectorate of trying to avoid the risk of 'safety culture' becoming a sort of responsibilisation of the work force (Silbey, 2009) while additionally acknowledging that an emergent property, like 'safety culture', cannot be found in its constituent parts (Leveson, 2011).

Figure 13

Examples of 'safety culture' symptoms used by regulator to build patterns (extracted from interviewee R10).



In 2008-2009 the regulator[3] noticed varying issues at Ringhals and chose to act before something happened, putting the power plant under special supervision. According to a former regulatory employee, they had not been able to act proactively in 2003 and 2006 but in their systematic way of collecting symptoms to build patterns, the regulator felt they could act assertively and with confidence.

The idea of patterns brought forward by the interviewees is interesting due to its multiple parallel dimensions approach. *Several* symptoms in *various* parts of the organisation need to have been evaluated *over time* in order to speak on cultural roots. These patterns also need to reflect underlying assumptions possibly impacting the organisation's treatment of safety related issues for it to be indications of *'safety* culture'. These symptoms, collectively called patterns, is reminiscent of what Grote & Weichbrodt (2013) call manifest problems.

[3] In 2008, the Swedish Nuclear Power Inspectorate ('the inspectorate') and the Swedish Radiation Protection Institute merged into what today is the Swedish Radiation Safety Authority ('the regulator').

MTO and Systemic View

MTO was coined before Chernobyl and became a central concept in the Swedish nuclear industry. Even after Chernobyl, MTO functioned as a pillar for human factor related issues and, according to one interviewee, around 1998-99 "MTO was the perspective in which safety culture was included" (R09_ID385). There is no dispute about there being a connection between MTO and 'safety culture', but the interviewees' perception of that connection varies. One interviewee said, "MTO and safety culture could be seen as siblings" (R04_ID170), and another interviewee, previously employed by one of the licensees, provided a more in-depth reasoning on the connection between MTO as a systemic view and 'safety culture', saying:

> Personally, I separate between systemic view and culture. You need a systemic view to enable a good safety culture, but it is not the same.… It helps us understand functional or dysfunctional interactions. Those interactions are not only connected to us humans, but the whole system. (R01_ID01)

By calling for identifying systemic structures that shape behaviour as means to improve culture, Goh et al. (2010) similarly hint to a connection between systemic view and culture while also recognising they are not the same. A complementary reflection came from a third interviewee who said, "to be able to achieve the level of safety we want, and what shapes our safety culture, we need to understand what contexts look like" (R06_ID292). The understanding of context in relation to 'safety culture' reflects an interpretivist approach in where culture *is* the context (Reiman & Rollenhagen, 2014).

One of the interviewees (R02) thought of MTO as a more pedagogical way of talking about safety and to concretise the otherwise diffuse or vague culture construct. When interacting with the organisation, the interviewee felt it was easier discussing human, organisational and technical factors and how these interact. According to another interviewee (R05), the main interest is in structures, how various needs are described and what goals the organisation is trying to achieve. Structures, needs and goals could all be related to the MTO concept and are all factors that shape 'safety culture'. Thus, 'safety culture' is, according to a third interviewee (R06), hard to adjust in any direction through specific 'safety culture' activities. It is rather the working prerequisites that need strengthening which will impact culture over

time. These statements correspond well with Reiman & Rollenhagen (2014) who argue that a systemic theory is needed to capture 'safety culture' in the context of the sociotechnical system. In Sweden that equals adopting a MTO perspective on various structures and processes because "MTO is systemic view" (R08_ID362).

When asked about interpretivist and functionalist views of 'safety culture', most interviewees recognise that culture is something organic, born out of interactions, but they do not discard the functionalist approach completely. Putting the perspectives against each other is not a reasonable solution as the interviewees think some sort of guidance and structure is needed for pragmatically working with the construct. They do, however, recognise that it is not possible to decide what the culture should look like and make people behave in a certain way.

'Safety Culture', or Safety and Culture?

Several of the interviewees (R03, R05, R07, R08) mentioned a shift in semantics, talking about a 'culture for safety' rather than 'safety culture'. Although not everybody thinks it adds value, one of the interviewees argued "many start with discussing the difference between safety culture and organisational culture. Is safety culture the whole or a part? You avoid that by saying it is the present culture in the organisation that must promote safety" (R08_ID370). Another interviewee said:

> Safety culture might not be anything at all. We talk about a construct and assume everybody knows what it is, but it might not be culture we are talking about. So, we started to play around with 'culture for safety' instead (R05_ID209).

A third interviewee (R09) acknowledged that there is no value in using 'safety culture' as a stand-alone term because further explanation of the symptoms is needed for it to be understandable. Reflecting on these last statements, they resemble the argument about folk models whose value "hinges on their common-sense appeal rather than their substance" (Dekker & Hollnagel, 2004, p. 80). However, a fourth interviewee said, "what we are trying to realise with the safety culture construct is important for a safety critical organisation" (R07_ID317) and, according to the interviewee, it does not matter what it is called if the organisations experience safety related problems.

Based on the idea that 'safety culture' is a result of interactions and how the organisation works, made visible through various patterns, many (R01, R03, R06, R07, R08, R09, R10, R11), but not all interviewees, said that culture 'just is' rather than something that is inherently good or bad. They instead expressed a view where the existing culture to a varying degree fosters safety in relation to conflicting goals such as production, very similar to Silbey (2009) who said we need to explore how competing interests are part of the process in creating culture. The interviewees seemingly differentiate between safety and culture, approaching these constructs as separate entities while also recognising the relationship between them.

Some of the interviewees (R03, R05, R07) also mentioned that they have questioned 'safety culture' altogether, whether using the construct adds value. In the end, the interviewees agree that it would be too difficult to stop talking about it, contrasting Hopkins (2016) and Sherratt et al.'s (2025) argument, and that it does add value. Even though 'safety culture', or 'culture for safety', is hard to explicitly frame, the construct is needed to highlight non-technical aspects of safety. This argument was also brought forward by Le Coze & Wiig (2013), who said the use of 'safety culture' is pushing organisations to explore issues that they otherwise would not, and making managers and workers think about a soft side of safety has made the construct beneficial (Reiman & Rollenhagen, 2014). Studying 'safety culture' in a Swedish context, this argument could also be connected back to the Swedish model. The regulatory use of 'safety culture' enables the regulator to avoid involving themselves in details, forcing the licensees to perform self-assessments to better understand how their organisation works, keeping the responsibility of safety where it belongs. In that sense, 'safety culture' could be used as a tool to create awareness and reflect ownership or as "a conceptual label denoting the relationship between culture and safety" (Antonsen, 2009b, p. 1119).

Even though 'culture for safety' could be just semantics, as one interviewee (R10) expressed, it captures an underlying, or created meaning that safety is the core of the nuclear industry and that the culture(s) present in the organisations should be discussed *in relation* to safety. It seems like what the interviewees are trying to say is that safety and culture are separate entities altogether and shifting semantics might make it easier to understand that separation. By using 'safety culture', safety and culture

are mixed into a single large construct resembling Goliath which might add to the confusion surrounding the construct. By mixing them it might also be harder to avoid normative language like 'good' or 'bad' instead of talking about the relationship *between* safety and culture and its various, non-dichotomous, qualities.

'Safety culture', in general, is a difficult construct to operationalise, and two interviewees (R07, R08) said it is a construct that contains two difficult concepts: safety and culture. One of them argued that both make it hard and even though safety to a greater extent could be problematised, it is probably culture that has done the most damage and that has been abused the most due to multiple approaches and varying interpretations, or definitions. This statement was not elaborated on further, but it might reflect 'safety culture' being seen as a catch-all for non-technical issues, much like Grote & Weichbrodt (2013) when they say combining safety and culture has provided an easy way out as a catch-all construct.

Safety Professionals' Perception of Conveyed Meanings

The second main theme explains what meanings the safety professionals have tried to convey to their respective organisations through various communicative activities and dialogue, while also examining the reception by these organisations.

Measurements as Representation of Meanings

From 1986 and up until early-mid 2000's, many seem to have given 'safety culture' meaning through survey averages, measurements and making sure the response rate was as high as possible. According to one interviewee (R06), that reflects a basic level of analysis, but even with a basic level of analysis, it created something of value to discuss in their organisation. However, the organisations were struggling with what to do with the results, initiating deeper analysis of the averages as a way of helping the organisation, moving away from surveys only being a numbers exercise. Some also started to question what it is they measure as climate is closely connected to culture, an issue also brought forward by Choudhry et al. (2007), Cox & Flin (1998), and Glendon & Stanton (2000) who said these terms are often used interchangeably, and Cooper (2000) who said safety climate is sometimes used as a surrogate measure to 'safety culture'. Today, one of the NPP's has enhanced their survey and all NPPs complement their

surveys with interviews and/or focus groups, aligning with the qualitative methods mentioned in the literature (Choudhry et al., 2007). 'Safety culture' today is said to be evaluated rather than measured and one interviewee (R01) argued that the data should be analysed with the intention to understand the underlying meaning in a non-normative, or neutral, manner to create a cultural understanding.

Efforts to Convey Meaning

To be able to convey meaning, or help the organisation in *their* process of creating meaning, some of the interviewees (R01, R02, R05) describe the need to simplify the construct. In many instances, other concepts such as MTO have been used as a surrogate in various activities. Short messages have been displayed on posters and table talkers, while also using networks of 'safety culture' ambassadors/coordinators to connect the construct to members of the organisation. 'Safety culture' programs have been used as a means of showing that isolated activities are not sufficient, but what is needed is a continuous and systematic approach. Three of the interviewees (R01, R07, R08) also mention Edgar Schein's model (see Figure 3) as a way of making sense of 'safety culture' as a construct. According to one interviewee (R01), the model is good despite simplifying something highly complex.

Even though artifacts such as posters and table talkers have been used, they change nothing. What is needed is, according to an interviewee (R06), dialogue in the contexts of the employees to make it meaningful, and to be present in the organisation. One interviewee, for example, said, "it was about doing missionary work, and to get the message across, clarify and simplify to stay concrete" (R02_ID70) while another said it is "continuous reconnaissance work" (R10_ID464). It is important, however, for such missionary, or reconnaissance work to not be unidirectional where the safety professionals deliver a message, but to be open for dialogue. Reciprocal dialogue could help capture the essence of daily work and to identify what makes work hard for the employees.

Some say they have started to focus their efforts on managers to ensure safety is present in all activities. The largest impact is created "in the bluntest of the blunt end" (R10_ID451) and focusing on the senior management could give "the most bang for the buck given that they listen" (R10_451). The interviewee mentioned inviting Sidney Dekker to facilitate a workshop with the senior management group,

saying it can sometimes help to involve a recognisable world name to get the support needed. Getting management's attention can, thus, be challenging, but keeping the dialogue on 'safety culture' alive introduces other obstacles. Safety professionals engage in conversations with managers and gradually, the managers' understanding of the construct increases, and attached meanings change, but it is described as a step-by-step process. One interviewee (R05), for example, said they got the advice to only say one thing at a time to not lose the audience's attention which, in the long run, is very time consuming.

Obstacles are not only present in the organisations in which the safety professionals work. Operationalising theoretical concepts has in some cases been, according to an interviewee (R02), met with criticism from other safety professionals as well due to these simplifications not being comprehensive, overlooking important aspects. Adapting to the organisation and finding a balance between theory and conveying a complicated message lead, for some, to a feeling of never being content because the work felt forced. Sometimes, these compromises even led to nothing at all instead of doing something that was not perfect.

Conveyed Meanings

Many of the interviewees (R02, R03, R04, R05, R06, R07) use WANO's 10 traits as an introductory framework, or as a baseline to show what could characterise a good 'safety culture', trying to bring simplicity and practicality to something complex. They are trying to problematise and talk to various decision makers to challenge their understanding of the construct. One interviewee (R05) argued for the need of bringing in theories stemming from anthropology and sociology into the 'safety culture' work but recognised the difficulties already existing with theories rooted in psychology and cognitive or behavioural science. These theories are, according to the interviewee, too far from engineers in language and mental models. Another interviewee also recognised their own contribution to the gap between safety professionals and the rest of the organisation when saying "it sometimes felt a bit elitist and too much theorising…. Sometimes it was hard to stand by theories when talking to someone from the organisation who said 'this is how reality works'" (R02_ID74-75). Some of the interviewees have found ways to avoid making 'safety culture' too theoretical. One (R01) mentioned small changes in language to convey a message, for example using 'areas for improvements' instead of 'corrective actions' to showcase culture is

not a quick-fix. Another interviewee (R05) spoke about trying to connect 'safety culture' meaning to other buzzwords such as organisational efficiency as a way of amplifying what they are trying to achieve, which is 'safety culture' as an integrated perspective.

Many interviewees (R01, R03, R06, R07, R08, R09, R10, R11), in accordance with Goh et al. (2010), Grote & Weichbrodt (2013) and Antonsen (2009b), believe they should be working with what could *impact* 'safety culture', rather than 'safety culture' itself. The greatest impact is not achieved through 'safety culture'-targeted activities, but rather how the employees, especially managers with influence, act, treat and communicate safety related issues. 'Safety culture' becomes visible in organisational structures and work processes, but trying to change culture, it is not enough to change structures and processes by re-drawing the organisational chart. Cultural change, according to an interviewee (R08), comes with changing the thought processes that created the structures as well. To succeed, the organisations need to rethink their approach to safety by creating prerequisites for new organic development and to work with new basic assumptions and values. Leadership is key because it is the leaders who need to convert assumptions and values into action.

