Strategic Foresight in High-Hazard Organizations

An Analysis of Case Studies in three U.S. Nuclear Power Plants

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Abstract

Contemporary societies rely on numerous organizations in hazardous environments to provide and maintain necessary infrastructures like energy and transportation. These organizations operate under constant hazards to themselves and to the people in their environment. Like all areas of society, high-hazard organizations are facing growing levels of complexity and an environment of constant and rapid technological and societal change. The increasing complexity and perpetual change simultaneously contribute to uncertainty and ambiguity. Especially in hazardous environments, the likelihood of failure increases with rising uncertainty and ambiguity. This accentuates the need to develop methods that can contribute to high-hazard organizations' continued safety. One such method may be strategic foresight. By challenging mental frames and contrasting and testing them against alternative futures, strategic foresight can help high-hazard organizations cope with rising levels of complexity.

This research investigates the distinct characteristics of high hazard organizations and how these affect their ability to employ strategic foresight. For this purpose, the researcher performed a qualitative content analysis of three case studies in U.S. nuclear power plants, as classic examples of high-hazard organizations. The investigation revealed significant challenges for the development of foresight capabilities, especially in regard to the ability to combine new with existing knowledge. This deficiency is due to strong departmentalization, which leads to silo behavior and split mental models, obstructing the effective diffusion of information.

The findings from this research may help researchers and practitioners to understand the peculiarities of high-hazard organizations better and may aid in developing methods to integrate strategic foresight in high-hazard organizations.

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Glossary

Account Acceptability:

People are prompted by their society or culture to put forward accounts of incidents, their causes, lessons learned, and improvement strategies acceptable to the shared believes promoted by their culture. In short, people adapt their accounts to the expectations of their audience (Carroll, 1995, p. 185).

Back Seating:

Putting a valve on its internal backseat is a procedure to stop liquid from flowing through. A stem at the valve's top connects to a disc at its bottom; turning the stem drops the disc into the valve's intake opening as a pressure boundary.

Freeze Seal:

A method routinely used in nuclear reactor fluid systems to drain or isolate components that, for various reasons, cannot be conveniently isolated by valving.

Outage:

The shutdown of a generating unit, transmission line, or other facility. An outage can occur for purposes of inspection, maintenance, or refueling (scheduled outage), or emergency reasons, a condition in which the equipment is unavailable due to an unanticipated breakdown (forced outage).

Root-cause Seduction:

Much of the analysis underlying event reviews is based on the assumption that events can be traced back to a root cause. This linear cause-effect thinking allows for identifying a single root cause and means that the analysis has found the event's source and so everyone can focus on fixing the problem. This satisfies people's need to avoid ambiguous situations in which one lacks essential information to make a decision or experiences a salient knowledge gap. Such an assignment of causality is often ambiguous or mistaken because there is unlikely to be a single cause for any serious or surprising event (Carroll, 1995, p. 180).

Sharp-end Focus:

The sharp end of a high-hazard system is understood as the set of tasks in which people interact with the hazardous process. The sharp end is where the last human barriers were located. People who had a choice and could have prevented an incident tend to be held accountable. Causal reasoning places particular attention on people who could have done otherwise, a type of fundamental attribution error. It is typical for outside observers to attribute actions and outcomes to the actors in the situation, whereas those actors identify features of the situation (including others' prior actions) as the causes of the incident (Carroll, 1995, p. 181).

Solution Driven Search:

Engineering training emphasizes the importance of finding solutions and trains students to focus on problems with known solutions. In this way, diagnosis and problem solving become a search through a space of solutions rather than a much harder de novo design problem. Such an oversimplification tends to break up more complex and dynamic interrelationships. This leads to a classification of problems in terms of available solutions and provides a comforting illusion of control due to the familiarity of and past practice with the solutions (Carroll, 1995, p. 182).

Tight Coupling:

Parts, people, and networks of any system are interconnected (coupled). These couplings differ in terms of their strength. Tight couplings are strong connections, where components of a system are directly dependent on another. Changes in one component necessarily cause changes in other areas. This influence is immediate, constant, and significant (Weick, 1976).

1 Introduction

The disrupting forces of globalization, digitalization, and the rise of the knowledge society make today's times increasingly turbulent. Therefore, organizations are facing "an accelerating pace of change driven by more connections and technology, and increasing sudden disruptive surprises" (Ramírez, 2016, p. 7). Strategic foresight has been proposed as a mechanism to help organizations cope with the rising complexity for several decades (Wack, 1985). Foresight practices are a helpful tool to accept and understand the uncertainty that is ubiquitous in today's environment by challenging mental frames and contrasting as well as testing them against alternative futures (Ramírez, 2016, p. 4). Strategic foresight is an interactive process based on creative and disciplined discovery, interactive immersion, and invention (Ibid.). One domain where the use of strategic foresight appears particularly relevant is high-hazard organizations. Those "are distinctive work settings that include potential harm or death to large numbers of individuals in a single event, such as an explosion or crash" (Carroll, Rudolph, et al., 2002, p. 92). Because these organizations face high levels of complexity, tight coupling, and invisibility, it is particularly challenging for members of those types of organizations to keep track of the status and interdependencies of the system at any given moment (Carroll, 1995, p. 177). At the same time, tight coupling and interactive complexity mean that failures may interact in unseen and unexpected manners and that system units are strongly interdependent (Naevestad, 2008, p. 130). Organizations in such an environment develop distinct learning strategies driven by a need to avoid potential catastrophes associated with trial-and-error based learning, and complacency arising from learning only by success (Carroll, Rudolph, et al., 2002, p. 92).

Furthermore, as a result of strict regulation, concern with reliable operations, and prevention of accidents, high-hazard organizations are strongly compliance-oriented. Staff is trained to avoid uncertainty, to dissect complex situations into coherent pieces, and to view people as sources of disruption to technology and strategy (Carroll, Rudolph, et al., 2002, p. 94). Taken together, these factors force high-hazard organizations to operate in a state of internal conflict between control and learning. On the one hand, maintaining predictable operations, minimizing variation, and avoiding surprises, and on the other, pursuing to increase variety to explore opportunities and prepare for the unexpected.

The goal of this research project is to investigate what challenges to the application of strategic foresight exist in the specific context of high-hazard organizations.

2 Rationale & Research Question

Contemporary societies rely on numerous organizations in hazardous environments to provide and maintain basic infrastructures like energy and transportation. Those organizations operate under constant hazards not only to themselves but also to the people in their environment. While most of these organizations possess a track record of extraordinary levels of safety, it is in the general interest to undertake any effort to ensure their continued safety. Like all areas of society, high-hazard organizations face growing levels of complexity and an environment of constant technological and societal change. Rising complexity and perpetual change are associated with uncertainty and ambiguity.

In such an environment, the likelihood of failure increases simultaneously to rising uncertainty and ambiguity. Thereby further accentuating the need to develop methods that contribute to the continued safety of high-hazard organizations.

Because of its associated risks, nuclear power, from its beginning, has faced substantial public scrutiny and skepticism, forcing operators and regulators to adopt ever new measures to increase safety. Despite all these efforts, the world to date has faced more than one hundred serious incidents and accidents from the use of nuclear power, with more waiting to happen in the coming years (Lelieveld et al., 2012). At the same time, the deregulation of energy markets subjected nuclear plants to growing economic pressures. In the past, the nuclear industry was often caught by surprise, leaving organizations scrambling for answers to the forces of change. Be it in the case of the accident at Three Mile Island, policies for the deregulation of energy markets, or recent decisions for nuclear phase-outs in some European countries. All these factors demonstrate that the nuclear industry is in urgent need of methods to keep up with continuous environmental change for safety as well as economic reasons. It seems, therefore, apparent to investigate the potential of strategic foresight to help nuclear companies cope with these conditions.

Even though strategic foresight has long been proposed to help organizations cope with rising uncertainty, relatively little research is concerned with establishing how organizational structures, cultures, and environmental conditions impact the ability to apply foresight. The extraordinarily complex environment of high-hazard organizations and the resulting unique organizational characteristics, coupled with their need to deal with uncertainty, make the investigation of strategic foresight in high-hazard organizations extremely relevant.

To the knowledge of the researcher, so far, no existing literature directly connects the academic fields of high-hazard organizations and strategic foresight. This project wants to contribute to filling this research gap by pursuing the following research question:

"How do the distinct characteristics of high-hazard organizations influence their ability to employ strategic foresight?"

The results of this study contribute to the research on strategic foresight by investigating how organizational conditions may impact the development of strategic foresight capabilities in the specific context of high-hazard organizations. Thereby, the findings could help to understand organizational requirements for strategic foresight as well as possible boundaries of its use. On a practical note, these insights may provide foresight practitioners with a framework to understand the peculiarities of high-hazard organizations and how they affect foresight work. This may enable practitioners to adjust their methods to the idiosyncrasies of high-hazard organizations.

3 Strategic Foresight

This chapter presents some concepts of strategic foresight and introduces the conceptualization that underlies this project, followed by a brief overview of the historical development of the field and its current state of research.

3.1 Definition

Strategic Foresight involves understanding the future and integrating future-oriented insights into organizational strategy and decision making (Iden et al., 2017). In its broadest sense, foresight can be defined as the creative reorganization of relevant information into meaningful future-oriented knowledge in contexts of accelerated change, and genuine uncertainty (Paliokaitė et al., 2014, p. 161).

Even though concepts of foresight have been around since the 1930s, strategic foresight as a research domain suffers from lacking clarity and consolidation. Furthermore, challenges persist stemming from ambiguous terminologies, with several terms used for similar or overlapping concepts.

Hamel and Prahalad (1994) advanced the term 'industry foresight' to denote harnessing deep insights on trends to rewrite industry rules and create new competitive space. For Slaughter

(1997), 'strategic foresight' represents a fusion of futures methods and strategic management. He defines strategic foresight as "the ability to create and maintain a high-quality, coherent and functional forward view and to use the insights arising in organizationally useful ways" (Slaughter, 1997, p. 1). Another understanding of foresight is put forward by Ahuja et al. (2005). They propose 'managerial foresight' as an individual capability of foreseeing. According to their definition, "Managerial foresight is the ability to predict how managers' actions can create a competitive advantage" (Ahuja et al., 2005, p. 792). 'Corporate foresight' is another terminology used by Rohrbeck et al. (2015) they propose the following detailed definition:

> *"Corporate foresight permits an organization to lay the foundation for future competitive advantage. Corporate Foresight is identifying, observing and interpreting factors that induce change, determining possible organization-specific implications, and triggering appropriate organizational responses. Corporate foresight involves multiple stakeholders and creates value through providing access to critical resources ahead of the competition, preparing the organization for change, and permitting the organization to steer proactively towards a desired future." (Rohrbeck et al., 2015, p. 6)*

Despite focusing on different nuances, the above definitions share some crucial commonalities. Namely, they perceive foresight as a dual-task process of 1) observing, perceiving, and capturing signals of future change, and 2) determining appropriate organizational responses (Iden et al., 2017).
Adding to the confusion about terminology is the overlapping and interchangeable use of terms, and the existence of rivaling conceptualizations under the same label. While there is a consensus that strategic foresight indicates a creative reorganization of relevant information into meaningful future-oriented knowledge in contexts of accelerated change and uncertainty, the above examples illustrate that conceptualizations of strategic foresight vary greatly among researchers (Paliokaitė et al., 2014).

A significant distinction within conceptualizations of strategic foresight exists regarding the organizational level where foresight takes place. Frequently, it is construed as an individualistic human attribute that enables visionary managers to seize opportunities overlooked by others (Major et al., 2001; McKelvey & Boisot, 2009). Contrasting this view are growing numbers of publications that consider the collective as the source of strategic foresight over the individual. Tsoukas and Shepherd (2004), for example, argue that ‘foresightfulness’ only becomes an organizational skill when future-oriented thinking ceases to be a specialized activity undertaken by experts and senior managers, in which they engage from time to time to deal with something called ‘‘the future,’’ but acquires the status of expertise that is widely distributed throughout an organization and is spontaneously put to action” (p. 10).