It is also important to make managers aware of what signals they are sending by how and what they communicate. Managers show employees what is important by focusing on varying problems, and "people do what they know is going to be followed-up" (R04_ID164). This connects to a statement from another interviewee who said "you get the safety culture you deserve" (R03_ID135). People will notice signals, what is being rewarded, and they adapt according to the law of least resistance (a blink to Rasmussen, 1997). If management want green indicators, the employees will deliver green indicators because delivering according to what is requested becomes a sort of survival mechanism. One interviewee (R03) saw this tendency when analysing survey results. According to the interviewee, employees tend to answer more favourably in surveys because they do not want to put effort into working with weak survey outcomes.

Reception by the Organisations

Working with 'safety culture' is, according to one interviewee (R01), always a 'we-work'. They said safety professionals need theoretical depth but are usually lacking the technical knowledge needed for credibility and to connect the construct to the rest of the organisation. Bridging the gap by involving others is also a way of building internal capacity that could function as a lever in 'safety culture' activities, but due to the gap in language and mental models, involving others in 'safety culture' related work has been hard because e.g. maintenance and operations, whose work are generally more controlled by procedures and rigid structures, are not used to working in such a dynamic and flexible way.

'Safety culture' has been treated by the organisations as a technical component like any other, and "if it does not work, we tweak it until it works" (R05_ID234) which, according to the interviewee, is not the way to treat 'safety culture', but it reflects a common belief. Another interviewee argued that "safety culture is done in a calculative way because the nuclear industry has always been requirements-driven, trying to fulfil requirements and tick boxes" (R03_ID148). Even guidelines from e.g. WANO get requirement status and 'safety culture' activities become a means to an end. Because it is impossible to put a number on 'safety culture', it is hard for engineers to approach the construct. What the interviewees are experiencing might reflect a very 'matter-of-fact' approach to 'safety culture' within their organisations, maybe even literal interpretations of written descriptions. The safety professionals on the other hand understand culture as having several dimensions where this dichotomous thinking in terms of good/bad or fixed/not fixed does not fit.

'Safety culture' has generally not been seen as a prioritised area and many of the interviewees (R01, R02, R03, R05, R06, R08), expressed frustration when it came to convincing the rest of the organisation of the importance of working with 'safety culture'. One of the issues is that "there is not enough time, resources or willingness to do something if the regulator has not said you must or if there has not been an accident" (R03_ID50). The interviewee said "it has been a battle trying to convey an argument to someone with a more digitalised view of the world. Behavioural science has not been seen as a science by engineers, but instead as borderline nonsense" (R03_ID119). The 'safety culture' construct has been disliked, probably because it is not properly understood. Being a safety professional is in that

sense lonely and not even the regulator is immune to this treatment. According to an interviewee (R10) previously employed by the regulator, the MTO unit was not initially included in handling the Forsmark event because the cause was deemed technical. They had to fight their way in, and the end result showed mostly organisational issues.

Safety professionals can plan activities to increase the understanding of 'safety culture' in the organisation, but if managers do not believe in these activities, the effects will not be as intended. The senior management set prerequisites for the whole organisation and "if you are working with safety culture further down, a decision from the top has the possibility to overthrow these efforts" (R10_ID457). Another interviewee acknowledged the role of the Managing Director, saying:

> In Sweden, the Managing Director bears the license to operate and is responsible for safety. If the Managing Director does not have proper understanding of what is needed to fulfil that responsibility, it becomes impossible to impact from further down in the organisation because intentions clash. If understanding from the top do not match intentions coming from beneath, even guerrilla tactics do not work. (R05_ID242)

This is why many of the interviewees say they are targeting managers in their 'safety culture' efforts, but some say many managers do not want the responsibility that comes with working with 'safety culture'. One interviewee reflected on this issue saying:

> The only way to develop their career is up the management hierarchy. They chose education based on their interest, which was hardcore engineering, not necessarily including human sciences. Suddenly, they must forget about what initially interested them to instead develop interest in issues that might not have been of interest from the beginning to be able to be a good leader. (R08_ID374)

The seemingly strained relationship between safety professionals and the rest of the organisation, as described above, might be due to the difference in mental models when it comes to how the world is understood. Another interesting factor raised by one interviewee (R03) is the origin of the 'safety culture' construct. Twenty years ago, it was very stigmatised and loaded and to hear 'you have a bad safety culture'

was almost understood as 'you are Chernobyl'. The stigma surrounding the construct might indicate the ethical undertone described by Reiman & Rollenhagen (2014), where weak 'safety culture' sometimes can be considered bad or evil. According to the interviewee, working against that perception was very hard and it felt almost like "being smeared in poo and people became uncomfortable" (R03_ID142).

Today, the industry is not as scared of the construct even though it is still hard to get heard sometimes. One interviewee (R02) said they got time at the table at various management groups, including the senior management. People started to listen and included the 'safety culture', human factors, and MTO-perspectives. A 'safety culture' training for two full days was approved for all new employees at one power plant which, according to the interviewee, showed the senior management invested a lot of time for 'safety culture' improvements. Even though its nature might have shifted to greater acceptance, integration of 'safety culture' related work or ideas is still lacking and the spontaneous response of saying 'lack of safety culture' still exists in the nuclear industry because if people are involved, it must be culturally related. The construct is, according to several interviewees (R03, R05, R06, R08, R10), used in a sloppy way, sometimes as a personal trait for people making mistakes. It has become convenient to use for everything non-technological and, according to these interviewees, the construct has become a catch-all for everything human, a strong label that tars everyone with the same brush, not understanding the existence of sub-cultures.

Re-Creating Meanings Based on External Influences

The third main theme explores what external influences that might have impacted both internal and external created meanings.

Accidents, Industry Organisations and Academia

Accidents and events have historically put focus on non-technical issues such as MTO and human factors. TMI paved the way for MTO in Sweden and Chernobyl highlighted 'safety culture' while Forsmark and Fukushima reinforced that idea. In the USA, the Davis Besse event in 2002 served as their wake-up call which, according to some of the interviewees (R01, R03), resulted in WANO releasing their first guideline on 'safety culture' in 2006. One interviewee said "it happened in the USA, so they could not

blame the Russians" (R03_ID146), UNO-reversing the West playing the 'culture card' in a political way following the Chernobyl accident (Busch, 2021).

Besides accidents and events, multiple interviewees have participated in meetings hosted by IAEA and WANO, but also industry specific forums shared by the Nordic countries such as Human Performance and Safety Culture' (HUSC). The interviewees also acknowledged academic influences such as Edgar Schein, James Reason, Erik Hollnagel and Sidney Dekker, while also mentioning influences from their close colleagues.

Regulation

Working with human factors-related issues following TMI, one former inspectorate interviewee (R08) experienced difficulties in getting the industry's attention. The Director General ordered the formation of a steering group for MTO within the industry to gain a common understanding for these issues. Gradually, the understanding increased and after two years, the group dissolved. The Chernobyl accident also made it easier for the inspectorate to argue for the importance of working with organisational factors, but they did not talk explicitly about 'safety culture' following the accident.

In the 1998 regulations, the inspectorate included 'safety culture' as a prerequisite for an effective defence-in-depth. When updating their regulations in 2004, one interviewee (R10) working at the inspectorate at that time said they discussed writing a formal requirement on 'safety culture' but the industry was deemed not mature enough. The regulator did not want to put a formal requirement on having a 'good safety culture' and was instead inspired by IAEA when formulating today's requirement. IAEA writes about promoting 'safety culture' through the management system, and the regulator felt it was suitable and chose to put it into writing in 2017 as a formal requirement. Putting it in the regulations was, according to a regulator interviewee (R09), also a way of making their inspections stronger.

The way the regulations are written, according to an interviewee (R06), reflects a systems view by the regulator, not intervening in details but rather seeking to see a systematic approach to the construct. The Swedish regulator has been in the forefront, showing the way for the rest of the industry regarding 'safety culture' and MTO. They were the first hiring human factors competence and having up to 13-14

human factors specialists has been unique compared to the rest of Europe. The regulator led the way "pouring holy water on these issues which had a positive influence" (R03_ID140). Many of the interviewees (R01, R03, R07, R09, R10) mention the important work of a specific individual and their role in cementing 'safety culture' and MTO into the Swedish nuclear industry. This individual has been a pioneer, paving the way for the industry. Reflecting on the regulator's role in general, and this individual's pioneering work in particular, this study emphasises the importance of strong voices, grit, determination and the power of pioneers to change, or influence, an industry.

Many of the interviewees (R03, R04, R06, R07, R09, R10, R11) describe the relationship between the regulator and the licensees as good with a mutual respect. The relationship is largely built on an open dialogue which requires trust, and some interviewees (R07, R09, R10) acknowledged the relationship's possible impact on the licensees' 'safety culture'. Whatever the regulator focuses on in their inspections, the licensees put in resources to fix. The regulator is highly aware of their potential impact, but the impact is mutual, and the licensees could, according to a regulator interviewee (R09), have an impact on their 'safety culture' as well.

Some interviewees (R07, R10) have noticed a pattern in recent years where the dialogue has decreased and become more formal. The Swedish model has become more dismantled when more lawyers are hired at both regulator and licensees. One interviewee (R07) said they had a feeling of both licensee and regulator being increasingly more scared of over-sharing and another interviewee (R10) said there might not always be a willingness to keep the dialogue going. This issue was not elaborated on further, but bringing in lawyers might give a more legal touch to the collaboration between regulator and licensee which might impact what they feel they can share with each other.

The Role of the Management System. The regulator requirement on 'safety culture' generally says that the management system shall support a culture where nuclear safety issues receive the attention warranted by their significance. When asked about the role of the management system regarding 'safety culture', some interviewees (R01, R06, R08, R09, R11) said that it is supposed to be a supportive tool for managing the organisation. The management system describes the 'when, where, and how', and it also interprets regulations and requirements to make it easier for the personnel to navigate daily work. Its

purpose is to make it easier to understand how various parts of the organisation and its accompanying tasks fits together. An integrated management system is, according to one interviewee (R08), a system that prioritises safety while also helps the organisation achieve quality and finance goals, etc.

The purpose of the management system in relation to 'safety culture' is to help make the construct an integrated part of all activities, so it does not become side-tracked. One interviewee (R07) said the connection between the management system and 'safety culture' is strong if the system is integrated, up to date, continuously improved and if it manages and steers the organisation *for real*. If the management system is written in accordance with a sort of 'pink world', describing how things *should* be, then it will not be the supporting tool it was meant to be. However, another interviewee (R06) acknowledges that the management system will not solve issues, but it is rather the organisations' abilities to act, cooperate and communicate.

The document review revealed that the management system has an important role in relation to 'safety culture'. Many guidelines and requirements focus, partly, on the written ideal. Some normatively describe what 'good safety culture' ought to look like while others argue for an integrated management system. What is interesting in this case, reflecting on the interviews, is the perception of the management system as a tool to support safety. Another interesting aspect is the regulatory requirement, seemingly separating safety and culture, as discussed earlier. The written requirement might imply an organisational culture in which safety is deemed important.

Politics

WANO's 10 traits have become accepted within the industry and even though WANO is not at the forefront of 'safety culture' research, using their traits was, for some interviewees (R02, R05), a way of legitimising what they were doing. Signing up for a WANO membership is partially a political move and according to one interviewee (R05), the NPP's do not even want to consider *not* being a WANO member. As a member, the NPPs are expected to use and implement available guides, including 'safety culture', thus WANO holds a lot of power in deciding how to approach the construct. Even though the safety professionals might not agree, it is hard for the rest of the organisation to see through the limitations

brought forward in the WANO guideline. It has been mentioned a couple of times throughout this analysis that the safety professionals have brought in international support as a way of getting the organisation's, or the industry's, attention. What this implies is that an external party is needed when these organisations do not pay enough attention to internal voices. WANO, being an external part, holds more power than these safety professionals ever can achieve. However, it is not an external part brought forward by the safety professionals, but by the international nuclear industry which is hard to fight against.

An example from an interviewee (R02) highlights this issue. They said they felt forced to show results because they felt questioned about what they really brought to the organisation. In doing so, they used the traits in an attempt to tag information in the reporting system as a way of measuring 'safety culture'. Not because they wanted to, but they felt the outside world demanded it. The same interviewee (R02) shared another example showing pressure from the owners. The owners wanted them to develop a scale, or gradient, for 'safety culture' forcing the interviewee and their colleagues to formulate parameters to measure. The owners said 'safety culture' needed to be concrete. The interviewee felt it was hard to relate to pressure from the top, resulting in compromises.

These two examples concretise many issues described in this analysis. The safety professionals' continuous adaptions and compromises, their view not being respected forcing them to use WANO's framework for credibility, and measuring something that, in their mind, cannot be measured. It is a challenge trying to integrate 'safety culture' and MTO without it being perceived as something that needs to be done solely due to regulations or to fulfil membership commitments. The organisations are forced to think in a certain way because WANO has described it as X or Y which to some degree dictates how the organisations relate to the construct, contradicting the safety professionals' own beliefs. One interviewee said "safety critical organisations where safety culture is important have a sort of engineering driven power, thus the power which decides and sets the rules and routines" (R07_ID299). Because the NPP's are technical organisations, the focus, according to another interviewee (R05), is not to understand what 'safety culture' is but rather treat it as something you can smear to solve problems. A third interviewee (R01) said there are a lot more politics in nuclear nowadays. Countries that used to be strong

have started to become more politicised where people who do not know anything about nuclear or 'safety culture' start working within the industry.