Somewhat recently, the view of foresight as a social practice has emerged. This stream of studies treats strategic foresight as a form of flexible and perpetual becoming (Tsoukas & Chia, 2002). Understanding the future then requires examining everyday organizing practices and micro-interactions between organizational members. Strategic foresight then is “understood not just as a set of processes or tools but as ingrained managerial competencies or capabilities manifest in the fabric of organizational life and upholstered in the ways of knowing and doing in an organization” (Sarpong et al., 2013, p. 33).

Recognizing this growing fragmentation Paliokaitė et al. (2014) classify distinctive conceptualizations of strategic foresight into three different approaches. 1) *The forecasting approach* represents a view of strategic foresight as a prediction of the unknown future primarily based on the use of quantitative techniques. 2) The *episodic intervention* approach postulates that strategic foresight is a derived outcome of corporate foresight exercises, usually relying on external consultants or futurists' contributions to facilitate the development of meaningful future-oriented knowledge. 3) The *practice approach* treats strategic foresight as an ongoing way of thinking about the future in an organization.

Given the multidimensional nature of strategic foresight, Paliokaitė et al. (2014) draw on organizational capabilities to propose an integrative approach. They advance a strategic foresight framework that consists of higher-level foresight capabilities underlaid by corresponding processes or activities [Figure 1]. They recognize three higher-order capabilities at the most comprehensive analytical level: 1) environmental scanning, 2) strategic selection, and 3) integrating capabilities. Environmental scanning capabilities refer to probing of the external and internal environment to detect signals of change. Strategic selection capabilities illustrate the second step in the strategic foresight process, which is concerned with identifying and selecting the data that is relevant to generate a coherent image of the future. Finally, integrating capabilities indicate the integration of the acquired future-oriented knowledge into organizational processes. Each of these higher-order capabilities depends on several underlying first-order capabilities. With their approach Paliokaitė et al. unify the rivaling conceptualizations of strategic foresight by unpacking it not only as a process, a method, or a practice but as an embedded organizing capability that provides organizations with the means to cope with the future (Paliokaitė et al., 2014, p. 165).

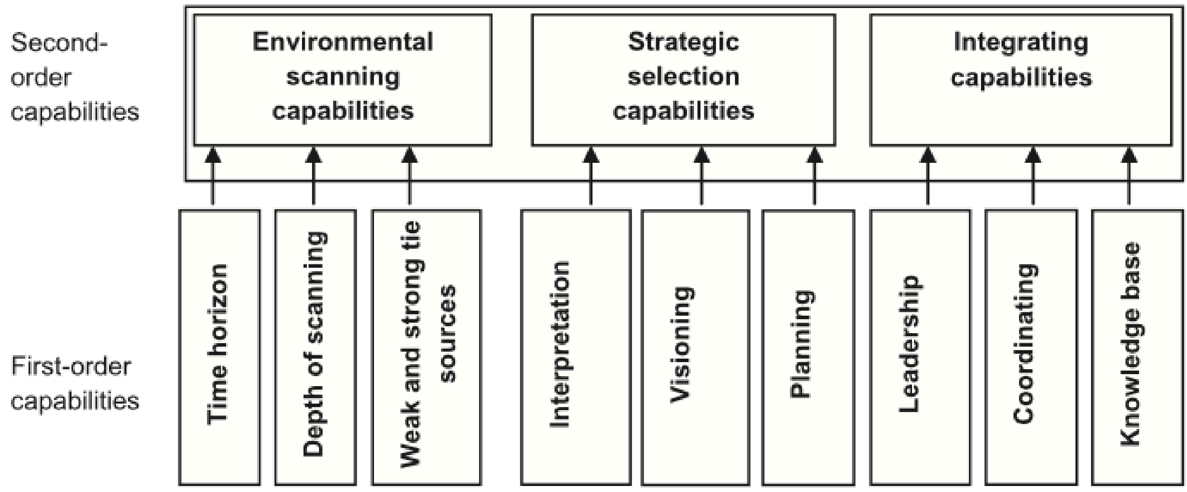

Figure 1 Capability Approach to Strategic Foresight (Paliokaite et al., 2014: 164)

This brief overview of the various contested definitions of strategic foresight illustrates the difficulty that any researcher encounters in academic attempts at rapprochement to strategic foresight.

This research project employs the integrative conceptualization of strategic foresight by Paliokaitė et al. as an ingrained organizational capability because its flexibility allows us to study foresight efforts in different manifestations. Furthermore, this understanding of strategic foresight seems well suited for this research's goal to identify potential challenges to applying strategic foresight in high-hazard organizations because it enables to dissect its constitutive components and analyze relevant factors for the application of strategic foresight.

3.2 History of the Field

The first mention of the term foresight dates back to the year 1933. Alfred North Whitehead was the first to assert that businesses of the future would need to acquire philosophical capabilities and engage in collaborative systems thinking to make sense of present and past, and to anticipate the future if they were to compete in highly complex societies of the future (Whitehead, 2010). These ideas remain highly relevant today and still constitute core elements of foresight. Despite these initial works, it took until the 1950s before foresight truly emerged as a research stream. Simultaneously, in France and the U.S., concepts of foresight were developed. Gaston Berger founded the French 'prospective' school, which revolves around the observation that organizational decision making is subject to high inherent complexity (Rohrbeck et al., 2015). To accommodate this complexity, foresight methods need to involve those actors responsible for making and implementing organizational decisions. Therefore, Berger's methods intend to enable collaborative thinking, future-oriented sensemaking, and facilitate collaborative decision-making. The concept was motivated by the observation that debates often lack a consensual understanding of desired ends, and instead revolve predominantly around means. Foresight exercises enable discussions of desirable futures and, thereby, provide the power to motivate for change and direct planning attention towards beneficial outcomes (Rohrbeck et al., 2015).

Less focused on the involvement of decision-makers was the 'foresight' school, based on the work of Hermann Kahn at the RAND Corporation in the United States. The RAND corporation acted as a think-tank tasked with collecting and consolidating expert opinions. For this purpose, RAND developed, among others, the Delphi technique, which has since proven valuable in consolidating expert opinions in an informed way. A strength of the Delphi method is that it enables a well-rounded debate among participants through multiple rounds of discussion (Rohrbeck et al., 2015).

Inspired by these two approaches, foresight began to grow in popularity with public and private organizations. One particularly prominent example of the successful application of foresight methods is the Royal Dutch/Shell scenario program. Realizing the inadequacy of the traditional linear economic planning tools for a world increasingly characterized by rising complexity and turbulence, Shell initiated the scenario program as a critical planning and decision-making tool (Jefferson, 2012). The Shell scenarios have notably contributed to the popularity of foresight with the scenario-based oil-price report to the board of 1971. The report described the potential for a sharp increase in oil prices, based on the insight that oil-exporting nations might not be able to meet growing demand, thereby foreshadowing several aspects of the oil crises of 1973 (Rohrbeck et al., 2015). Nonetheless, the point of the scenario program was not to predict the future but to create plausible scenarios that could initiate a dialogue about the future and help "break the habit, ingrained in most corporate planning, of assuming that the future will look much like the present" (Wilkinson & Kupers, 2013). As a result of Shells' success, many other companies, such as Motorola, General Electric, and

United Parcel Service, installed scenario-planning as part of their business and corporate planning systems (Rohrbeck et al., 2015).

Globalization and deregulation during the 1980s led to significantly increased competitive pressures, forcing businesses to innovate to attain and maintain a competitive advantage. Consequently, corporations realized the potential of foresight to assist in strategic decision-making and to enhance innovation management (Rohrbeck et al., 2015). As a result, new methods emerged, and, more importantly, foresight exercises began to be undertaken as continuous scanning and interpretation activities. This new approach implied a significant shift in the way foresight was applied. Previously, foresight was typically conducted in the form of large projects that were repeated with varying regularity, often every few years. However, for innovation management, foresight was more and more performed on an ongoing basis to inform about technology and market trends (Rohrbeck et al., 2015). This change meant a much closer integration of foresight with other organizational units to translate signals into operations.

Since the turn of the millennium, foresight practices have seen another surge in demand. Many firms have since created organizational routines that facilitate the development of future insights. Nonetheless, challenges persist in integrating these insights into organizational processes (Sarpong et al., 2013). Overcoming those challenges remains one of the main objectives for researchers and practitioners in the field of foresight to this day.

3.3 State of Research

Though research is still relatively limited, strategic foresight has seen a continued rise of academic interest over the past few years (Jissink et al., 2014). This trend can be attributed to two main drivers. First, accelerating technological change has resulted in an era of unprecedented uncertainty. As a result, organizations have a strong desire to understand potential implications of emerging business models and technological trajectories, to enhance their ability to prepare for the unknown future (Bilodeau & Rigby, 2007; Daheim & Uetz, 2008). Second, empirical evidence increasingly suggests that foresight can benefit organizational outcomes by enhancing adaptive learning capabilities, ambidexterity, innovation, and strategic agility (Sarpong et al., 2013).

Despite the rising interest, however, the field remains weakly organized, and the literature is fragmented and lacks proper integration (Rohrbeck et al., 2015).

In a systematic review of the existing strategic foresight literature, Iden et al. (2017) give a comprehensive overview of the state of the research field. They identify adoption, approach, and outcome as the most commonly investigated areas of research on strategic foresight. Within these areas, strategic foresight methods, organizing strategic foresight, and experiences with strategic foresight are the most dominant topics.

Concerning methods, Daheim & Uetz (2008) point out that strategic foresight activities come in various approaches, organizational forms, and tools, as well as deviating aims and outputs. Nonetheless, they face similar challenges, such as a tension between pressures for quickly achieved outputs and the demand for methodological rigor, unclarity about the congruence of tools and aims, and needs for communicating results and linking them tightly to today's decision-making (p. 8).

Experiences with strategic foresight are some of the most extensively addressed issues in the literature. This includes critical success factors, barriers for adoption, and lessons learned (Iden et al., 2017). While the research proposes a multitude of critical success factors, empirical evidence remains inconclusive concerning explanations of how to conduct strategic foresight programs successfully and how to measure success and effort.

Iden et al. further conclude that there is lacking research on motivation and use, value contribution, and innovation regarding strategic foresight. The literature that exists on the motivation for the use of strategic foresight suggests that it is applied by organizations to support decision making, improve long-term planning, enable early warning, improve the innovation process, and improve reactions to environmental change (Iden et al., 2017, p. 4). Other motivations mentioned in the literature are concerns regarding uncertainty (Tapinos, 2012; Vecchiato & Roveda, 2010) and supporting business development (O'Brien & Meadows, 2013).

The literature lists several ways in which strategic foresight may produce value for organizations. Rohrbeck & Schwarz (2013), for example, distinguish an enhanced capacity to interpret changes and propose adequate responses, organizational learning, and the capacity to influence other actors. Furthermore, strategic foresight is linked with improved decision-making (Vecchiato, 2012), organizational ambidexterity (Bodwell & Chermack, 2010), strategic agility (Doz & Kosonen, 2008), as well as dynamic capabilities in competitive, uncertain environments (Ramírez et al., 2013). However, Iden et al. (2017) point out that most value contributions mentioned in the literature are somewhat generic, and therefore fail to convincingly define the value added by strategic foresight and provide empirical evidence of its advantageousness for organizations over time.