Power is something rarely addressed in 'safety culture', or safety science research (Antonsen, 2009a; Dekker & Nyce, 2014) and this study shows indications of power in the nuclear industry as well. Power relations that probably need addressing at some point.

Discussion

Literature Review

Searching for 'safety culture' in Scopus gives more hits than one can handle manually within the timeframe of doing the thesis. Sorting by citations for the narrative review and choosing a fixed number to apply inclusion/exclusion criteria was good in the sense that the papers most relevant to the topic in general were, probably, captured. This method, however, did not capture niche areas within the 'safety culture' discourse that were of importance for the research question. One example is the connection between 'safety culture' and systemic view. The systematic review result was narrower and included more applied research than theoretical discussions which therefore complemented the narrative review.

Methods

Regarding the review of industry documentation, it was important to not only find the current version of each document, but older revisions as well, because the temporal aspect is part of the research question. IAEA has marked their documents making it easy to find older revisions, but for regulations it is harder. Due to the merge between two regulatory bodies in 2008, old regulations were hard to access because the current regulator only has their regulations tracing back to 2008 available online. Older versions were accessed through one of the licensee's documentation system and one was provided by one of the interviewees. The extensive documentation on written 'safety culture' meanings within the industry turned out to be too large to also analyse with the provided time frame of this thesis. The documentation would probably provide sufficient data to enable a full thesis on documents alone.

The biggest challenge regarding the interviews was to find people to be able to connect the lived experience all the way back to 1986. Having a network in the industry helped identify people working with 'safety culture' 35-40 years ago. The interviewees collectively cover 1984 to present day, which would have been harder with fewer interviewees. The eleven interviewees were all safety professionals who were or had been working with the construct, so the created meanings are limited to a rather small group of people. Even though the choice was intentional to enable reflections beyond surface level, it introduces a limitation. Culture is not homogenous and free from conflict (Antonsen, 2009a), and attached meanings

are probably not either, but only one group of people were interviewed, excluding other possible sub-cultures or meanings. Silbey (2009) says that competing interests as part of the process in creating culture need exploring, and similarly competing interests need to be explored when trying to understand culture. Even though this study identified some competing interests in the gap between safety professionals and the rest of the organisations, only one side was heard.

'Safety culture' is a large topic with many possible aspects or angles to cover making it challenging to, during interviews, fully know whether the depth of the dialogue would be sufficient for the research question and phenomenology as a methodology. It really was a 'trust the process' kind of situation where the depth was made visible when going through the whole dataset. Looking back, previous experience with performing interviews gave an advantage in having that trust, but also the patience to rely on the plan and to follow through.

Phenomenology, as presented by Dahlberg et al. (2008), does not have fixed steps to follow, for either formulating interview questions or performing the analysis, so much is left to the researcher to figure out. The methodology rather provides general principles and overall guidance. Having an open approach results in both positive and negative side effects. It is positive because it provides flexibility and a possibility to adapt to the phenomenon being researched. It is negative because, for someone new to the methodology, it is not until the end that there are indications of whether various choices were successful or if there is a need to go back and re-do parts of the process. This is mostly due to not knowing what to expect when examining a phenomenon and not knowing if the responses given in interviews will help provide clarified meanings. Initially, there were doubts and thoughts about changing the interview approach, but it all came together in the end.

Synergy of Findings and Analysis

The following discussion includes a holistic perspective on the findings and analysis, adding what the underlying meaning of 'safety culture' within the Swedish nuclear industry possibly could be. Arrival at a new whole, if you will. It also includes reflections on whether or not 'safety culture' is something to still

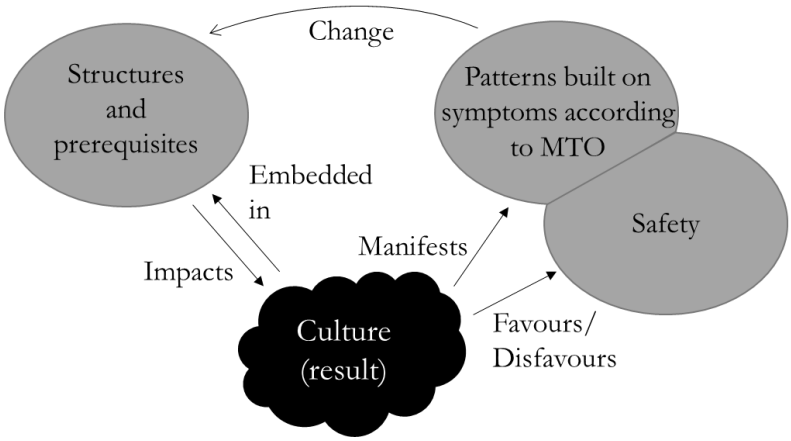
pursue and the difficulties of trying to apply non-technical aspects of safety in organisations where engineers hold a lot of power.

Arriving at a New Whole

The purpose of this study was to examine what meanings the Swedish nuclear industry has created out of the 'safety culture' construct. The results highlight that the industry from the start connected culture to MTO, a systemic view on structures and prerequisites for safety. These structures and prerequisites will, over time, shape the organisational culture(s). Thus, culture is the result of how the organisations work (see Figure 14). Culture is covertly embedded in our social processes and structures (Reiman & Rollenhagen, 2014), which hints at a reciprocal relationship similar to the arguments provided by Antonsen (2009a) and Silbey (2009) who said that most researchers now see culture as both a product and a process. Culture shapes our processes but is at the same time shaped by them as well.

Figure 14

Culture in relation to safety.



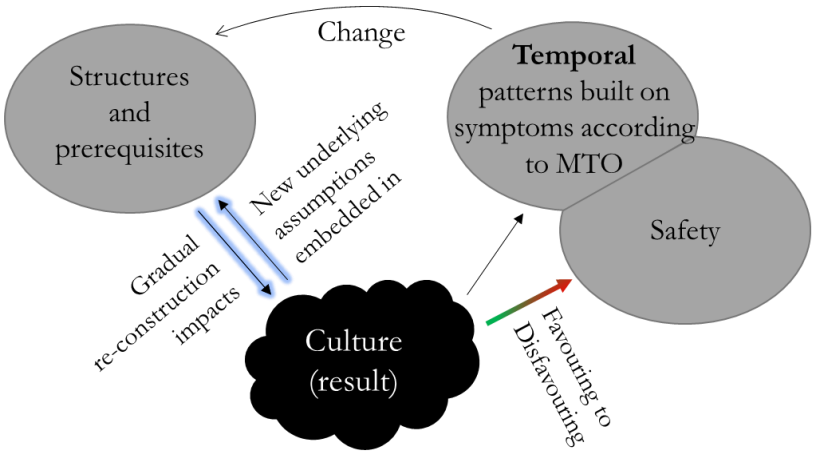
When the interviewees spoke about symptoms as a manifest for culture, they mentioned varying factors that easily could be connected to the MTO concept (see Figure 13). However, a personal reflection is that MTO reflects the *current* context, while the interviewees also spoke about the importance of time to be able to visualise temporal patterns and not just situational patterns. What if the meaning of 'safety culture' in the Swedish nuclear context could be described as MTO with an added temporal aspect? Various emerging symptoms, connected to the MTO concept, brought together as a way of identifying

situational patterns, but analyses or evaluations of these situational patterns over time make it possible to identify temporal patterns, i.e. manifestations of culture, as well. It could be described as creating meaning of something hidden through the use of MTO as something familiar.

The results of this study strongly imply that the safety professionals within the Swedish nuclear industry differentiate between 'safety' and 'culture'. The interviewees instead argue for a relationship between these concepts in which culture to a varying degree can favour safety. By trying to identify and understand emerging patterns, it might be possible to evaluate *the relationship* between culture and safety and its various qualities. However, such evaluation is not straightforward because of normalisation, i.e. the gradual re-construction of what *normal* looks like (Vaughan, 1996). Gradual re-construction might slowly change structures, impacting culture, resulting in new underlying assumptions being embedded in our daily context (see Figure 15). Normalisations that occur might gradually turn the relationship between culture and safety from favouring to disfavouring (and vice versa) without the organisation's knowledge. The temporal aspect is key in trying to identify how structures and prerequisites have changed over time, resulting in re-constructing safety as well.

Figure 15

Normalisation impacting the relationship between culture and safety.



Note: Blue arrows indicate where the normalisation happens, and the green and red arrow shows a gradual shift from favouring (green) to disfavouring (red).

Based on this reasoning, the results in this study show that the use of 'culture for safety' instead of 'safety culture' might be something of far more value that exceeds the semantics. It could help the industry in their sensemaking process moving forward, keeping culture and safety separated while instead talking about the relationship between them. The approach to working with the construct might also change, moving from activities targeting culture directly, to instead target structures and prerequisites, just as Goh et al. (2010), Grote & Weichbrodt (2013) and Antonsen (2009b) suggest. The safety professionals interviewed are seemingly further ahead in this thinking and understanding, but the industry as a whole needs to follow.

To Be or Not to Be

Is 'safety culture' something that should be abandoned and removed from the safety science lexicon (Hopkins, 2016; Sherratt et al., 2025)? The answer to this question is probably twofold. From an academic point of view, there seems to be more confusion than clarity surrounding the construct. It is reminiscent of folk models where other concepts are needed to explain the main concept (Dekker & Hollnagel, 2004). 40 years after its introduction, there still is no consensus of its meaning or definition, so to still pursue some sort of agreed clarity from a theoretical standpoint looks fruitless.

From a practical and applied point of view, the results from this study show that 'safety culture' as a construct *is* useful, in part because it forces the industry to think about non-technical aspects of safety. That contribution should not be easily overlooked because it adds value. Another aspect is the regulatory use of the construct. From the interviews it is clear that the Swedish model is central to the nuclear industry where the relationship between regulator and licensees is built on mutual trust and respect. The responsibility for safety is and has always been with the licensees but listening to the interviewees, the regulator has found a way of not intervening in a disruptive manner but rather carefully using their authority to enable open communication while also acting assertively if deemed necessary. The regulatory use of 'safety culture' is vague enough to make the licensees for themselves analyse issues to gain greater understanding of what is happening within their organisations without having a regulator telling them. In that sense it could be seen as a tool.

Dysfunctional Interactions

The interactions between the safety professionals and their respective organisations described in the analysis seems dysfunctional and reflect what Le Coze (2024; Le Coze et al., 2025) calls the blues, as well as the dilemmas and difficulties presented by Shorrock (2020). Some examples brought forward in this study include forced simplifications, different mental models between the safety professionals and engineers regarding theories about interpretations of the world, safety professionals not being respected, and behavioural science being seen by engineers as borderline nonsense. Although Le Coze (2024) argues this is sometimes due to an inability to update basic philosophies, this study shows safety professionals being forced by their circumstances rather than having flawed understandings. The interviewees indicate that when they have tried to be theoretical, it has been perceived as almost elitist, or they have been recommended to only say one thing at a time. Opposing, or minority, voices are seemingly being silenced in the way the system or organisation is set up, not in a calculated, intentional manner, but as a result of how these organisations work.

If the organisations view 'safety culture' as a technical component that can be fixed, it must be very challenging trying to argue for complexity and culture as something covert, shaped by interactions. Even though a few of the interviewees said it is easier to talk about today, the gap between safety professionals and engineers is still present. The stigma surrounding the origin of the construct, as mentioned by one interviewee, might still be strong especially if historical and contemporary developments regarding 'safety culture' have been driven by accidents or events. If the industry only opens up to discuss 'safety culture' following accidents, that stigma will probably never disappear due to the given negative connotation, and the safety professionals will continue to fight for their existential right.

Sweden experienced both the Barsebäck and Forsmark events, the Soviets had Chernobyl, Japan Fukushima, and the USA TMI and Davis Besse. It gives the impression that large events or accidents are what spark developments, but they also highlight the difficulty in accepting identified causes, or issues, if the accident happened in another country, within another cultural context. A serious event or an accident within the industry's own cultural context is seemingly needed for 'safety culture' to be seen as something that could add value to safety work and for the creation of meaning in relation to national culture.

Structures and prerequisites differ, so the mechanisms shaping our culture are not the same. This thought makes it hard to think of WANO's 10 traits as a one-kind-fits-all approach, but that is the reality when signing up for a membership, implying power and politics trump deeper understanding. The safety professionals as experts are put up against the view of engineers who seemingly accept WANO's approach. The industry is seemingly not fully trusting their own experts in that regard, but external influence has greater power. The trust in external influence was also brought up by an interviewee who mentioned bringing in a recognisable world name to get the support needed.

Study Implications and Future Research

Despite these limitations, this study suggests a tight relationship between MTO as a systemic view and culture. While this connection to some extent is present in the literature, it could be highlighted even more as a pragmatic way of approaching culture, especially when combining it with the separation of 'safety' and 'culture' to highlight these concepts as separate entities. The literature identified numerous theoretical discussions, and the few applied studies seemingly approach the 'safety culture' construct as a thing, trying to evaluate or describe *it* in various models, or describe different activities to strengthen *it*. This study adds to a void in the literature, unconditionally examining underlying, created meanings without claiming *it*. Future research could benefit from a similar approach as a way of showing its diversity instead of arguing for a shared, agreed-upon definition.