Iden et al. (2017) also emphasize a lacking coherence within the research: "The field looks immature, dominated by explorative research using case studies to construct arbitrary categories to organize and summarize empirical observations. Some attempts to build conceptual foundations exist, but these are without formal structures of explicit assumed propositions" (Iden et al., 2017, p. 9)

4 High-Hazard Organizations

Most of the scientific literature does not provide a general definition of high-hazard organizations. Instead, the majority of the research on this topic is conducted in the domain of accident research. The following section defines high-hazard organizations and uses the existing literature to determine characteristics that distinguish high-hazard organizations from other types of organizations.

4.1 Definition

Definitions of high-hazard organizations mostly stem from research on organizational accidents. In this respect, literature has devoted surprisingly little effort towards defining high-hazard organizations in particular. Instead, research has identified those organizations that operate in error-likely hazardous environments and poses a track-record of reliably error-free operations. The problem of such definitions for this research is twofold. First, such understandings narrow the organizations under investigation to a small subset of successful organizations in high-hazard environments. On the one hand, this would further limit the database of potential organizations. On the other hand, one can argue that especially those organizations that do not possess a track record of high-reliability exhibit a particular need to apply strategic foresight. The second is a practical reason. It is relatively difficult to define reliable organizations from the outside as it requires an objective measurement of the operating history of an organization and an accepted definition of reliability in this context. Incidents of varying magnitude are common even in high-hazard organizations. Therefore, it is challenging to determine what a track record of reliable, error-free operations means in this context.

Hence, this research chooses a rather generic definition of high-hazard organizations, which conceptualizes high-hazard organizations as “distinctive work settings that include potential harm or death to large numbers of individuals in a single event, such as an explosion or crash” (Carroll, Rudolph, et al., 2002, p. 92).

4.2 State of Research

Organizational research has long focused on the peculiarities of high-hazard organizations. Drawing interest from researchers in diverse academic fields such as psychology (Rasmussen, 2003; Reason, 1990), political science (LaPorte & Consolini, 1991; Wildavsky, 2017), and management (Karlene H. Roberts, 1990; Weick, 1987). In broad terms, the literature on high-hazard organizations can be divided into two rival schools of thought. Normal accidents theory (NAT) and high-reliability organizations (HRO) both have their origins in studies of the Three Mile Island (TMI) incident of 1979.

Normal accident theory is based on the works of Charles Perrow on the contribution of human factors to the incident at TMI. His main argument is that some technological systems, such as nuclear power plants, are traversed by interactive complexity and tight coupling. According to Perrow (1999), if in a sufficiently complex organization, two components that interact with each other fail unexpectedly, this interaction leads to the failure of further components triggering a chain reaction. This tendency to interact is not a characteristic of specific parts or an operator, but of the system itself. That is because introducing any fix into the system inevitably increases the number of potential interactions that can fail. In tightly coupled systems, these processes of interaction happen very fast and cannot be stopped. When isolating parts becomes impossible, production cannot continue safely. In such a case, recovery from the initial failure is unattainable, and the disturbance will continue to spread throughout the system. In some systems, unsuspected interactions and tight coupling can be reduced through experience, better designs, and improved equipment and procedures. However, high-hazard organizations require organizational structures with large internal contradictions, and they apply sophisticated technologies that only increase interactive complexity and tighten the coupling (Perrow, 1999, p. 5). NAT is considered a pessimistic approach to the origins of disasters, and has been criticized as fatalistic and not offering constructive input on how organizations may improve safety (Hopkins, 1999).

Perrow does, however, develop a set of policies that serve as recommendations derived from his findings [Figure 1]. The representation maps the potential for catastrophe of some system with the cost of alternatives. Therefore, it indicates which systems are highly risky and less essential, and thus could be abandoned, and which are hard to replace but have less catastrophic potential (Perrow, 1999, p. 304). Perrow specifically names nuclear weapons and nuclear power as systems where inevitable risks outweigh any reasonable benefits that, therefore, should be abandoned.

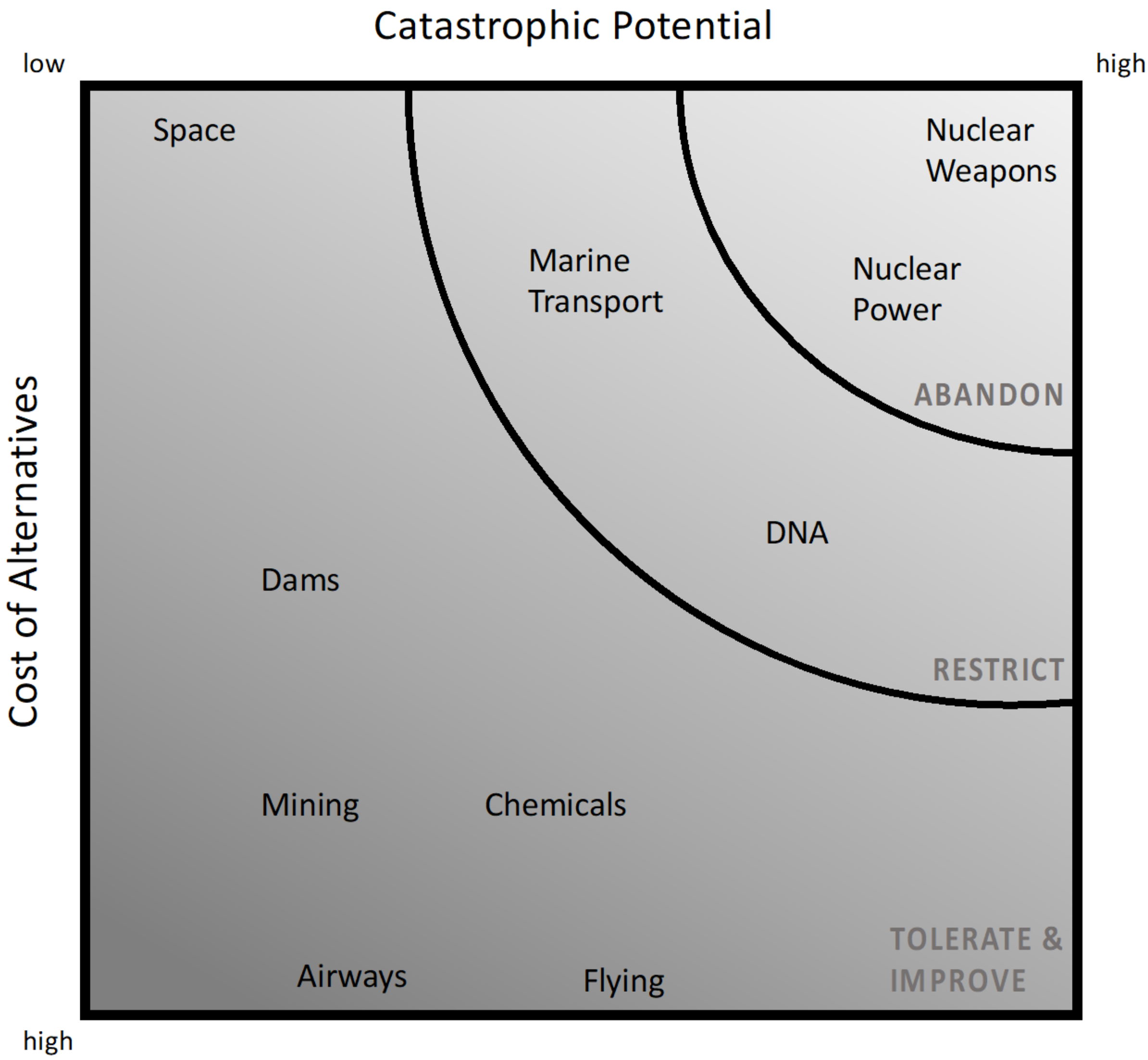

Figure 2 Policy Recommendations for High-Risk Systems (Perrow, 1999)

Originating around the same time is disaster incubation theory by Barry A. Turner (1976). He proposes that disasters happen as a result of failures of foresight. He attributes the development of catastrophe to breakdowns in communication (e.g., information is distrusted, ignored, or insufficiently distributed across the organization). Turner exhibits an optimistic view of the onset of disaster by arguing that disaster is not inherent in the system but is a consequence of the failure of people. Hence, organizations can prevent accidents by taking appropriate precautions. By analyzing past accidents, incubation theory has produced a host of factors and features that are accident precursors that organizations should minimize to prevent accidents from occurring (Hayes, 2013, chapter 2.4.2).

High-reliability organizations (HRO) theory is situated closer to high-hazard organizations themselves, as it investigates how specific organizations sustain safety over extended periods in an environment of high complexity and risk. Studying organizations that require very high standards of safety due to the potential harm they can cause to their environments. Researchers established a list of criteria that provide a working definition for HROs:

> *„1. The organization is required to maintain a high level of safety performance if it is to be allowed to continue to operate.*
>
> *2. The organization must also maintain high levels of capability, performance and service to meet public and/or economic expectations and requirements.*
>
> *3. Because of the consequences of error or failure, the organization cannot easily make marginal trade-offs between capacity and safety. Safety is not fungible.*
>
> *4. As a result, primary task-related learning cannot proceed by trial and error since the first error may be the last trial.*
>
> *5. The technology and primary task are both so complex that safety and capacity issues must be actively and dynamically managed.*
>
> *6. The organization will be judged to have failed and will be criticized almost immediately if either the safety performance or service/product delivery degrades" (Rochlin 1993 as cited in Hayes, 2013, chapter 2.1)*

In a shortened variation, Karlene Roberts defined an HRO as „an organization in which errors can have catastrophic outcomes, but which conducts relatively error-free operations over a long period of time making consistently good decisions resulting in high quality and reliable operations" (Bourrier, 2005, p. 94). HROs are faced with twofold challenges. On the one hand, managing highly complex hazardous technologies while avoiding large-scale failure. On the other hand, maintaining the capacity to meet very high demand and production amid intermittent periods of unpredictability. "This is a situation in which any change in circumstances, internal processes or technical innovation is more likely to degrade than to improve existing operations" (La Porte, 1996, p. 61). In contrast to normal accidents theory, HRO researchers argue that even though highly demanding and unlikely, nearly error-free organizational performance under said circumstances is possible. HRO research is committed to identifying those organizational qualities that enable these organizations to operate at high reliability. To achieve this goal, HRO researchers have conducted several studies in a variety of high hazard organizations such as, among others, aircraft carriers (Roberts, 1990), nuclear power plants (Carroll, 1998; Carroll, Rudolph, et al., 2002; Carroll et al., 2006; Schulman, 1993), chemical plants (Carroll, 1998), and air traffic control systems (LaPorte & Consolini, 1991). Weick et al. later synthesized the findings of these studies into a theory depicting HROs as mindful organizations [Figure 3].

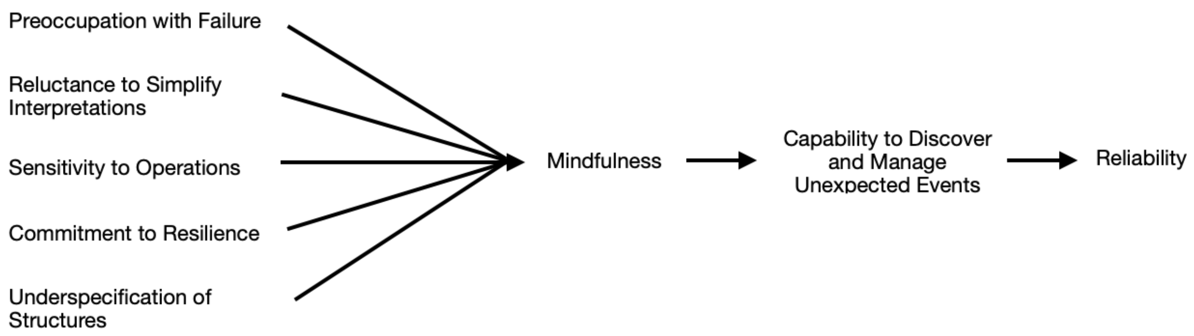

Figure 3 A Mindful Infrastructure for High Reliability (Weick et. al, 1999)

By fostering the qualities of preoccupation with failure, reluctance to simplify, sensitivity to operations, commitment to resilience, and deference to expertise, mindful organizations can improve their capability to discover and manage unexpected events, leading to high reliability (Weick et al., 1999).