Conclusion

In Sweden, 'safety culture' was early on given meaning through surveys and calculated means. That approach was later questioned, and the industry incorporated more qualitative methods for evaluations while also using WANO's traits to provide a frame of meaning, albeit reflecting a functionalist approach. The past 10-15 years show a shift in thinking and created meanings, and the introduction of a more systematic way of working with the construct through various programs and initiatives seemingly led to a divide within the industry. The safety professionals started to develop a greater understanding of the construct reflecting an interpretivist approach while the rest of the industry to a greater extent got stuck in an interpretation based a more functionalist approach. This divide led to compromises and simplifications in an industry where engineers have greater power, amplified further with political pressure coming from WANO membership and adopting their guidelines.

The Swedish safety professionals seemingly believe in an approach based on understanding how structures and prerequisites shape culture(s) and made visible through various patterns that can favour or disfavour safety. Structures, prerequisites, and patterns are understood using the well-established MTO (human-technology-organisation) concept, and with an added temporal aspect, this approach might reveal cultural manifestations. Thus, culture can be seen as a set of long-lasting patterns of various phenomena that are seen throughout the organisation, but with culture being a long-lasting phenomenon, it is likely that organisations do not know when culture changes, because it is a continuous, socially constructed, process. The Swedish nuclear industry seems comfortable adopting an MTO perspective to safety, so to utilise it to also conceptualise the 'safety culture' construct is not too far-fetched but rather pragmatic.

The interviewees seemingly differentiate between safety and culture, approaching these constructs as separate entities while also recognising the relationship between them. Slowly moving away from 'safety culture', to instead talk about 'culture for safety', provides a base for discussing the relationship between two separate constructs instead of trying to manage a single large construct resembling Goliath. Even though 'culture for safety' could be just semantics, as one interviewee expressed, it captures an underlying, or created meaning that safety is the core of the nuclear industry. It also highlights that the culture(s) present in the organisations should be discussed *in relation* to safety and separating the two might make it

easier to understand that separation. By mixing them it might also be harder to avoid normative language like 'good' or 'bad' instead of talking about the relation *between* safety and culture and its various, non-dichotomous, qualities. Due to a gap in language and mental models that interviewees describe to exist between the safety professionals and the rest of the organisations, this approach still resides only within a smaller group of employees within the Swedish nuclear industry. This gap has resulted in there still being a view on 'safety culture' present that treats the construct as a catch-all for non-technical issues, sometimes even as a personal trait for someone making an error.

For the future dialogue between the safety professionals and the organisations to be fruitful, the safety professionals need to be fearless and bring the discussion about 'safety culture' to the table without compromises and simplifications. Targeting the senior management is probably most effective because, as one interviewee said, it is "in the bluntest of the blunt end" (R10_ID451) that the largest impact is created. This is not to say the safety professionals are not trying; they are. They go above and beyond to adapt the messages to the rest of their organisations as a way of getting through. However, an alternate approach might be what the industry needs.

Some of the interviewees also mentioned that they have questioned 'safety culture' altogether, whether using the construct adds value. In the end, the interviewees agree that it would be too difficult to stop talking about it, contrasting Hopkins (2016) and Sherratt et al.'s (2025) argument, and that it does adds value. Even though 'safety culture', or 'culture for safety', is hard to explicitly frame, the construct is needed to highlight non-technical aspects of safety, but not as a catch-all.

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Swedish Nuclear Power Inspectorate. (1998). SKIFS 1998:1 Statens kärnkraftsinspektions föreskrifter om säkerhet i vissa kärntekniska anläggningar: Allmänna råd om tillämpningen av Statens kärnkraftsinspektions föreskrifter enligt ovan [The Swedish nuclear power inspectorate's regulations concerning safety in certain nuclear facilities: Genereal guidance on the application of the Swedish nuclear power inspectorate's regulations]. 2 kap, § 1.

Swedish Nuclear Power Inspectorate. (2004a). SKIFS 2004:1 Statens kärnkraftsinspektions föreskrifter om säkerhet i vissa kärntekniska anläggningar [The Swedish nuclear power inspectorate's regulations concerning safety in certain nuclear facilities] 2 kap, § 10.

Swedish Nuclear Power Inspectorate. (2004b). *Återkommande säkerhetsgranskning Oskarshamn 1* (SKI Rapport 2004:21) [As Operated Safety Analysis Report (ASAR) Oskarshamn 1]. SKI. https://www.stralsakerhetsmyndigheten.se/contentassets/5f2c83de7ce7415ba4c870d2c709818e/200421-ski---asar---o1

Swedish Nuclear Power Inspectorate. (2004c). *Återkommande säkerhetsgranskning 1991-2000 Ringhals 3 och 4* (SKI Rapport 2004:42) [As Operated Safety Analysis Report (ASAR) 1991-2000 Ringhals 3 and 4]. SKI. https://www.stralsakerhetsmyndigheten.se/contentassets/3dcb09ad0a4e4c5e949a42bba05a7773/200442-ski---asar---r3-r4

Swedish Nuclear Power Inspectorate. (2004d). *Säkerhets- och strålskyddsläget vid de svenska kärnkraftsverken 2003* (SKI Rapport 2004:16) [Current status of safety and radiation protection at the Swedish nuclear power plants 2003]. SKI. https://www.stralsakerhetsmyndigheten.se/contentassets/21f659bdcc8e428caf404f6860c92fdd/200416-sakerhets--och-stralskyddslaget-vid-de-svenska-karnkraftverken-2003

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Swedish Radiation Safety Authority. (2018a). SSMFS 2018:1 Strålsäkerhetsmyndighetens föreskrifter om grundläggande bestämmelser för tillståndspliktig verksamhet med joniserande strålning [The Swedish radiation safety authority's regulations concerning basic provisions for activities requiring a permit involving ionizing radiation] 3 kap, § 6, 10, 16-18. https://www.stralsakerhetsmyndigheten.se/contentassets/edd48d6fa0114e9cb3ae07f3956babcc/ssmfs-20181-stralsakerhetsmyndighetens-foreskrifter-om-grundlaggande-bestammelser-for-tillstandspliktig-verksamhet-med-joniserande-stralning-konsoliderad-version.pdf

Swedish Radiation Safety Authority. (2018b). SSMFS 2018:1 Vägledning med bakgrund och motiv till Strålsäkerhetsmyndighetens föreskrifter (2018:1) om grundläggande bestämmelser för tillståndspliktig verksamhet med joniserande strålning [Guidance with backround and motive to the Radiation Safety Authority's regulations (2018:1) concerning basic provisions for activities requiring a permit involving ionizing radiation]. https://www.stralsakerhetsmyndigheten.se/contentassets/edd48d6fa0114e9cb3ae07f3956babcc/vagledning-med-bakgrund-och-motiv-till-stralsakerhetsmyndighetens-foreskrifter-ssmfs-20181-om-grundlaggande-bestammelser-for-tillstandspliktig-verksamhet-med-joniserande-stralning.pdf

Wahlström, B., & Gunsell, L. (1998). *Reaktorsäkerhet: En beskrivning och en värdering av säkerhetsarbetet i Norden* (NKS/RAK-1(98)R8) [Reactor safety: A description and an evaluation of the safety work in the Nordic]. Nordisk Kärnsäkerhetsforskning. https://www.nks.org/en/nks_reports/view_document.htm?id=111010111119656

World Association of Nuclear Operators. (2006). *Principles for a strong nuclear safety culture* (WANO GL 2006-02). WANO.

World Association of Nuclear Operators. (2013). *Traits for a healthy safety culture* (WANO PL 2013-1). WANO.

Appendix A

Performing the Literature Review

A systematic literature review (SLR) uses a predetermined structured method which includes searching, screening, selecting, appraising, and summarising findings as a way of answering a narrowly focused research question (Green et al., 2006; Greenhalgh et al., 2018). The performed systematic literature review follows the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA), items 4-9, 16a, 17 and 23a-23b (Page et al., 2021), for identifying literature specifically connected to the presented research question. In addition, a narrative literature review (NLR) was performed with a more general purpose of understanding the 'safety culture' research area(s) as a whole. The narrative literature review followed methods presented by Green, Johnson & Adams (2006) and Creswell & Creswell (2018). The goal and purpose of this narrative literature review was to present the information gathered on 'safety culture' in a structured way that summarises the current knowledge.

Table A1 presents the searches made in Scopus using various combinations of search words.

Table A1

Results of the Initial Search.

Date of search	Data-base	Search string	Hits	Type of LR
25-03-04	Scopus	TITLE-ABS-KEY ("safety culture") AND PUBYEAR > 1985)	9 165	NLR
25-03-04	Scopus	(TITLE-ABS-KEY ("safety culture") AND (TITLE-ABS-KEY (sweden) OR TITLE-ABS-KEY (swedish)) AND (TITLE-ABS-KEY (nuclear) OR TITLE-ABS-KEY (chernobyl) OR TITLE-ABS-KEY (tjernobyl) OR TITLE-ABS-KEY (insag) OR TITLE-ABS-KEY (international AND nuclear AND safety AND advisory AND group))) AND PUBYEAR > 1985	18	SLR
25-03-04	SSM	Publications Search term: "safety culture" Filter: Research	6	SLR

Note. SSM is the Swedish Radiation Safety Authority who finances research within the nuclear domain. Research publications are published at their web page, Publications.

https://www.stralsakerhetsmyndigheten.se/publikationer/

Inclusion and Exclusion Criteria

For a NLR, Creswell & Creswell (2018) suggest collecting literature "that are central to your topic" (p. 70). When searching for literature including "safety culture" in either title, abstract or keywords, published between 1986 and present day (4th of March, 2025), in Scopus, one gets 9,165 hits. To identify those most central to 'safety culture', the result was sorted based on citations as those would probably be the most influential within 'safety culture' research. The first 50 hits were reviewed based on the title, and the ones that were too far off topic were excluded (see Table A2). The reviewing process was iterated, first reading abstracts and for the last round reading conclusions and the reference list. The final result of the NLR is 1 book chapter, 1 conference paper, 2 reviews and 5 articles.

Table A2

Reviewing of the Identified Literature, NLR.

Input	Review	Exclusion/Inclusion criteria	Output
9 165	Number of citations	Included: • The top 50 hits	50
50	Title	Excluded: • Topic too far from 'safety culture', e.g. hand hygiene in infection prevention, management studies in the construction business, AI systems, burnout after COVID, etc. • Studies measuring culture/climate in other domains, e.g. questionnaire studies.	37
37	Abstract	Excluded: • Studies measuring culture/climate in other domains, e.g. questionnaire studies, survey studies. • 'safety culture' mentioned but not in focus, e.g. studies focusing on reporting systems, safe operations, modelling safety climate etc.	14
14	Conclusion and reference list	Excluded • Studies in other industries, e.g. patient 'safety culture'. • Studies measuring culture/climate in other domains. • Expected references not included.	9

Note. The review process was made by the author, independently. No automation tools were used.

For the SLR, the initial hits were only 18 for Scopus and 6 for SSM, so all of them were reviewed. The reviewing processes are presented in Table A3 and A4, but they followed the same steps as the NLR. The final result of the SLR is 1 article, 1 book chapter, 2 conference papers, and 3 research reports.

Table A3

Reviewing of the Identified Literature, Scopus SLR.

Input	Review	Exclusion/Inclusion criteria	Output
18	Title and abstract	Excluded: • Studies too far off topic, e.g. maintenance training, newspaper reporting on hazards, managing acoustic noise, etc.	12
12	Conclusion and reference list	Excluded: • 'safety culture' not in focus, just briefly mentioned, or not mentioned at all in conclusions, or result of study could impact 'safety culture'. • Scope too big, e.g. organisational culture and plant reliability. • Scope too narrow, e.g. safety climate and shift work.	4

Note. The review process was made by the author, independently. No automation tools were used.

Table A4

Reviewing of the Identified Literature, SSM SLR.

Input	Review	Exclusion/Inclusion criteria	Output
6	Title and abstract	Excluded: • Studies too far off topic, e.g. evaluating another factor as a driver for 'safety culture', or factors that could make practical implementations of a 'safety culture' difficult.	3
3	Conclusion and reference list	Included: • Studies presenting models for 'safety culture'. • Studies presenting experiences on 'safety culture' practices in the Swedish nuclear industry	3

Note. The review process was made by the author, independently. No automation tools were used.

Synthesising the Literature

The narrative and systematic literature reviews resulted in nine respectively seven included items (see Table A5). All items were imported into Nvivo and read in full by the author. When reading each item, data was sought that in some way defined 'safety culture', described 'safety culture' attributes, challenged the construct of 'safety culture', described practical work with 'safety culture' and/or described interpretations of the underlying meaning behind 'safety culture' and possible subsequent implications from such interpretation. Text was coded using codes that emerged when reading. After reading and coding all items, a summary of the collected data for each code was written. The literature map in Figure

A1 summarises these identified themes/codes and the final result of the literature reviews can be found in chapter 3 of this thesis.

Table A5

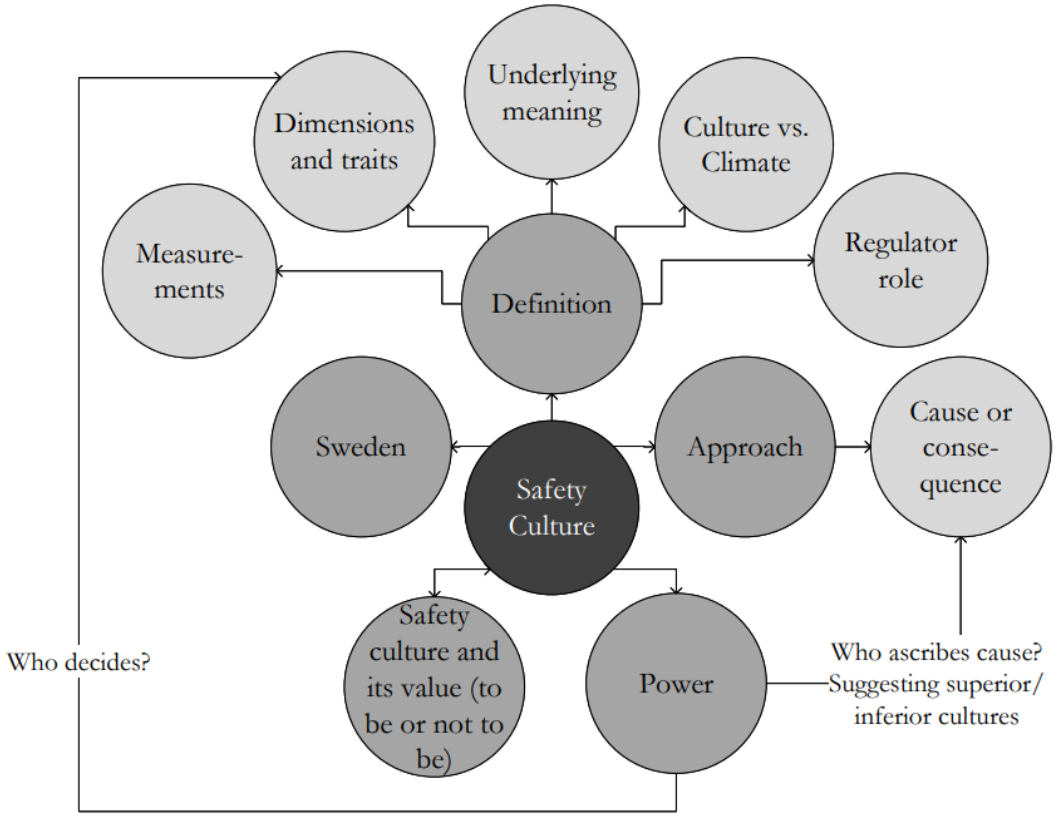
Final Items After NLR and SLR.

Type of LR	Reference	Relevance
NLR	Breakwell, G. M. (2007). *The psychology of risk* (1st ed.). Cambridge University Press	Descriptive. Introduces the 'safety culture' concept, the regulator role, measurements, and 'safety culture' improvement.
NLR	Choudhry, R. M., Fang, D., & Mohamed, S. (2007). The nature of safety culture: A survey of the state-of-the-art. *Safety Science, 45*(10), 993-1012.	Literature review on 'safety culture' research, 1998-2007. Presents multiple definitions and models with various measurements. Paper concludes by presenting a 'safety culture' model for construction work.
NLR	Cooper, M. D. (2000). Towards a model of safety culture. *Safety Science, 36*(2), 111-136.	Sees 'safety culture' as a sub-facet of organisational culture. Provides a reciprocal 'safety culture' model as a theoretical and practical framework to measure and analyse 'safety culture'.
NLR	Cox, S., & Flin, R. (1998). Safety culture: Philosopher's stone or man of straw? *Work and Stress, 12*(3), 189-201.	Presents issues and concerns regarding definition, measurement and utility of 'safety culture' as well as distinctions/relationships between culture and climate.
NLR	Glendon, A.I., & Stanton, N.A. (2000). Perspectives on safety culture. *Safety Science, 34*(1-3), 193-214.	Presents distinction between functionalist and interpretive perspectives as well as clarification on the terms culture and climate. Uses a case study to illustrate two measurement types.
NLR	Guldenmund, F.W. (2000). The nature of safety culture: A review of theory and research. *Safety Science, 34*(1-3), 215-257.	Literature review on 'safety culture' and climate.
NLR	Pidgeon, N.F. (1991). Safety culture and risk management in organisations. *Journal of Cross-Cultural Psychology, 22*(1), 129-140.	Presents definition of 'safety culture' and what 'good' 'safety culture' might look like.
NLR	Reason, J. (1998). Achieving a safe culture: Theory and practice. *Work and Stress, 12*(3), 293-306.	Present distinction between individual and organisational accidents. Equates 'safety culture' with an informed culture where a reporting and a just culture are prerequisites.
NLR	van Nunen, K., Li, J., Reniers, G., & Ponnet, K. (2018). Bibliometric analysis of safety culture research. *Safety Science, 108*, 248-258.	Present a bibliometric analysis of 'safety culture'.
SLR Scopus	Berglund, J. (2020). After Fukushima: Safety culture and fostering critical thinking. *Safety Science, 124*, 1-6.	Discusses skill as an important contributor to 'safety culture'. Also discusses how power and critical thinking might influence 'safety culture'.
SLR Scopus	Rollenhagen, C. (2021). From classical human factors toward a system view: Experiences from the human factors nuclear field in Sweden. In A-M, Teperi & N, Gotcheva (Eds.), *Human factors in the nuclear*	Presents the history of MTO in the Swedish nuclear industry, from the perspective of the NPPs.

Type of LR	Reference	Relevance
	industry: A systemic approach to safety (pp. 55-71). Woodhead Publishing Series in Energy.	
SLR Scopus	Rollenhagen, C., & Wahlström, B. (2007, August 26-31). *Management systems and safety culture: Reflections and suggestions for research* [Paper presentation]. 2007 IEEE 8th Human Factors and Power Plants and HPRCT 13th Annual Meeting, Monterey, CA, United States.	Conference paper. IAEA has (when this paper was written) released new guidance on management systems. The paper present possible research topics to meet this demand. 'Safety culture' should be seen as an integrated part of the management system.
SLR Scopus	Rollenhagen, C., & Westerlund, J. (2007, August 26-31). *Development of a safety climate questionnaire for nuclear power plants* [Paper presentation]. 2007 IEEE 8th Human Factors and Power Plants and HPRCT 13th Annual Meeting, Monterey, CA, United States.	Conference paper. Presents 49 items included in a safety climate questionnaire. Also, interesting discussion about different kinds of safety, i.e. nuclear safety and occupational safety. An ongoing discussion withing Swedish nuclear.
SLR SSM	Lowe, A., & Hayward, B. (2006). *SKI report 2007:26 Safety culture enhancement project: A field study on approaches to enhancement of safety culture.* Swedish Nuclear Power Inspectorate.	Objective: To enhance 'safety culture' in the Swedish nuclear power industry. Data gathering included interviews, focus groups and management workshops at three nuclear facilities in Sweden. Finding include current status of 'safety culture' in the Swedish nuclear industry.
SLR SSM	Oedewald, P., Pietikäinen, E., & Reiman, T. (2011). *SSM report 2011:20 A guidebook for evaluating organizations in the nuclear industry: An example of safety culture evaluation.* Swedish Radiation Safety Authority.	The purpose of the study was to test a previously developed model for evaluating safety critical organisations, and to further develop a tool for this evaluation. The test case was evaluation of 'safety culture'.
SLR SSM	Reiman, T., & Pietikäinen, E. (2010). *SSM report 2010:07 Indicators of safety culture: Selection and utilization of leading safety performance indicators.* Swedish Radiation Safety Authority.	According to the Swedish Radiation Safety Authority, 'safety culture' should be regularly assessed, and the use of indicators could be a useful tool. This study presents an overview of existing types of indicators and the utilisation of indicators in the nuclear industry. Also, the study presents a framework for selection and use of indicators.

Figure A1

Literature Map.



Appendix B

Extensive Document Review Findings and Timeline

Following the Chernobyl accident in 1986, the International Nuclear Safety Advisory Group (INSAG) released a summary report, INSAG-1, (INSAG, 1986) on the post-accident review meeting held in Vienna that same year. The report gave a first introduction to 'safety culture' stating that "there is a need for a 'nuclear 'safety culture" in all operating nuclear power plants" (p. 76). According to the report, the root cause of the accident can be found in the human element, and moving forward INSAG wanted to see actions regarding simulator training to gain good understanding of the reactor and its operation, internal and external auditing to prevent complacency, and permanent awareness by all personnel of potential safety implications of deviating from procedures. INSAG-1 also added emphasis on placing complete authority and responsibility regarding safety on a senior member of the operating staff.

Two years later, INSAG released a new report, INSAG-3, (INSAG, 1988) concerning basic safety principles for nuclear power plants in which 'safety culture' was seen as a fundamental management principle. The report says that "an established 'safety culture' governs the actions and interactions of all individuals and organizations engaged in activities related to nuclear power" (p. 10). It all starts with the senior management, while also requiring personal dedication and accountability for all individuals. Sound procedures should be developed, strict adherence demanded, and admission of errors encouraged. Similar to INSAG-1, the report included training to emphasise the reasoning behind practices and risks with shortfalls in performance as well as understanding the plant and knowledge of its equipment. In INSAG-3, 'safety culture' was for the first time mentioned as being part of defence-in-depth, protecting the integrity of the barriers.

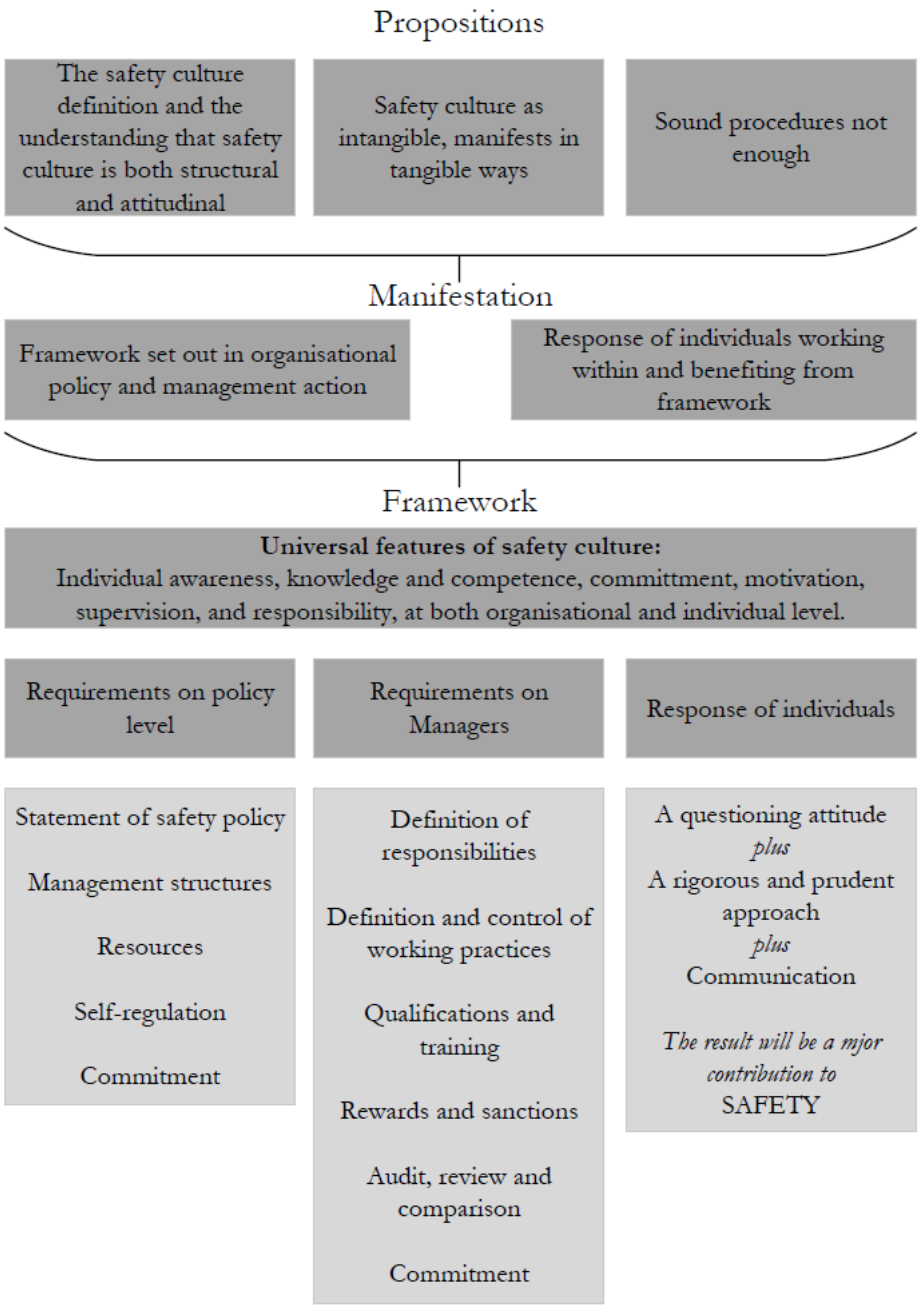
In 1991, the IAEA's Director General remarked in the foreword of INSAG-4 that the term 'safety culture' had been increasingly used since the release of INSAG-1 and INSAG-3, but acknowledged that "the meaning of the term was left open to interpretation and guidance was lacking on how safety culture could be assessed" (INSAG, 1991, Foreword section, para. 2). The INSAG-4 report aimed at describing 'safety culture' and how the concept relates to organisations and individuals, and it is in this report that the first version of the 'safety culture' definition appears: "safety culture is that assembly of

characteristics and attitudes in organizations and individuals which establishes that, as an overriding priority, nuclear plant safety issues receive the attention warranted by their significance" (p.1). This definition is said to be the first of three propositions describing 'safety culture'. The definition, according to INSAG-4 (1991), highlights the notion that 'safety culture' is both structural and attitudinal and relates both to organisations and individuals. The second proposition says that 'safety culture' is generally intangible but can manifest in tangible ways. INSAG-4 devotes a whole chapter presenting what they call 'tangible evidence', listing for example that the management style of the regulatory agency ensures that common concern about safety leads to open and cooperative relationship with operating organisations, safety responsibilities and detailed practices at all levels of the plant defined, and nuclear safety is kept under constant scrutiny, to name a few. The third proposition emphasises that sound procedures are not enough as these need to be carried out correctly, with alertness and good judgement.