4.3 Peculiarities of High-Hazard Organizations:

High hazard organizations are extraordinarily difficult to manage (Carroll & Cebon, 1990). That is because they are socio-technical systems. In these organizations, processes are subject to complex interactions between technology, human factors, social interaction, external demands, and resources (Carroll & Cebon, 1990, p. 13). In such systems, social and technological phenomena are inseparable. These organizations are co-evolving systems of mutually inter-dependent social interaction and technology (p. 17).

Another feature of high hazard organizations is that they are often operationally process driven organizations (Offstein et al., 2013). The risk associated with a process driven approach to organizing is that strict adherence to procedures can negatively impact learning and knowledge capturing capabilities (Sitkin et al., 1994). Therefore, research suggests knowledge captured within these organization in the form of reports, and root cause analyses suffers from intellectual shallowness, lack of imagination, and a dearth of creativity (Carroll, 1995; Offstein et al., 2013). Carroll (1995) argues that four factors in particular limit the interpretive process in high hazard organizations: root cause seduction, sharp-end focus, solution-driven search, and account acceptability.

Mintzberg (1992) offers another angle on the peculiarities of high hazard organizations. He proposes that there are five stereotypical forms of organizations. Three of those are relevant for high-hazard organizations. The “machine bureaucracy” uses explicit rules and standards to control working routines tightly. Its emphasis is on efficiency. The “professional form” grants organizational members considerable autonomy to apply their skills and deliver complex, standardized services. Its focus is on proficiency, and it uses professional training and collegial relations to achieve desired outcomes. The “innovative form” organizes experts into multi-disciplinary project teams to create novel, complex outputs. It accentuates learning.

According to Mintzberg, high-hazard organizations, particularly nuclear power stations, are hybrids of those forms. Their emphasis on the design and implementation of standardized procedures makes them equally machine-like and professional. However, at the same time, they have to cope with unexpected problems and ensure those are corrected requiring significant capacity for innovation. Therefore, high hazard organizations simultaneously embrace the values of proficiency, efficiency, and learning. Subsequently, high-hazard organizations face constant contradictions, forcing management to cope with the discrepancies between machine-like compliance on the one hand, and innovative learning on the other (Mintzberg, 1992).

High hazard organizations are also faced with heightened scrutiny from external stakeholders as a result of the potential threat they pose to their environment. As a result, in addition to the complexity of managing internal stakeholders, management frequently has to interact with outside stakeholders such as government agencies, public interest groups, insurance companies, lawmakers, the media, etc. (Offstein et al., 2013). Juggling the demands from internal as well as external stakeholders further adds to the complexity of managing high-hazard organizations.

5 Foresight Capability Frameworks

Establishing best practices and measuring success has been a significant preoccupation within strategic foresight research. Terry Grim (2009) proposed the foresight maturity model (FMM) as a measurement system for foresight practices. The model defines six disciplines (Leadership, Framing, Scanning, Forecasting, Visioning, Planning) and a set of three to five corresponding practices to measure an organization's foresight capabilities. Competences in each practice can be placed on a scorecard ranked from one (Ad hoc) to five (World-class) to determine an organization's level of foresight maturity. The model is a developmental model, which means an organization must develop its foresight capabilities by evolving through the different maturity levels. Starting with ad-hoc level competencies, an organization inevitably must ascend through levels one to five to be able to build out the highest level of world-class foresight competences. Each level is associated with specific skills that must be mastered before the next higher level of competencies can be reached. Thus, in the model, an organization cannot directly build out level three competencies or evolve from level two directly to level four. Grim intended to develop a model that enables organizations to measure their foresight capabilities according to their individual needs, and that guides firms on how they can develop and improve these capabilities.

On an individual level, Hines et al. (2017) developed a foresight competency model to determine individuals' proficiency in performing the role of a futurist. The model intends to answer what qualities a person should possess to practice as a professional futurist. Figure 4 depicts an illustration of the model. Hines et al. propose six competencies at the core of foresight: framing, scanning, futuring, designing, visioning, and adapting. These competencies are reinforced by three foundational, and two professional competency clusters. The foundational clusters consist of personal, academic and workplace competencies. The professional competencies are subdivided into sector and occupational roles (p. 132).

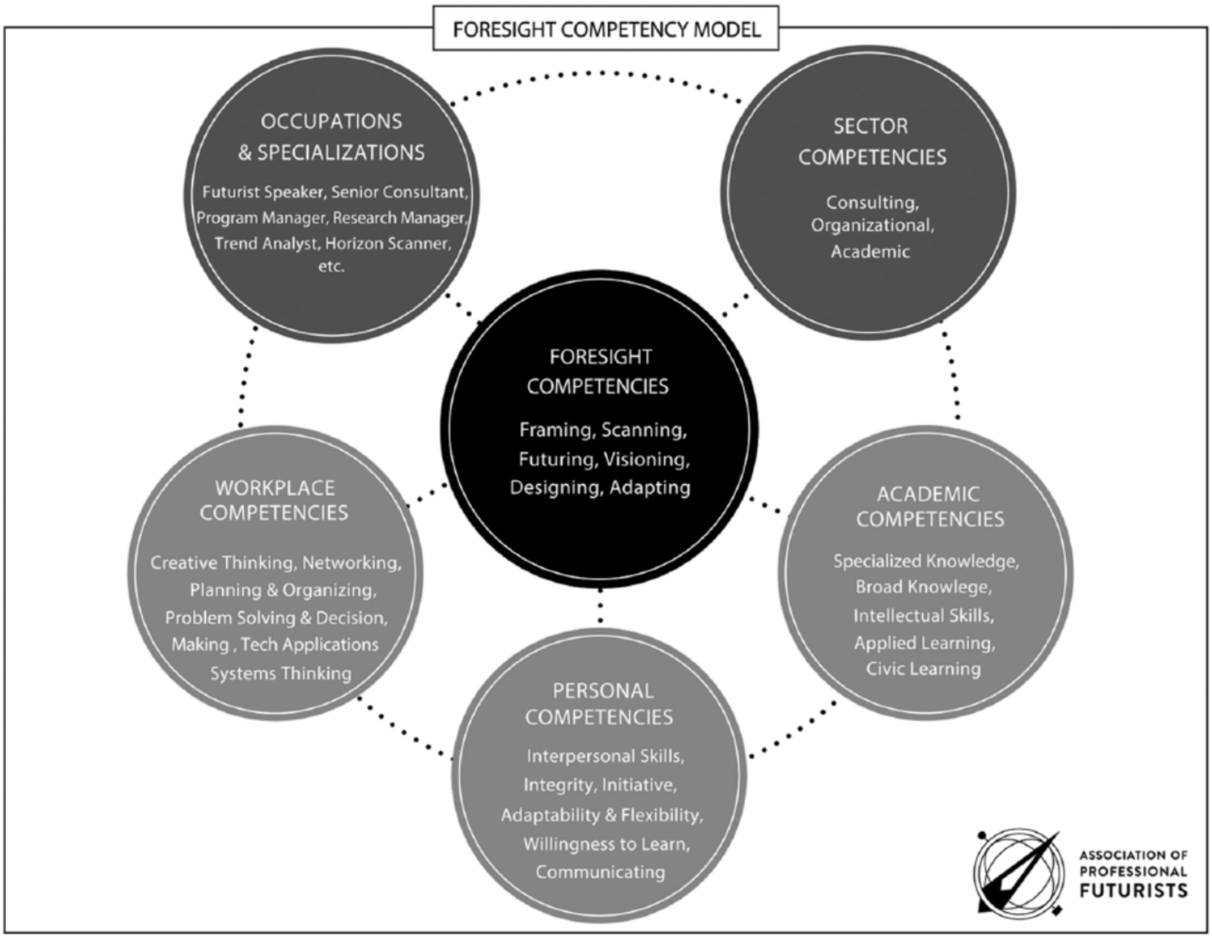

Figure 4 Foresight Competency Model (Hines at al., 2017: 17)

Several authors describe foresight in terms of a process consisting of varying numbers of stages (Daft & Weick, 1984; Horton, 1999; Popper, 2008; Rohrbeck, 2011). Daft and Weick (1984), laid the groundwork for this approach with their model of the interpretation process in organizations [Figure 5]. They describe three stages, namely scanning, interpretation, and learning, that constitute the process by which organizations interpret their environment. Scanning refers to monitoring the environment and providing data. In the second stage, interpretation, this data is given meaning. Finally, in the learning stage, interpretations are translated into actions. Feedback from organizational actions may then provide new insights for subsequent scanning and interpretation, meaning that all three phases are interconnected through a feedback loop (Daft & Weick, 1984: 286).

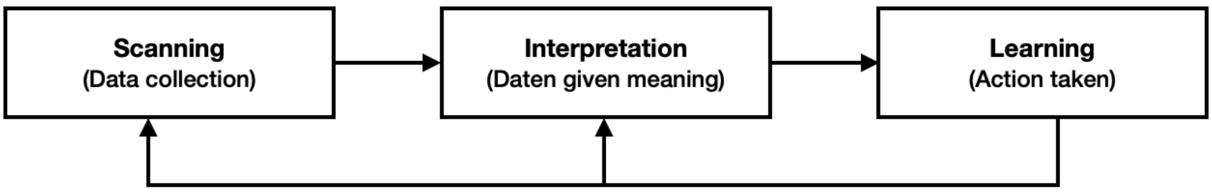

Figure 5 Model of the Organizational Interpretation Process (Daft & Weick, 1984)

Rohrbeck (2011) used the organizational interpretation model by Daft and Weick and extended it to develop his corporate foresight model. Rohrbeck (2011: 114) added two additional steps to the original model, and describes corporate foresight processes in terms of five stages:

1. Identify (Similar to scanning in the original model)
2. Assess (Similar to interpretation in the original model)
3. Convince (Convincing decision-makers of the relevance of foresight insights)
4. Plan (Develop strategies to respond to decision-makers)
5. Act (Similar to learning in the original model).

Based on this model of the foresight process, Rohrbeck goes on to develop a foresight capability framework consisting of 21 capabilities structured into five dimensions [Figure 6].