According to INSAG-4 (1991), 'safety culture' manifests itself in two major components. It is 1) a framework set out in organisational policy and by management action, and 2) the response of the individuals working within and benefiting from this framework. This framework is laid out in detail in the report, but in short it contains requirements at policy level, requirements on managers, and it also contains the response of individuals (see Figure C1). Policy statements should declare commitment to excellence and "policies promoted at a high level create the working environment and condition individual behaviour" (INSAG, 1991, p. 7). To achieve this, strong lines of authority, clear accountability, adequate resources, regular reviews of practices, and commitment are defined, and managers shall ensure that these prerequisites are in place and working well. It is the task of individuals to respond to these prerequisites, or framework, set out in policy and reinforced by managers, by, for example, being alert of the unexpected, proceeding with deliberate care, and collecting and sharing information with others.

Figure B1

Illustration of the presentation of 'safety culture' in INSAG-4 (adapted from INSAG, 1991).



These three documents, INSAG-1, 3 and 4, marked the beginning of the nuclear industry trying to understand and create meaning out of the 'safety culture' construct. In 1992, a new INSAG report was released, INSAG-7, (INSAG, 1992) which was an update of the original INSAG-1 report. Due to new information coming out of the Soviet Union regarding what happened at Chernobyl, parts of the INSAG-1 report needed revision. The conclusions from INSAG-1 were not affected, but the balance of factors

contributing to the accident shifted and the role of the operators eased (INSAG, 1992). 'Safety culture' seemingly got more attention in INSAG-7 than in the original report. The updated version makes some general remarks on "the lack of safety culture" (p. 21):

> In its report on the Chernobyl accident, INSAG coined the term 'safety culture' to refer to the safety regime that should prevail at a nuclear plant.… It has been pointed out several times in the preceding discussion that safety culture was lacking in the operating regime at Chernobyl. In conformity with its views as expressed in INSAG-4, INSAG now confirms the view that safety culture had not been properly instilled in nuclear power plants in the USSR prior to the Chernobyl accident (INSAG, 1992, p. 21-22).

According to INSAG-10, a report on defence-in-depth released in 1996, Chernobyl showed the need for an effective regulatory regime and for a 'safety culture' (INSAG, 1996). Even though INSAG-10 argues that human error could jeopardise defence, humans are also recognised as crucial to safe operations and professionalism. 'Safety culture', according to INSAG-10, allow the staff to contribute to reliable operation. 'Safety culture' is, thus, said to be part of the defence-in-depth as previously mentioned, and two factors of great importance are a questioning and a learning attitude. INSAG-10 seemingly targets the operating, and to some extent also the maintenance, organisation saying that initiatives by the operators based on adequate understanding and 'safety culture' have been beneficial in abnormal situations.

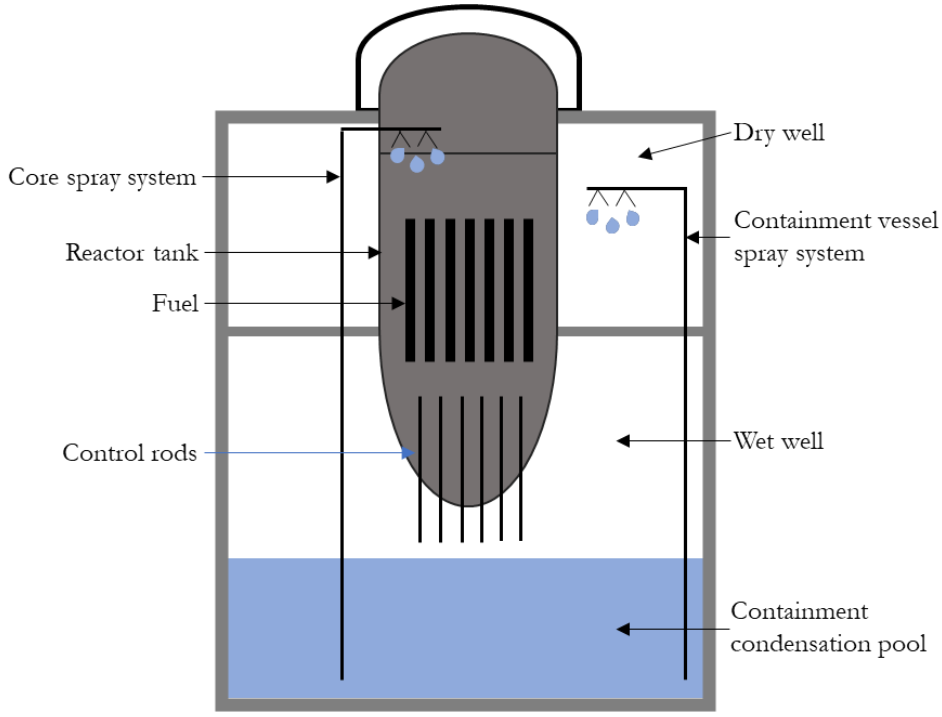
Sweden Awakens

When restarting Barsebäck unit 2 (B2) after the yearly outage in 1992, a rupture-disc opened at high pressure inside the containment (see Figure C2) due to a control valve being unintendedly open (Wahlström & Gunsell, 1998). The steam release caused pipe insulation to be ripped off and large amounts of mineral wool insulation was transported down to the wet well (containment condensation pool) where it blocked the emergency core cooling suction strainers in the pump inlet to the containment vessel spray system and the core spray system. When it became apparent that these safety systems were flawed, the Swedish Nuclear Power Inspectorate ordered the shutdown of all five reactors in Sweden with similar design until the safety systems had been reconstructed. The event also caused modifications on the

rest of the seven reactors to be made, specifically regarding backflush functions and choice of insulation materials. According to Wahlström & Gunsell (1998), the event was handled well by the power companies and the Swedish inspectorate, but the event could be argued to be the most significant event in the Swedish nuclear history to that date. In the aftermath of the event, analysis of the engineering principles raised questions about internal audits at the NPP's as well as in the oversight by the regulator. Wahlström & Gunsell even say gullibility might have existed to some degree in the industry regarding high reliance on the function of safety systems in case of a pipe rupture in the containment. Wahlström & Gunsell (1998) argue that international events, such as Chernobyl and Three Mile Island (TMI) had cultural roots, and that the B2 event was the most prominent event with roots in the Swedish culture.

Figure B2

Boiling water reactor, containment.



From the documentation, it is unclear how much the B2 event impacted the industry regarding 'safety culture', but Ringhals NPP started their 'safety culture' work in 1991-1992 and between 1995-1996 'safety culture' was a prioritised area of focus in their business plan (Swedish Nuclear Inspectorate, 2004c). At Sydkraft group, owner of Oskarshamn NPP, a 'safety culture' assessment was performed in 1993 and the result showed that a more structured approach towards safety work was desirable (Swedish Nuclear

Inspectorate, 2004b). This evaluation constituted the foundation for Sydkraft's safety policy (see Figure C3) (Wahlström & Gunsell, 1998).

In 1994, the Swedish Nuclear Industry's Safety Coordination Body (SKISOS) wrote a report on the Swedish interpretation of INSAG-4 (SKISOS, 1994). According to this group, 'safety culture' is the result of all attitudes, traits and routines that affect reactor safety. Thus, it is not a single trait but rather a collective term for the safety enhancement work taking place at multiple frontiers within the organisation. Managers set an example while the employees adopt organisational values and actively contribute to safety. SKISOS also recognised that 'safety culture' is part of the more general construct of organisational, or corporate, culture. The SKISOS report presented several traits based on INSAG-4 but adapted to the Swedish context taking Swedish values/culture/traditions into consideration (see Figure C4).

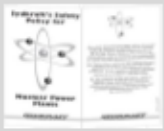
In 1995, Sweden signed the Convention on Nuclear Safety which says that all contracting parties shall promote an effective nuclear 'safety culture' (IAEA, 1994). In its first report to IAEA, the Swedish Ministry of the Environment (1998) recognised that organisational and 'safety culture' issues had been identified and needed closer attention while also writing that the Swedish power plants were well aware of the importance of these issues.

In its next report in 2001, the Ministry of the Environment (2001) described various actions taken by the power plants to deal with the 'safety culture' issues mentioned in 1998. At this point in time, all power plants used a safety climate questionnaire, distributed periodically. General 'safety culture' training was regularly held, and special sessions could be arranged after specific 'safety culture' related incidents.

Figure B3

Sydkraft's safety policy for nuclear power plants (adapted from Ministry of the Environment, 1998).

Sydkraft's Safety Policy for Nuclear Power Plants



- Barsebäck Kraft AB and OKG AB are licensed under the Nuclear Technology Act to operate the Nuclear Power Plants in Barsebäck and Oskarshamn and, as licensees, are responsible for safety and safe operation at the Power Plant.
- This Safety Policy represents the Sydkraft Group's guidelines as to how operations are to be conducted. Every employee shall be informed and act in accordance with this Policy.
- For the purposes of this document, safety is defined as those methods and safeguards employed against any unplanned and/or not permitted radioactive discharges into the environment.

We intend to honour and support the Swedish Approach

- This means that we are active in identifying, analyzing, evaluating and taking the initiative in issues of safety. We shall maintain an open, constructive relationship with the nuclear safety and protection authorities through respect for each other's roles.

We strive for broad cooperation on safety issues between nuclear utilities

- Cooperation must encourage and increased regardless of competition in electricity markets.

We strive continuously towards increased safety

- We must never be content with achievements. Complacency leads to the relaxation of standards.

We always consider safety to have a higher priority than plant availability and economy

- We are convinced that in the long term our combined efforts towards higher levels of safety, operational availability and efficiency reinforce each other.

We strive for a good safety culture

- Quality is the input, safety is the output.

Signed by Göran Ahlström, President and Chief Executive Officer

We intend to honour the Swedish Approach

- Regulations established by the licensing authorities are a minimum standard. Independently of these we shall instigate our own initiatives in matters on safety.
- Current safety criteria shall be mer with reassuring margins. The criteria are based on Swedish and international standards and recommendations, whose details have been evaluated, adapted and supplemented in accordance With our own conditions.

We strive for a broad cooperation on safety issues between nuclear utilities.

- The dialogue with other power companies shall be open and objective.
- We shall actively evaluate our own experience and that of others, in order to find opportunities for improvements. Our own experience shall be made known so that it can be of use to other interested parties.

We strive continuously towards increased safety

- Management shall be active in ensuring that employees are fully competent to perform their duties. To this end, education, professional training, personal motivation and the working environment shall all be taken into account.
- We shall take an active and leading role in research end development.
- We shall continuously and systematically analyze plant design, its condition and state of maintenance, and the management organization, to detect weaknesses in equipment or operational control. Analyses will result in proposals for improvement where necessary.
- Continuous improvement requires continuous assessment and selection. This is required in order to give priority to measures which makes the largest contribution in relation to the effort expended. As our resources are limited they should therefore be used effectively and responsibly.
- Measures to raise safety levels shall be given priority if safety analyses show that: 1) core damage frequently exceeds, with a high level of confidence, 10-5/year, or 2) the probability of discharge of more than 0,1% of the core inventory, excluding noble gases, exceeds 10-7/year.