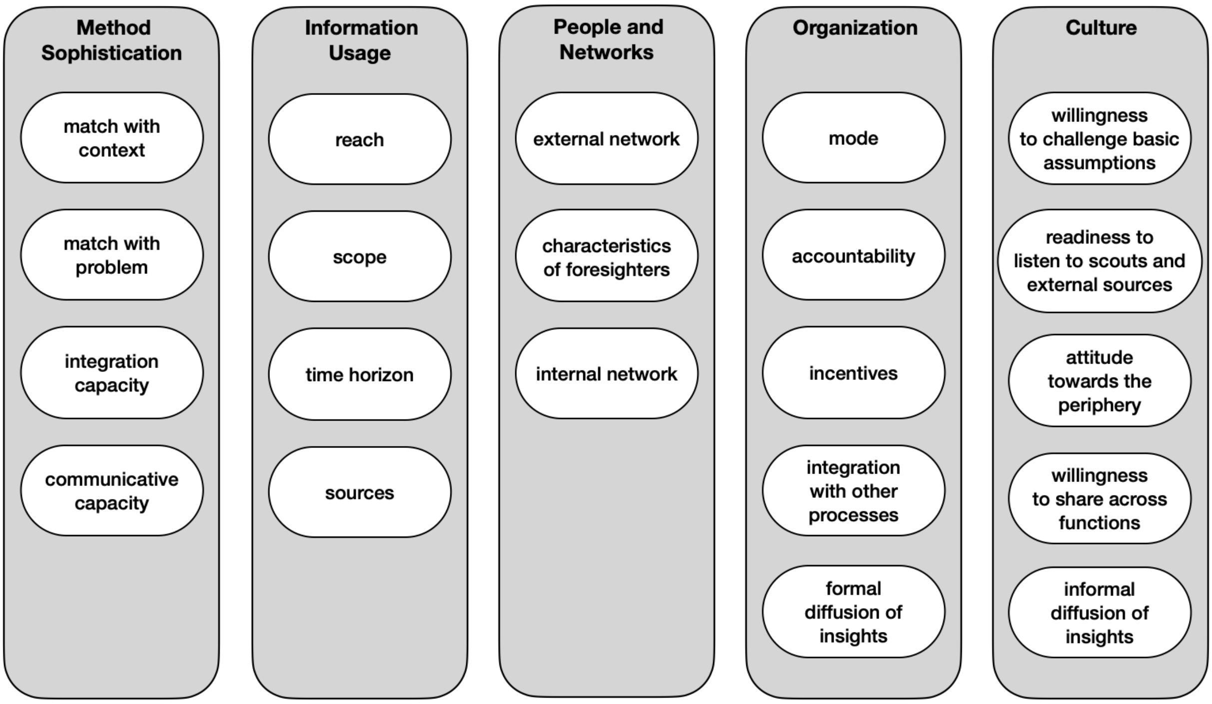

Figure 6 Rohrbeck's Foresight Capability Framework (Own representation)

The "method sophistication" dimension describes the abilities of an organization to interpret information systematically. It is measured in terms of how deliberately methods are chosen to match a specific context or problem, and how useful a method portfolio is for integrating diverse types of information and communicating insights externally and internally (Rohrbeck, 2011, p. 77).

"Information usage" describes the kind of information that organizations gather and feed into the foresight process. It consists of the reach and scope of scanning activities, the time horizons on which foresight is conducted, and the variety of sources an organization has access to (Rohrbeck, 2011, p. 74f).

"People and networks" captures the need for strong internal and external networks to enable effective and efficient communication in a foresight system. Furthermore, it is essential to involve the right people to achieve a high impact from foresight activities (Rohrbeck, 2011, p. 78).

The dimension "organization" defines the ability of an organization to identify, interpret, and diffuse future insights, irrespective of nature and place of the foresight operations. This dimension is evaluated in terms of integration with other processes, formal diffusion of future insights, accountability for detecting and acting on weak signals, incentives to encourage future orientation, and the mode in which organizations engage in foresight activities (top-down vs. bottom-up; continuous vs. issue-driven) (Rohrbeck, 2011, p. 80).

The dimension "culture" captures, to what extent corporate culture supports or hinders foresight activities. Rohrbeck adopts most of the corresponding capabilities from Day and Shoemaker (2005). Namely, willingness to share across functions, readiness to listen to scouts and external sources, attitude towards the periphery, and willingness to challenge underlying assumptions. To those capabilities, Rohrbeck adds the role and effectiveness of informal communication for the diffusion of future insights (Rohrbeck, 2011, p. 81).

5.1 From Capabilities to Foresight Prerequisites

This project adopts Rohrbeck's framework as a point of departure and integrates it with other foresight frameworks, in an attempt to identify organizational prerequisites for foresight.[1]

This project is less concerned with what constitutes good foresight and how foresight can most successfully be applied in organizations, but rather with identifying organizational levers and barriers to the application of foresight. Therefore, some adjustments to the original model have been made. For example, additional variables were derived from the literature and added to the framework.

The dimension of method sophistication has mostly been disregarded for the development of the framework since the aim is not to evaluate existing foresight exercises but to understand

[1] An overview of which variables and models form the basis for the development of the foresight factors can be found in appendix one.

the determining factors for the implementation of strategic foresight in high hazard organizations.

Also, in some cases, the wording was changed from Rohrbeck's framework to a more universal language. This results from the before-mentioned intention to assess the prerequisites necessary to the development of foresight capabilities rather than to measure the foresight capabilities themselves. For example, where Rohrbeck is concerned with the 'attitude towards the periphery,' his focus is on top management. In distinction to Rohrbeck, the framework proposed here includes all organizational members, as the understanding of foresight underlying this research views foresight as an organizational rather than an individual capacity.

Furthermore, some of the capabilities proposed by Rohrbeck were left out or merged. For example, questions regarding the adequate selection of methods for a foresight project were deemed irrelevant for assessing the organizational prerequisites for applying foresight in general. Moreover, 'formal' and 'informal diffusion of insights' have been included in the accessibility category to simplify the model and allow for a broader understanding of the accessibility of information in high hazard organizations.

Furthermore, in deviation from Rohrbeck and in agreement with Baškarada et al., (2016), the categories "reach", "scope", and "time horizon" were merged into one category. The reason for combining them was their high degree of interrelatedness.

Finally, this framework employs a different rationale to group the foresight factors into dimensions, which requires some elaboration. As mentioned, the aim of this project is to understand how the peculiarities of high-hazard organizations influence their ability to develop strategic foresight capabilities.

Research has long been concerned with determining which internal characteristics are critical to success and how they influence outcomes of organizations. In this regard, interest in the internal organizational context focuses on broad and relatively stable categories such as culture, structure, or power (Pettigrew, 1979). There is a growing consensus that a fit between organizational context and organizational strategy impacts organizational performance (Daft, 2013).

	Foresight Factor	Description
Knowledge	**Reach, Scope, Time Horizon**	The extent to which organizations gather information with different reach, scope, and time horizons.
	Sources	Amount of effort an organization undertakes in order to access information from a variety of sources that may not be easily accessible.
	Accessibility	The extent to which information can flow across units and functions through formal and informal channels.
	Foresight Mindset	Extent to which the organizational members display a foresight mindset (lateral thinking, cross disciplinary oriented, imaginative, communicative).
Culture	**Willingness to share across functions**	Degree of openness and inclination to share information.
	Readiness to listen to scouts and external sources	Openness and inclination to listen to external sources.
	Willingness to challenge basic assumptions	Degree of willingness of executives to challenge underlying assumptions.
	Attitude towards the periphery	Level of curiosity of organizational members toward the periphery.
Structure	**Mode**	The approach that an organization takes towards scanning activities. Differentiation between top-down vs. bottom-up scanning initiatives, and continuous vs. project-based investigations.
	Integration	The extent to which scanning activities are integrated with other organizational processes.
	Formalization	Extent of standardization of processes and procedures. Balancing need for efficiency and creativity.
	Training	Extent to which employees are trained to scan for weak signals.
	Networks (internal & external)	Extent and intensity of internal and external ties for the organization as a whole to bring insights into the firm.
	Accountability & Incentives	Extent of responsibility and incentives for scanning for weak signals.

Table 1 Foresight Factors (Own representation)

Adding to these findings, Zheng (2010) et al. point out that knowledge management serves as a mechanism to leverage organizational, structural, and strategic influence on organizational effectiveness. Taking these findings into account, the foresight factors are embedded in the three broader categories of knowledge, structure, and culture. The first category combines factors regarding the management of knowledge in an organization, the second category is concerned with cultural factors, and the third category establishes structural aspects. Table 1 gives an overview of the foresight factors that were ultimately selected for the framework.

5.2 Absorptive Capacity

Major and Cordey-Hayes (2000) point to the high degree of similarity between the concepts of absorptive capacity and conceptualizations of the foresight process. Absorptive capacity was first introduced by Cohen and Levinthal (Cohen & Levinthal, 1990), and has since become a fundamental construct in the organization science literature (Baškarada et al., 2016, p. 416). Absorptive capacity can be defined as a firm's ability to value, assimilate, and apply new knowledge to improve organizational learning (Carayannis, 2012).

	Zahra & George (2002)	**Baškarada et al. (2016)**
Acquisition	A firm´s capability to identify and acquire externally generated knowledge that is critical to its operations.	The ability to identify and acquire relevant information.
Assimilation	The firm´s routines and processes that allow it to analyze, process, interpret, and understand the information.	The ability to analyze, interpret, and understand relevant information, as well as to infer relevant consequences.
Transformation	A firm´s capability to develop and refine the routines that facilitate combining existing knowledge and the newly acquired and assimilated knowledge.	The ability to combine existing knowledge with new information.
Exploitation	The routines that allow firms to refine, extend, and leverage existing competencies or to create new ones by incorporating acquired and transformed knowledge into its operations.	The ability to incorporate acquired and transformed knowledge into operations.

Table 2 Understandings of Absorptive Capacity According to Zahra & George (2002) and Baškarada et al. (2016)

Conceptually it is conceived of as a dynamic capability related to a firm's ability to acquire knowledge and use it systematically to enhance the firm's performance (Zahra & George, 2002). How organizations process knowledge is a critical factor in their success and competitiveness. The main activities related to processing knowledge in organizations are the creation of knowledge and transferring knowledge across time and space (Carayannis, 2012). Zahra and George (2002) advanced the notion of absorptive capacity by describing it as a set of organizational routines and processes consisting of the four components of acquisition, assimilation, transformation, and exploitation. The elements of absorptive capacity reveal a significant similarity with the conceptualizations of foresight as a process consisting of multiple stages mentioned above. Emphasizing the similarity between the foresight process stages and the components of the absorptive capacity model, Baškarada et al. (2016) use Rohrbeck's framework to investigate the relationship between foresight and organizational learning in a qualitative study. By surveying 13 foresight practitioners, they observe that many of Rohrbeck's capabilities represent attributes or characteristics instead of capabilities as such. Using absorptive capacity as a theoretical lens, Baškarada et al. derive four broad foresight capabilities that are underpinned by several interdependent factors.