We always consider safety higher than availability and economy

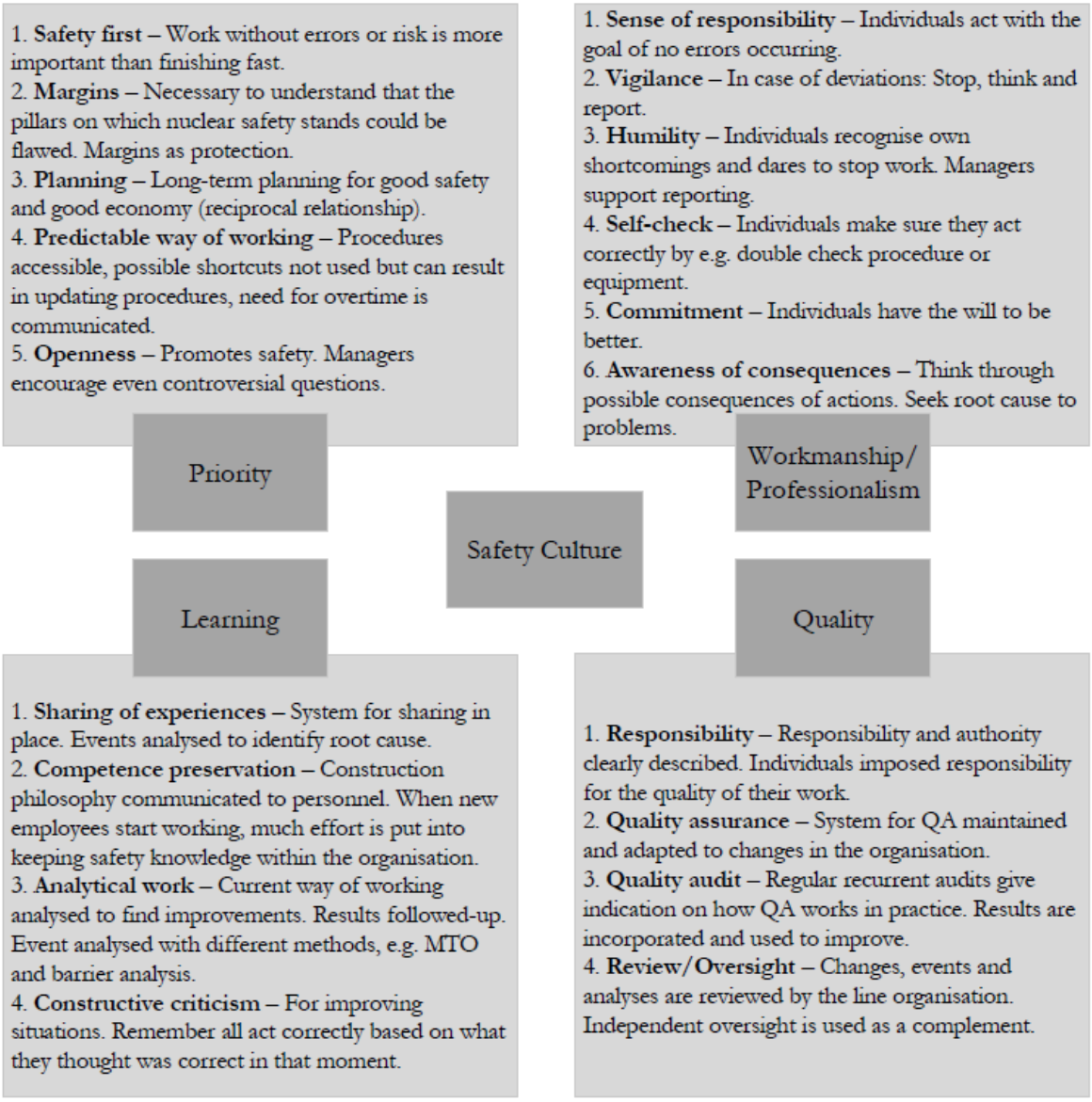
- In the event of a conflict of goals, safety will always be given precedence over financial or other considerations. Situations which arise do not always provide a clear basis for decision-making, bur the declared aim is that at least two persons with an insight into all aspects of the problem will, independently of each other, provide their evaluation and advice to decision makers.
- We shall at all times be well prepared to deal with abnormal plant conditions and to take the necessary actions to minimize their consequences.

We strive for a good safety culture

- We shall adopt a total quality concept in which attainment goals, regular review of progress and achievements, and an active improvement program form essential elements.
- Employees shall demonstrate humility and respect their own and the plant's limitations. We shall encourage a watchful and questioning approach.
- Management shall express in word and in deed that working to adequate standards, without error or risk, is more important than speed. Unapproved short cuts are not to be taken, but suggestions for potential approvements should result in proposals for modified routines.
- Management will encourage an open attitude in safety issues, such that individual employees will report abnormal or unexpected occurrences as a matter of course, and will also feel free and able to raise controversial issues for consideration within the organization.
- All employees shall be encouraged to develop a feeling of ownership and responsibility for all activities, regardless of the formal division of duties within the organization. Clear lines of communication shall exist within and between units of the organization.
- Areas of responsibility and authority shall be clearly defined and communicated. However, the individual employee is always responsible for the quality of his or her own work.

Figure B4

SKISOS adaptation of INSAG-4 (summary based on SKISOS, 1994).



In 2002, Barsebäck unit 2 (B2) installed new piping in the feedwater system and later that year the control room personnel noticed fluctuations in the water flow (Kärnsäkerhetsutredningen, 2003). The organisation assumed the fluctuations were caused by an already known problem, so no further analysis was initiated. In the beginning of 2003, it was discovered that the new piping was damaged and partly blocked the water flow. This event had little impact on safety, but, according to Kärnsäkerhetsutredningen, showed a lacking 'safety culture'. Not long after, on the 23rd of September 2003, southern Sweden experienced a power outage and when the power returned, Oskarshamn unit 3

(O3) was exposed to a large temperature increase inside the reactor causing it to exceed its highest allowed temperature increase rate (Swedish Nuclear Power Inspectorate, 2004d). Following the event, the Inspectorate required the organisation to take action to strengthen their 'safety culture' to resolve issues regarding their handling of operating experiences, the role of the safety department, giving lower priority to projects, and uncertainties regarding roles in decision making in unforeseen circumstances.

The inspectorate (2004d) wrote that 2003 in general showed the importance of working with 'safety culture' and they noticed that the licensees acknowledged this by added resources to their organisations to increase their safety management and 'safety culture' work. According to the inspectorate, senior management commitment, visible leadership, safety as the highest priority, a proactive approach and a long term perspective, openness and communication, housekeeping, organisational learning, motivation and job satisfaction, change management, resource allocation, employee commitment, good working conditions regarding time, workload and stress, clear roles and responsibilities, a systemic perspective on safety, and quality in documentation and procedures are all prerequisites for a good 'safety culture' (Swedish Nuclear Power Inspectorate, 2004d).

In 2007, the Ministry of the Environment (2007) reports about an event at Forsmark unit 1 (F1) on the 25 July 2006. It was a "complicated electrical event…resulting in loss of power supply to two out of four redundant safety trains during 22 minutes" (p. 21) where half of the instrumentation in the main control room went dark (Sanne, 2012). The operators did not know whether the control rods had been inserted into the reactor core, or the reactor water level or pressure. After 22 minutes, the operators managed to figure out what happened and manually connected the unit to the regional 70kV grid. According to the Ministry (2007), this event together with others indicated deficiencies in safety management and 'safety culture'.

In the same report it was written that both Ringhals and Oskarshamn had put in place 'safety culture' programmes while Forsmark had a so-called 'safety culture' initiative (Ministry of the Environment, 2007). In general, these programmes contained activities including training, workshops, analyses, evaluations, and research initiatives, seemingly with the aim of creating awareness of the 'safety culture' concept throughout the organisations. According to the Ministry, maintaining a vital 'safety

culture' was seen as the largest challenge for the licensees during the near future. This was especially shown in 2009 when Ringhals was put under special supervision from the regulator, partly due to a weak 'safety culture' (Ministry of the Environment, 2010). In 2012, it was Oskarshamn's turn to be put under special supervision from the regulator, mostly due to safety-related maintenance shortcomings (Ministry of the Environment, 2013).

The 'safety culture' work up until 2015 followed the programmes and planned activities as described earlier, but in 2015, evolution started to happen. Forsmark and Ringhals merged their 'safety culture' programmes and expertise, and best practises were shared between the power plants (Ministry of the Environment, 2016). At the same time, Oskarshamn analysed their 'safety culture' programme and realised their approach was not effective. Instead of performing general activities targeting all employees, the programme changed to adapt different activities based on each departments' individual needs, recognising that, for example, the maintenance and HR departments might need varying kind of support in their 'safety culture' development.

The regulator also began reflecting on their role in the wider national safety infrastructure and Lund University performed an external evaluation (Ministry of the Environment, 2019). As a result, the regulator incorporated five principles presented by the Nuclear Energy Agency (NEA) (2016) into their management system (Ministry of the Environment, 2022). The regulator together with WANO and OECD/NEA held a country-specific 'safety culture' forum in 2018, aiming at "providing an arena to explore the impact of the national context on nuclear safety and derive approaches to sustain and improve nuclear safety culture" (Nuclear Energy Agency, 2018, p. 11) summarising national factors present in a Swedish context influencing 'safety culture' in the Swedish nuclear industry. The identified national factors were 'samskap', meaning "being in unity and the will to take a collective accountability for well-being and harmony" (Nuclear Energy Agency, 2018, p. 28), 'allskap', which "relates to the idea that everyone should have the same rights and that all things should be fair" (p. 28), security and trust, freedom, complacency/national pride, and a drive towards shared understanding.

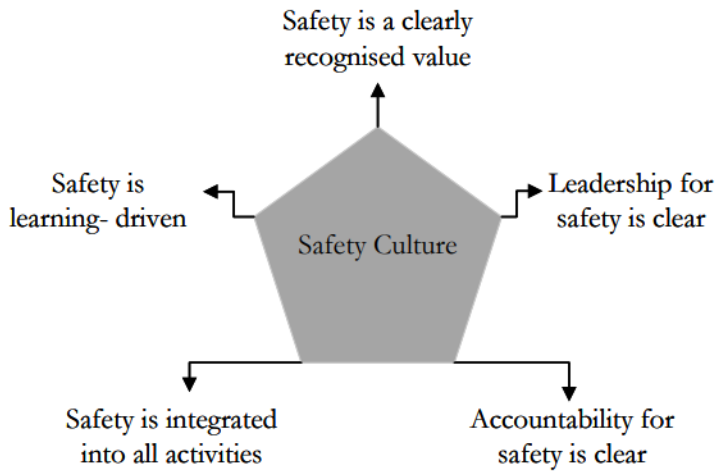
Requirements and regulations

In 1998 the Swedish Nuclear Power Inspectorate (1998) put 'safety culture' explicitly in their general guidance regarding the application of the regulations, saying it was part of upholding an effective defence-in-depth. In the updated regulations set in place in 2004, 'safety culture' assessment was introduced in the general guidance concerning evaluation of plant safety (Swedish Nuclear Power Inspectorate, 2004a).

In 2006, IAEA published their Safety Standard series (IAEA, 2006a, b, c). In the Fundamental Safety Principles (SF-1), principle 3 specifically targets 'safety culture' (IAEA, 2006a) which is then elaborated on in the Safety Requirements describing the management system for facilities and activities (GS-R-3) (IAEA, 2006b). The focus is on the management system and how it can support a strong 'safety culture', for example by ensuring a common understanding of key aspects of 'safety culture' within the organisation and reinforcing a learning and questioning attitude at all levels. The Safety Guides (GS-G-3.1 and GS-G-3.5) add yet another level of detail, presenting important attributes for a strong 'safety culture' (see Figure C5) (IAEA, 2006c, 2009).

Figure B5

Important attributes of a strong 'safety culture' (adapted from IAEA, 2006c, 2009).



In 2008, the Swedish Nuclear Power Inspectorate merged with the Swedish Radiation Protection Institute, forming the Swedish Radiation Safety Authority. This also meant merging the regulations from two regulatory bodies, resulting in new regulations coming into force in 2008. The 2008:1 regulation

(Swedish Radiation Safety Authority, 2008) still only covered 'safety culture' in the general guidance. It would take until 2017 for 'safety culture' to be specifically mentioned in a requirement. The 2017 amendment to 2008:1 now included a 'safety culture' definition (chapter 1, paragraph 2) stating that 'safety culture' is "the collection of characteristics and attitudes in organisations and individuals that in all situations demonstrate whether safety issues receive the attention warranted by their significance" (Swedish Radiation Safety Authority, 2017, p. 2). Chapter 2, paragraph 8 was also amended with the phrase "the management system shall also be used to support and promote a good safety culture" (p. 3).

10 years after the publication of SF-1, IAEA (2016) released new Safety Requirements regarding leadership and management for safety (GSR part 2). It included two specific requirements targeting 'safety culture'. The first requirement says that all individuals, from senior managers and downwards shall foster a strong 'safety culture', while the other requirement says that managers shall regularly commission assessments of leadership for safety and 'safety culture' in the organisation.

Here in Sweden, new regulations were released in 2018 which resulted in the 'safety culture' requirements being moved from 2008:1 to 2018:1 (Swedish Radiation Safety Authority, 2018a). In these regulations, 'safety culture' got a stand-alone requirement (chapter 3, paragraph 6) stating that the management system shall support and promote a culture where nuclear safety related questions get the attention warranted by their significance. Another requirement (chapter 3, paragraph 18) also mentions 'safety culture' specifically. The requirement says that nuclear safety related events shall be investigated systematically, and the investigation shall take into consideration the interaction between man, technology, and organisation (MTO) as well as culture, in accordance with paragraph 6.

The regulator presents more details on 'safety culture' in their guidance text to chapter 3, paragraph 6 (Swedish Radiation Safety Authority, 2018b). The attributes for a good 'safety culture' are based on IAEA, saying, for example, that safety as a core value should be documented, communicated and reflected in decision-making, the responsibility for safety is clear and well known in the organisation, there is a clear leadership for safety, safety is integrated in all activities and safety is learning driven. The regulator also describes the differences and similarities between safety and security culture.