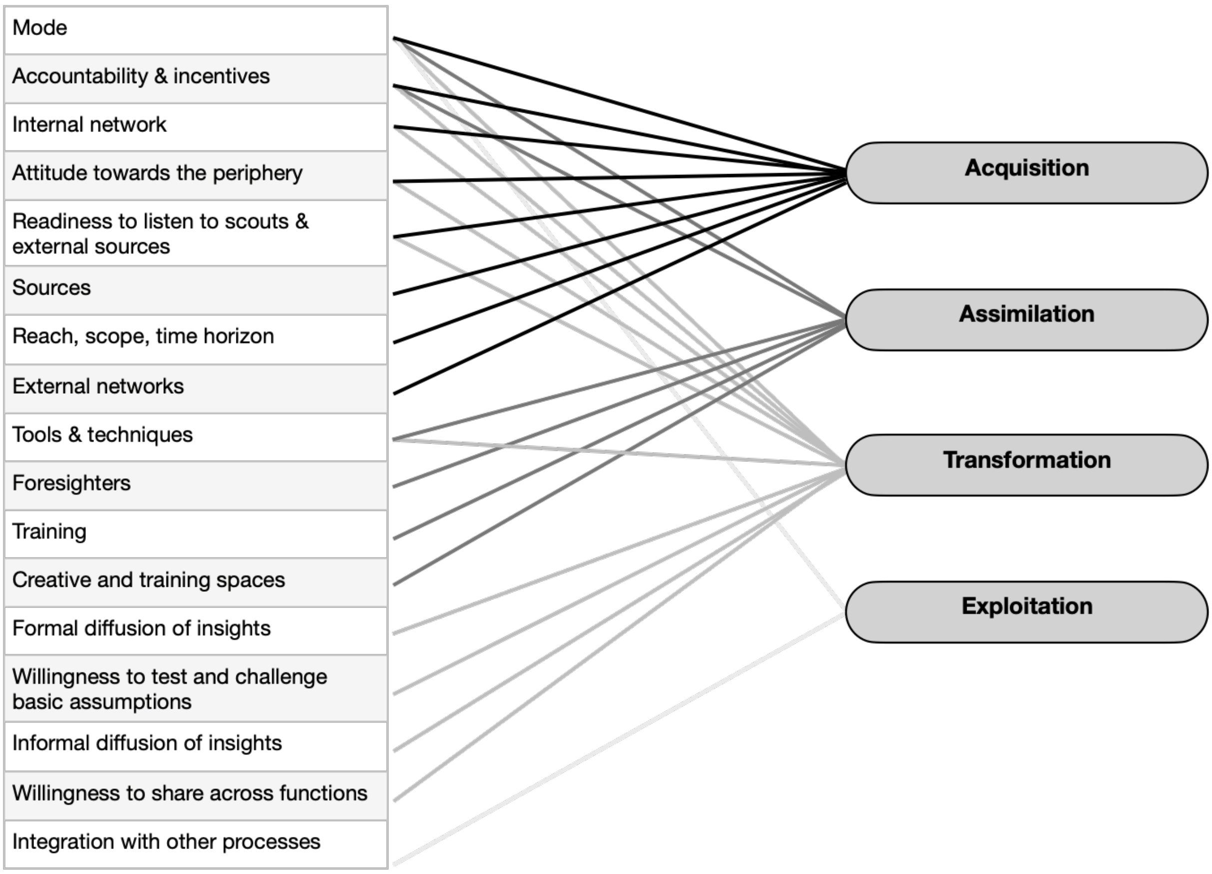

Figure 7 Baškarada et al.´s Model of Foresight Factors Connected to Foresight Capabilities (Own representation)

Table 2 contrasts the definitions of the components of absorptive capacity according to Zahra & George (2002), with the foresight capabilities derived by Baškarada et al. (2016). Notably, the foresight capabilities by Baškarada et al. are less specific and constitute capabilities in the proper sense of the ability to achieve an effect. In contrast, the absorptive capacity components are geared more towards routines and processes that enable the development of certain capabilities (Baškarada et al., 2016, p. 421). These foresight capabilities depend on a variety of interdependent foresight factors. Baškarada et al. connect certain foresight factors directly to specific foresight capabilities. Figure 8 displays a representation of the Baškarada et al. framework. It reveals which foresight factors underly each of the foresight capabilities.

5.3 A Framework for Foresight Prerequisites

Based on the models of Rohrbeck (2011) and Baškarada et al. (2016), this project proposes a framework to study organizational prerequisites of strategic foresight. Therefore, the model integrates the foresight factors altered from Rohrbeck, with the capability framework proposed by Baškarada et al. (2016).

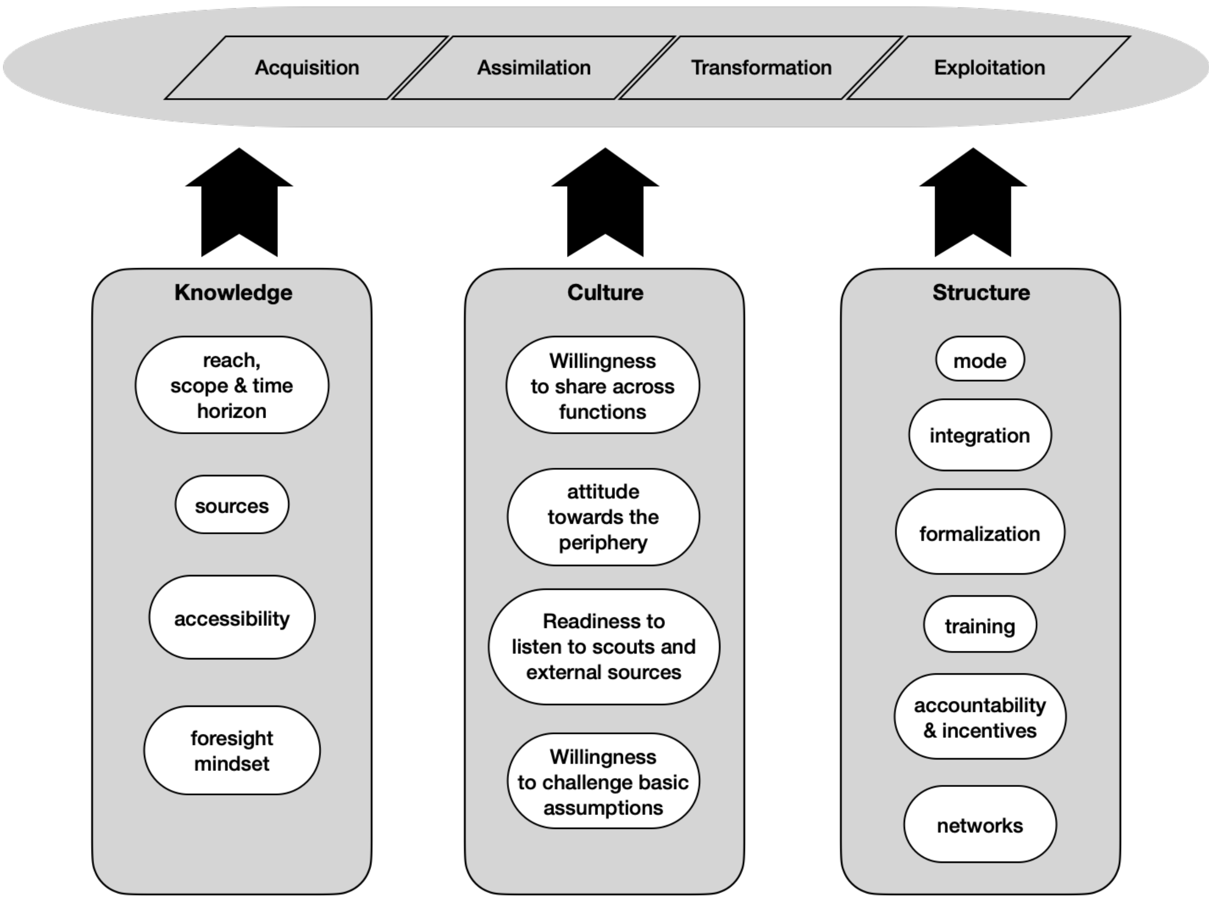

Figure 8 Foresight Factor and Capability Framework (Own representation)

Figure 8 displays the resulting framework. The model is structured along the lines of foresight capabilities and related foresight factors.

The higher-level foresight capabilities are situated at the top, with the foresight factors grouped into the categories of knowledge, culture, and structure underneath. In contrast to the model of Baškarada et al., certain factors are not tied to specific capabilities beforehand. Instead, the basic assumption is that the foresight factors can potentially affect any of the foresight capabilities. Although it is assumed that patterns exist in the relationship between specific factors and capabilities, this framework intends to let these patterns emerge from applying the model to specific organizations. By connecting foresight factors to capabilities, the framework can help specify precisely where organizations may lack foresight skills and how that relates to their overall capabilities in generating, processing, and implementing future insights.

6 Methodology

This research can be divided into two phases. The initial stage of the project was concerned with a thorough review of the literature on high-hazard organizations and strategic foresight. Studying the literature resulted in the discovery of conceptual similarities between organizational learning processes in high-hazard organizations and process models of strategic foresight capabilities. Based on the extensive literature concerned with strategic foresight frameworks and capabilities, this project developed a framework that consist of fifteen foresight factors that translate into four strategic foresight capabilities. The aim of developing the framework was to enable researchers to map specific organizational characteristics that factor into the development of foresight capabilities.

The framework was then applied to three case studies of nuclear power plants. Case studies provide detailed empirical descriptions of particular instances of a phenomenon typically based on a variety of data sources (Eisenhardt & Graebner, 2007, p. 25). Therefore, case studies were chosen as objects of investigation because they can provide rich, in-depth descriptions of organizing practices that may impact the development of foresight capabilities. Nuclear power plants were chosen as objects of study because they constitute classic examples of high-hazard organizations, as explained in more detail in the next chapter.

The case studies are taken from Constance Perin's "Shouldering Risks – The Culture of Control in the Nuclear Power Industry." In her book, Perin draws on her extensive field research in the nuclear industry and introduces three case studies about four events at three U.S. nuclear plants. The case studies are particularly well suited to apply the framework because of the wide-ranging access Perin was granted to these usually not readily accessible organizations. The case studies are based on more than 60 interviews from which Perin quotes extensively and in great detail. Since she gives much space to the perspectives of the people involved in operating the nuclear plants in numerous direct quotations, the case studies are particularly suitable for re-examining these statements in light of the foresight factor and capability framework.

For this purpose, a qualitative content analysis was performed. Coding data in a qualitative content analysis has several properties that are advantageous for the goals of this research project. First of all, it enables researchers to acquire in-depth, comprehensive, and thorough insights because it allows the researcher to revisit all aspects of the data in detail (Skjott Linneberg & Korsgaard, 2019, p. 7). Furthermore, qualitative coding makes the data more easily accessible and retrievable, allowing iterations and returning to the data in light of discoveries or changes in the path of the research (Ibid.). Sorting and structuring also reduce the amount of overall data, making the analytical task of interpreting and drawing conclusions for the final analysis easier (Ibid.).

Moreover, analyzing qualitative content through coding can also ensure transparency by showing the reader how conclusions are linked to the data. Coding enables the researcher to pick relevant examples from the data to illustrate his conclusions to the reader. Showing examples of the data to the reader forces the researcher to develop a chain of evidence depicting arguments and how they lead to convincing conclusions (Pratt, 2009, p. 860).

The analysis was conducted with the qualitative data analysis software MAXQDA2020. MAXQDA is a data analysis software that offers a wide range of tools for the organization and analysis of qualitative, quantitative, and mixed-methods data.

The process of qualitative content analysis was done in three cycles. The first cycle was done as a directed content analysis. The goal of a directed content analysis is to validate or conceptually extend a theoretical framework or theory (Hsieh & Shannon, 2005). It is a structured approach to qualitative content analysis that uses existing theory or prior research to identify key concepts or variables as initial coding categories (Potter & Levine-Donnerstein, 1999). For this research project, the developed foresight factors and capability framework provided the initial categories for coding. Predetermining a coding frame before starting to code the data helps to focus the coding on those issues that are known to be relevant to the research endeavor (Skjott Linneberg & Korsgaard, 2019).

In the first cycle of coding, the foresight factors from the framework were employed as categories for the coding framework. For this purpose, those passages that contained information relating to one of the fifteen foresight factors were coded accordingly.

For the second coding cycle, a clean copy of the same case studies was coded again, following essentially the same process, except this time employing the foresight capabilities as the coding framework.

This resulted in two separate code systems, one pertaining to foresight factors, and the other to foresight capabilities. These two systems, representing the two dimensions of the foresight factor capability model, were then related to each other by analyzing their co-occurrences.

This means that those segments of the case studies were highlighted where foresight factor codes overlapped with foresight capability codes.

This process was intended to synthesize the data and apply it to the foresight factor and capability framework. Thus, enabling a better understanding of how foresight factors and foresight capabilities interact with each other. The resulting segments from the case studies were then subjected to a third cycle of content analysis.

The third cycle of the analysis followed the conventional content analysis approach, also referred to as inductive category development (Mayring, 2000). This type of analysis is usually used to describe a phenomenon (Hsieh & Shannon, 2005). Instead of using preconceived categories, researchers immerse themselves in the data and allow codes and categories to flow from the data (Kondracki et al., 2002). Accordingly, the data was first coded relatively close to the texts to capture key concepts, before these codes were then sorted into broader categories depicting themes of organizational struggles for NPPs. The methodology presented here served to discuss in a structured way in which areas particular challenges or opportunities arise for high-hazard organizations in the development of strategic foresight capabilities, and which organizational idiosyncrasies play a role in this context. The upcoming chapter starts with an explanation of why nuclear power plants constitute classic examples of high-hazard organizations, before giving a short account of the events at the nuclear plants examined in the case studies.

7 Nuclear Power Plants: Classic Examples of High-Hazard Organizations

Nuclear power plants (NPP) are perhaps the prototypical example of high hazard organizations. The potential for catastrophic consequences they pose is enormous, as the accidents at Chernobyl and Fukushima forcefully illustrate. NPPs also face considerable public skepticism resulting from this risk potential. Since the real risks associated with nuclear power production are perceived as unknown, but consequences seem potentially catastrophic to the general public, even small incidents are subject to high public and media attention that can produce large ripple effects (Slovic, 1987). The intensive pressures NPPs face from external stakeholders are also visible in the weight of political influence. Non-governmental organizations have long advocated against nuclear power, creating societal pressures that have led to political decisions to phase out nuclear energy in several countries.

Another characteristic that sets nuclear power stations apart from other organizations is the absolute demand for safety (Kettunen et al., 2007). Accidents in NPPs are not only associated with substantial potential damage to people and the environment, but also with tremendous economic costs that far exceed the costs of preventive measures.

Like all high hazard organizations, NPPs are highly regulated. This means that they have to comply with extensive national and international regulations. They not only have to operate safely, but they also need to display the ability to keep plants safe under all circumstances (Kettunen et al., 2007).

NPPs are socio-technical systems. Therefore, they are technically complex and challenging to manage. Nuclear power stations incorporate many different technologies and hazardous substances. They consist of a whole array of complex, interrelated subsystems. Furthermore, in many stations, old and new technologies operate simultaneously, adding to the complexity of integration, maintenance, and modification of systems (IAEA, 1998). The complications in the organization of NPPs are increased even further during outages, which are conducted regularly for refueling and maintenance purposes. During those periods, usually more than 1000 plant employees and outside contractors work on various assignments. These activities require incredibly high levels of work planning and co-ordination, while overall risk levels are heightened (Barriere et al., 1994). Plant outages are planned with significantly constraint schedules to keep the downtime as short as possible and revenue loss minimal. At the same time, the scope of tasks that need to be completed is usually enormous and concerns all sides of the plant (Wahlström & Kettunen, 2000).

To ensure safe operations despite these extraordinary demands, nuclear plants rely on extensive rules and guidelines, such as license conditions, technical specifications, management control procedures, maintenance programs, work instructions, and quality systems. All personnel from external contractors must receive certification and undergo a security screening before being allowed to work in NPPS. Furthermore, technical modifications and organizational change initiatives are subject to a safety analysis before implementation. Intensive formal requirements and procedures for construction, maintenance, and modifications far exceed those of most other industries (Kettunen et al., 2007, p. 429).

Developments in recent years have further contributed to the complexity levels of nuclear plants confronting NPPs with new challenges. Deregulations of electricity markets beginning in the 1980s and 1990s have put operators under intense pressure to reduce costs without compromising safety (Kettunen et al., 2007).

Taken together, these factors underline the exemplary nature of NPPs as high-hazard organizations marked by extreme levels of complexity.

7.1 Incidents at three U.S. Nuclear Plants

This research uses three case studies conducted by Constance Perin in nuclear plants in the United States as an entry point to the organizational logics of high-hazard organizations. The case studies are based on event reports and interviews with personnel at those plants. Each case study is related to the investigation of an incident at each plant. Even though Perrin published the case studies in 2005 and conducted her research in the 1990s and early 2000s, the cases still provide a relevant database for the study of nuclear power stations. This is because the way nuclear plants are operated has seen relatively little change since the 1960s and 70s when most of the units were constructed. Initially, NPPs were usually scheduled to operate for around 40 years. However, many plants have meanwhile far exceeded their lifespans now running for 60 years and more. Although the nuclear industry has made fundamental improvements in reducing operational risks over the past decades, patterns of

overconfidence and complacency still pose problems that the industry hasn’t been able to control for decades (Behr, 2009).
The studies provide a useful starting point for this investigation as they focus on the accounts of organizational members involved in the daily operations of a high hazard organization. Therefore, the cases should produce insights about the organizing practices at different organizational levels in NPPs. From these insights, conclusions can be derived how cultural, structural, and knowledge management characteristics of these organizations impact their ability to employ strategic foresight. Because the case studies relate to instances of organizational failure of varying magnitude, the insights generated through the analysis can help understand patterns of organizational behavior that may pose a challenge to the application of strategic foresight.

In the first case, at Arrow station, a repair effort at a leaking valve in containment was unsuccessful and led to a leak of cooling water.
The second case is concerned with investigations into two events caused by ‘human error.’ In one case causing an automatic reactor trip, and in another leading to a breach of Nuclear Regulatory Commission (NRC) security regulations. At Bowie station, an experienced plant operator was tasked with finding an electrical ground when he confused a panel and operated a wrong switch causing an automatic reactor trip. In the other incident, Bowie station was preparing for a refueling and repair outage. For this purpose, 1,200 outside contractors were hired, requiring security clearances for each outsider. During this process, a piece of information about a contractor was overlooked that should have led to a decision to deny him access to the plant.
The third case revolves around an incident where risk management had to decide about shutting down the reactor at Charles station, after encountering an unusual hotspot on a transformer in the switchyard.
By relying on data about organizational errors that led to incidents, this research intends to identify underlying systemic issues that obstructed organizational learning processes in these NPPs. Because of the conceptual proximity of organizational learning and strategic foresight, those issues can serve as entry points to draw inferences about organizational foresight capabilities.

8 Preliminary Results

A total of 386 segments were coded in relation to the foresight factors. These are divided into 150 codings for case 1, 74 codings for case 2, and 144 codings for case 3. The results of the initial round of coding of the case studies are displayed in Figure 9. The representation contains the foresight factors on the left and the three case studies that were analyzed on the top. The squares located on the intersecting lines display the occurrence of the respective foresight factors in the individual case studies. The size and color of the square represent their incidence. A bigger sized square indicates a higher occurrence of segments coded in relation to the given foresight factor.

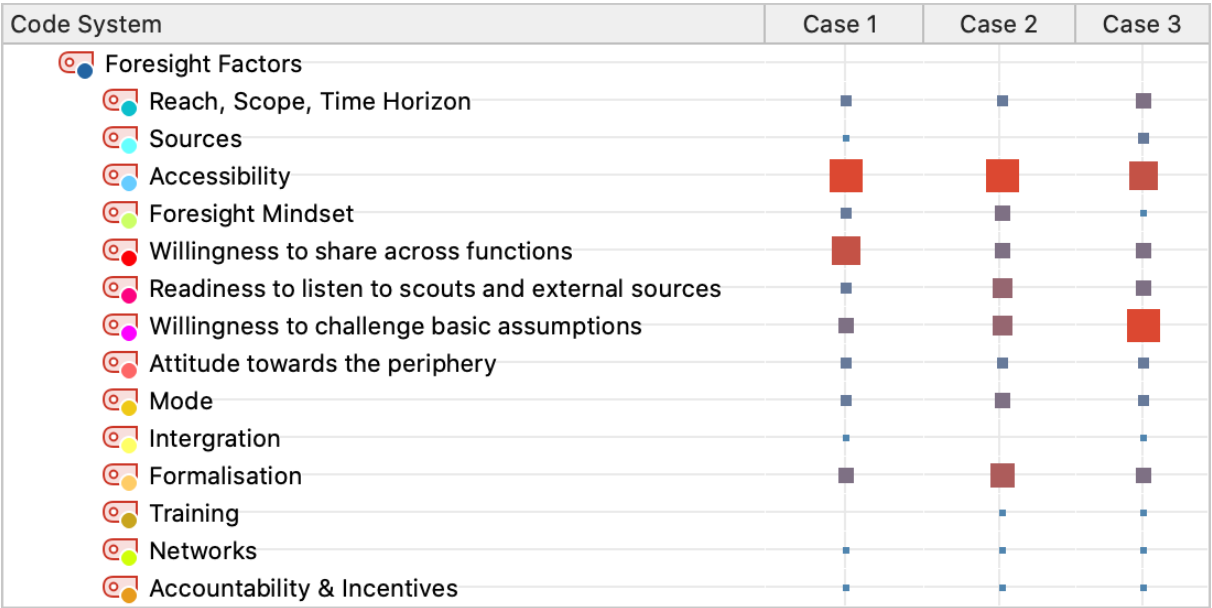

Figure 9 Foresight Factors Case Distribution (representation with MAXQDA2020)

Figure 10 is another depiction of the distribution of codings relating to the foresight factors for all cases accumulated. The most codings are related to ‘Accessibility’ with 91. The second most is related to ‘Willingness to challenge basic assumptions’ with a total of 63 codings. The third is ‘Willingness to share across functions’ with 53 coded segments across all three case studies. It is apparent from the overview of the codings that most of the data is related to the cultural aspects of the foresight factors. Within the knowledge category by far the most data was connected to ‘Accessibility,’ with ‘Reach, Scope, Time Horizon,’ and ‘Foresight Mindset,’ also revealing considerable data. Within the category of structure, only ‘Formalization’ and ‘Mode’ produced noteworthy accumulations of coded segments.

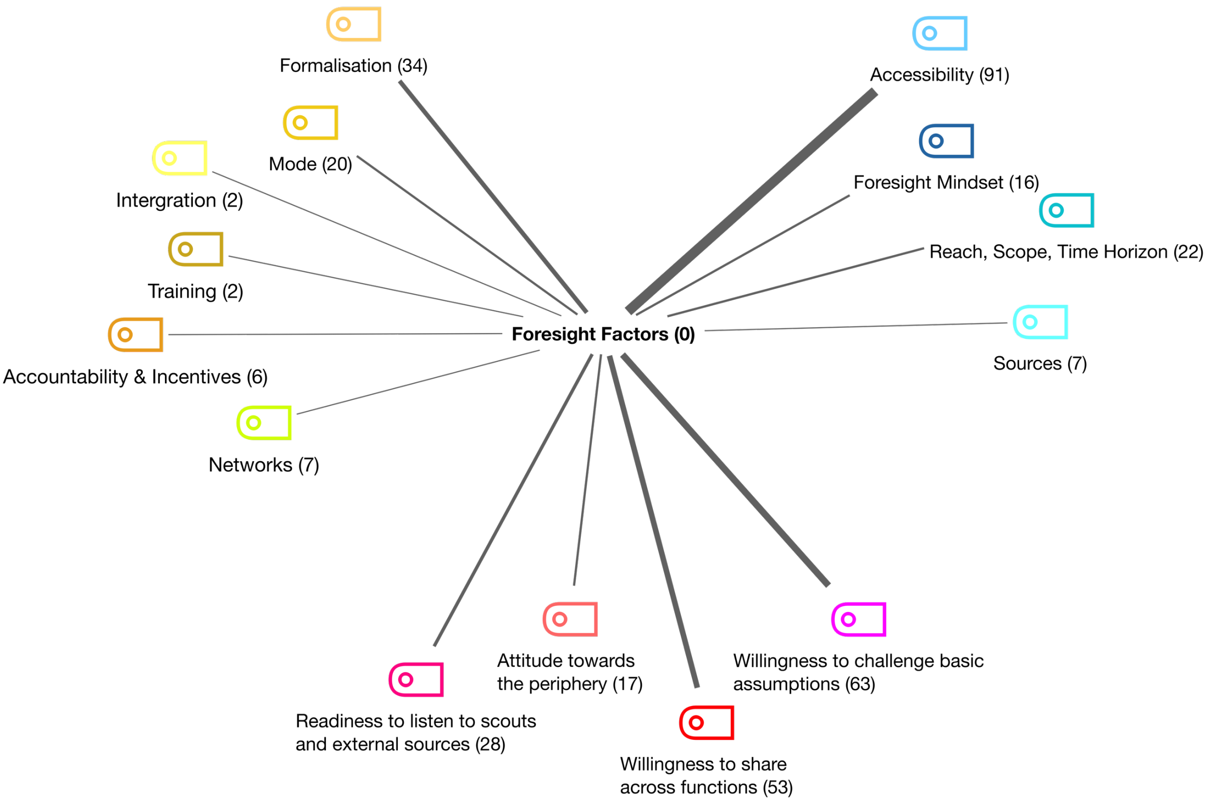

Figure 10 Foresight Factors Distribution (graphical representation with MAXQDA2020)

The analysis of the case studies in relation to foresight capabilities resulted in a total of 255 coded segments. Those were distributed among the cases into 93 in case 1, 69 in case 2, and 93 in case 3. Overall, 74 segments were coded in relation to 'Acquisition,' 43 related to 'Assimilation,' 86 connected to 'Transformation,' and 52 to 'Exploitation.'