World Association of Nuclear Operators

In 2006, WANO released their guideline describing eight principles for a strong nuclear safety culture (WANO, 2006):

1. Everyone is personally responsible for nuclear safety.
2. Leaders demonstrate commitment to safety.
3. Trust permeates the organisation.
4. Decision-making reflects safety first.
5. Nuclear technology is recognised as special and unique.
6. A questioning attitude is cultivated.
7. Organisational learning is embraced.
8. Nuclear safety undergoes constant examination.

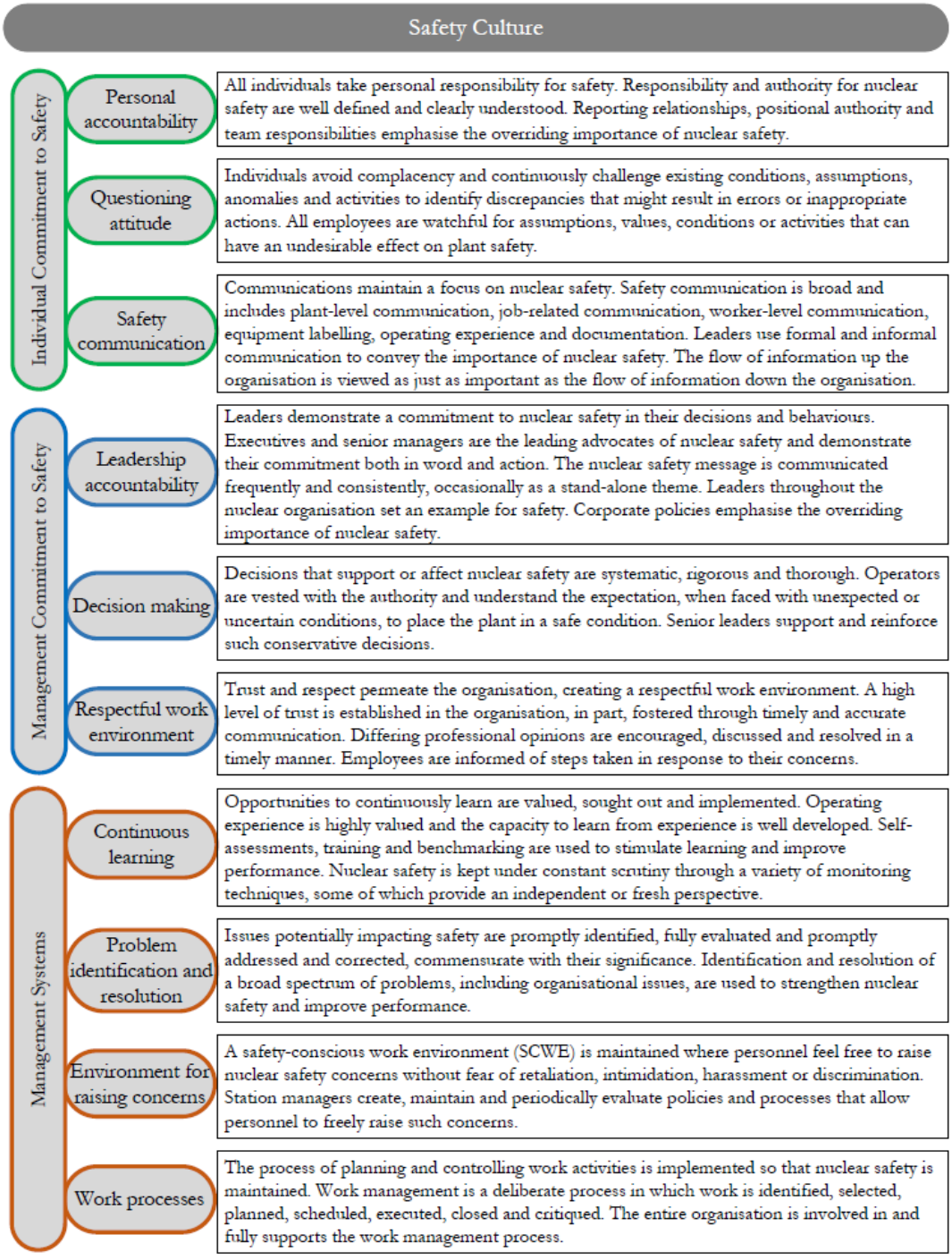
According to WANO (2006), Three Mile Island (TMI) acted as a wake-up call in the industry and Chernobyl was a stark reminder. More recent incidents, such as Davis Besse in 2002 where a degradation in the reactor vessel head was discovered, and Paks in 2003, which suffered severe damage to fuel external to the reactor, highlighted problems that arise when the safety environment receives insufficient attention.

WANO's eight principles were revised in 2013 when they published their 10 traits for a healthy nuclear safety culture (see Figure C6) (WANO, 2013). A trait is, by WANO, defined as "a pattern of thinking, feeling, and behaving such that safety is emphasised over competing priorities" (p. 4). According to WANO (2013), "experience has shown that the personal and organisational traits described in this document are present in a positive 'safety culture'. Conversely, shortfalls in these traits and attributes are a significant contributor to plant events" (pp. 4-5). The Fukushima accident in 2011 was in this revision added together with the other incidents mentioned in the previous version. In 2011, an earthquake triggered a tsunami that swept in over the Japanese east coast flooding the emergency diesels leaving the Fukushima Daichii power plant in a station black-out. The accident showed the importance of assessing external events (no matter how improbable), emergency response, training, and resource availability. It also highlighted the importance of working with 'safety culture' (WANO, 2013).

WANO (2013) identifies a common theme in all the above-mentioned incidents and accidents. Various problems crept in over time without being properly assessed which, according to WANO, is a direct result of plant culture. "The series of decisions and actions that resulted in these events can usually be traced to the shared assumptions, values and beliefs of the organisation" (p. 9).

Figure B6

10 traits for a healthy nuclear safety culture (extracted from WANO, 2013, p. 15-35).



Note: The top three green boxes represent 'Individual commitment to safety', the three blue in the middle represent 'Management commitment to safety', and the bottom four in orange represent ''Management systems.'

Summary

After the release of the INSAG-1 report, the industry needed a more comprehensive description of the 'safety culture' construct which triggered the release of INSAG-4 in 1991. More documents and guides were released in the following years, expanding the understanding of 'safety culture'. Generally, various guides and descriptions seem to have followed a similar layout, dividing 'safety culture' into the roles of managers, the roles of individuals and the role of the management system.

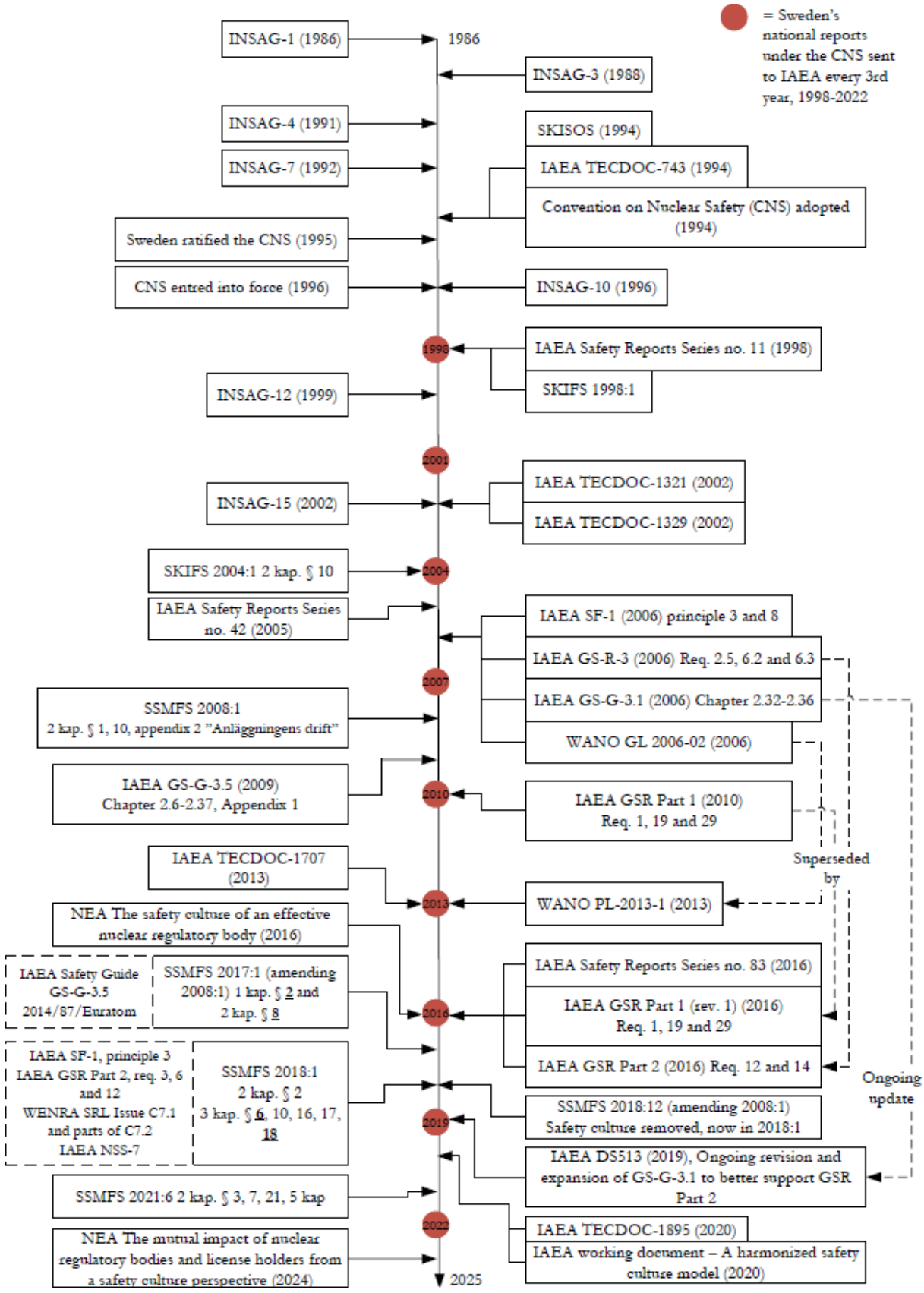
In the early 1990's, Sweden began their 'safety culture' work while at the same time handling the consequences of the B2 event that, according to Wahlström & Gunsell (1998), was an event with roots in the Swedish culture. SKISOS made a Swedish interpretation of the INSAG-4 report to better suit a Swedish context. The group included safety as the highest priority, workmanship/professionalism, quality, and learning in their interpretation.

Other events at B2 in 2003 and O3 in 2003 highlighted the importance of 'safety culture' within the industry which triggered a more systematic approach to 'safety culture' and the introduction of 'safety culture' programs and initiatives. That work has continued ever since with various developments. An event at F1 in 2006 again showed the importance of working with 'safety culture'.

In 2006, IAEA put requirements on 'safety culture' and WANO released their first guide. The Swedish regulator released new regulations in 2008, and 10 years later, 'safety culture' got its own requirement.

Figure B7

Document Timeline.



Appendix C

Informed Consent Form

Project: Safety culture meanings and interpretations – 1986 to present day

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Supervisor: Rogier Woltjer, Lund University

Purpose of the Study:

To examine the meanings the Swedish nuclear industry has attached to the construct of 'safety culture' since the release of the INSAG-1 report in 1986.

Background:

'Safety culture' as a concept was first used when explaining the Chernobyl accident and has since been extensively researched and used. Throughout the years, the construct of 'safety culture' has evolved, and different definitions and traits have been included to describe and explain the construct. In the Swedish nuclear industry, the regulator provides 'safety culture' requirements that the licensees need to adhere to, while IAEA and WANO provide industry guidance. These requirements and guidelines need interpretation to guide subsequent actions. This research study is interested in examining how the people involved in this work has created meaning out of the 'safety culture' construct, from 1986 up until today.

Your Participation:

You have been invited to participate in an interview because of your work within the 'safety culture' community here in Sweden, being from one of the licensees or the regulator. The interview will last a maximum of 90 minutes and during this time, you will be asked to share your interpretation of what

'safety culture' is and what the construct means to you. After your participation, the researcher might contact you for follow up questions or clarifications.

Confidentiality, Anonymity, and Handling of Data:

The interview will be recorded and later transcribed. Recordings and anonymised transcriptions will be stored on the author's personal computer, in a folder that only the author has access to. The recordings will be deleted upon approval of the thesis while the anonymised transcripts are saved. You will be sent a copy of the transcription for review to make sure the interview captured your intentions accurately.

The data will be analysed together with information collected through other interviews, but also through document review. Anonymised transcribed segments or quotes might be used in the thesis. Care will be taken so that quotes cannot be derived back to you. Your name will not appear in the final thesis, however, due to the limited number of people who work with 'safety culture' in the Swedish nuclear industry, some might recognise your participation, while the general public will not.

You will be sent a copy of the final thesis upon approval which is estimated to take place in the spring of 2026. Subsequent scientific publication may occur after the approval of the thesis.

Your Right to Withdrawal:

Your participation is voluntary, and you can decline participation by rejecting this interview invitation. If you do accept to participate, you have the right to withdraw your participation at any time during the interview. You also have the right not to answer any specific questions during the interview. If so, let the researcher know and we will skip to the next question.

Terms of Agreement:

By signing this form, I accept participation in the research study as it has been described to me. I understand the information and terms of participation and consent to the information I will give to be used as described.

Print out, sign the form, and send back to the researcher's email (see above).

Date:_____

Name:_____

Signature:_____