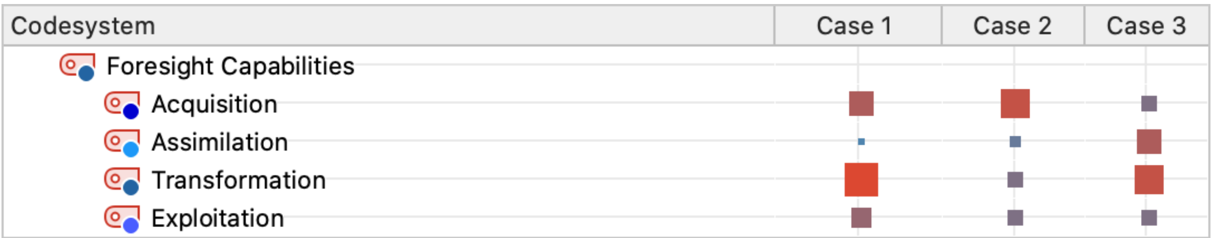

Figure 11 Distribution of Data on Foresight Capabilities Across Cases (representation with MAXQDA2020)

Figure 11 displays the distribution of coded segments related to foresight capabilities across the three cases. Interestingly, each case revealed insights concerning significantly different aspects of the capability framework.

Cross-referencing the two different sets of codings resulted in 421 segments where codings of foresight factors intersected with codings of foresight capabilities. Figure 12 illustrates the relations between the two dimensions of the framework within the analyzed cases. On the foresight capabilities axis, the representation depicts the highest data accumulation connected to ‘Transformation’ with 156 hits. Followed next by ‘Acquisition’ with 103, ‘Exploitation’ with 93, and ‘Assimilation’ with 69. On the foresight factors axis, by far the most intersections occurred related to ‘Accessibility’ with 110, the second most to ‘Willingness to challenge basic assumptions’ with 73, and third ‘Willingness to share across functions’ with a total of 64.

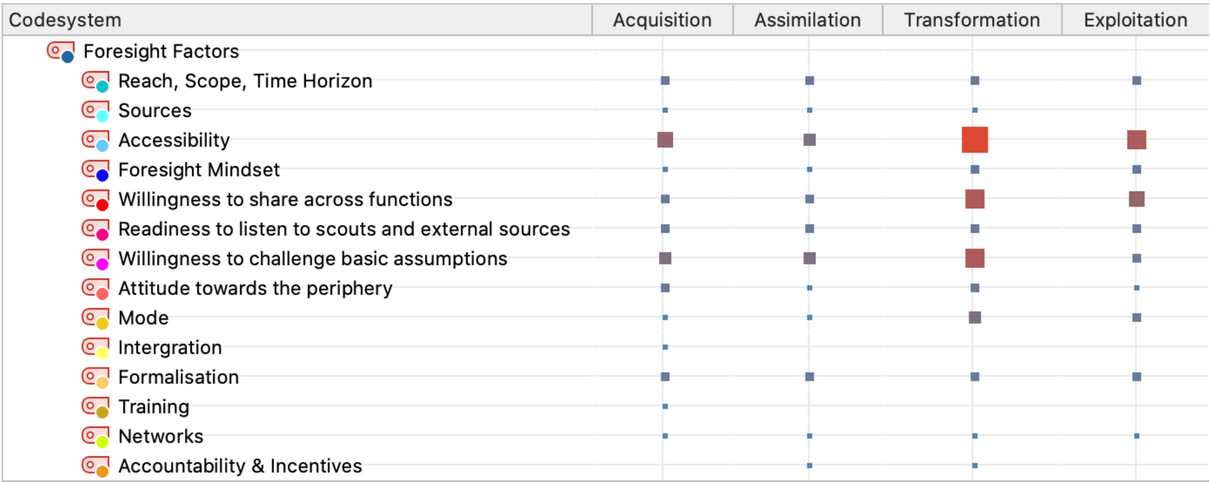

Figure 12 Foresight Factors & Capabilities Relations Browser (representation with MAXQDA2020)

The segments where foresight factors and foresight capabilities intersected were analyzed again in a third cycle of coding which followed the conventional content analysis approach, also referred to as inductive category development (Mayring, 2000). This exercise was done to let underlying explanatory patterns emerge from the data. The result of this exercise was a total of 196 coded segments distributed across fifteen themes. Among these themes, nine contained ten codings or less and were therefore disregarded for further analysis. Therefore, six underlying themes remained that influence foresight factors and foresight capabilities. In the following section, the findings resulting from the coding are explained in detail. First, some of the results concerning the foresight factors are examined before the derived themes, and their impact on the foresight capabilities are considered.

9 Findings from Analyzing Three Case Studies of Nuclear Power Stations in the U.S.

The previous chapter gave a preliminary overview of what data the coding of the case studies produced. However, these results only indicate how the data pertaining to the framework's different dimensions are distributed. Therefore, the following section is concerned with the interpretation and deriving meaning from the coded data. The chapter consists of two parts. The first part of the chapter lays out the findings relating to foresight factors. By using quotations from the case studies, the manifestations of the respective foresight factors are illustrated. This section aims to build an understanding of the state of the foresight factors in the different NPPs investigated in the case studies.

The second part elaborates on the results of the inductive category development. Quotations from the case studies are used to explain the broader themes that underlie many of the organizational struggles of NPPs and may impact the development of foresight capabilities.

To substantiate the themes, further research on NPPs is used and the themes' relevance is discussed using the foresight factors and capabilities framework.

9.1 Willingness to share across functions

The results from the coding of the case studies revealed a strong intersection of the foresight factor `willingness to share across functions` and the foresight capability 'transformation.' That these two components of the framework interrelate seems apparent because combining existing knowledge with new information (transformation) inherently depends on organizational abilities to share knowledge. Therefore, the preliminary results seem to emphasize the strength of the model in highlighting how organizational factors contribute to foresight capabilities. The question is, how developed these factors are in the NPPs investigated in the case studies.

The findings from the case studies regarding 'Willingness to share across functions' are somewhat ambiguous. While there are instances where relevant information is not shared sufficiently across units and functions, it seems like this is not due to a general unwillingness to share information with others. On the contrary, organizational members repeatedly emphasize the need for openness and acknowledge the importance of exchanging information to the safety of operations. However, it seems that the willingness to listen to and receive information from other functions is much less developed. Functional units seem so attached to their operating ways that information concerning other functions is met with skepticism:

> *"One question I have is about the kinds of evidence people pay attention to and what kinds they discount. And when you ask that question about this event, and look at the reports again, it becomes sort of a theme. Like the maintenance manager not giving great credence to the system*

> *engineer's observations. What does it take for people in different positions— because everybody has their own perspective—to give something credence and credibility?*
> If I had the answer to that question, I'd bottle it and be a millionaire and retire. I think that ties in with this silo effect that we see in the unit. Yeah, maintenance is a silo, engineering is a silo, ops is a silo, operations doesn't respect the system engineers, so they don't give them the credence that they deserve. You know, engineering doesn't respect ops, so they don't give weight and credence to points that operations tries to make. Maintenance doesn't respect system engineers, so they're not working together. Ops and maintenance don't respect each other so they're not working together. You know, it all leads to the silo. If I had the answer to that question, all our problems would be solved." (Perin, 2007, p. 75)

Sharing of information is hampered not by a general unwillingness to share with other units, but by the failure to see the bigger picture. Information is usually not suppressed or intentionally kept from others, but rather pieces of information lack consolidation with perspectives from other functions. This is often a result of the heavy reliance on expertise as an organizing principle. Failing to reflect the consequences of their actions on other organizational functions usually leaves those other units entirely in the dark. Simply because focusing on one's owns expertise leads to a neglect of the broader context. This challenge is summarized in the accounts of two station operators at Arrow and Overton Station:

> "It's that, to me that's the biggest part, that mentality, 'We've done this a hundred times,' and they don't look at it as 'What could happen?'—the what-if. They don't look at that type of thing… And quite often it turns out to be very complicated and they start finding problems that they could have got into." An Overton Station maintenance supervisor was explaining a gap in communication during an outage. "At the backshift turnover, ops pulled out without talking to anyone about what had been going on. We need to get people talking. They're not there just to stroke a valve." (Perin, 2007, p. 62)

This inability to communicate across functional boundaries creates vast inefficiencies and can in the worst case incubate failure. An operations manager recalls how failure to include operations in the planning of a critical repair effort required management to start over completely:

> "The next big challenge we had after this leaking valve event was a feedwater valve that was a direct containment penetration. And in that one, it was about halfway through the management meeting that they realized that they had not invited anybody from operations to discuss the repair plan on this containment penetration. So they called me, and I grabbed one of my supervisors, who was a direct control room supervisor, and brought him in. And we sat there and listened to the

> plan and said, "No. We're not going to allow you to do this." And that put planning back to square one, to develop a plan that we felt met the safety needs of the plant, not merely the technical needs of going in to repair the unit." (Perin, 2007, p. 68f)

To consolidate knowledge across functions requires someone particularly designated for the task of taking the bigger picture into account. Experts are trained to narrow things down instead of looking at the wider context; if left on their own, experts see everything through the lens of their craft. So much so, that it requires someone who is trained to mediate among functions to enable cooperation:

> "Jerry, the manager of engineering technical support in operations, calls this "stepping back" and "sitting back," which is usually the task of "appointed" people. I don't think information was shared well on what they found when the packing started to extrude. I think there were suppositions made, "Oh yeah, we just put a freeze seal on it, and we can get the freeze seal people in." My organization was tasked with getting that stuff ready, but at no time was there a consideration that this was a time constraint, that we had to hurry up and do it. So I think, as an organization, between communications and how we work together, we really fell down." (Perin, 2007, p. 70)

The NPPs in the case studies exhibit severe inefficiencies in the sharing of information across units and functions. The challenge seems to be rooted in a culture that values technical expertise over the ability to see the bigger picture. This results in a situation where people get caught up in the details, making them unreceptive to information shared by others. Overcoming these difficulties requires specifically designated people and responsibilities to make sure no crucial pieces of information get lost.

9.2 Readiness to listen to scouts and external sources

The case studies' coding resulted in a relatively low number of coded segments for the foresight factor 'readiness to listen to scouts and external sources.' Therefore, while there is some evidence connecting 'readiness to listen to scouts and external sources' to 'acquisition' and 'transformation,' it should be viewed as not much more than anecdotal evidence.

Nonetheless, from the perspective of the foresight factors and capabilities framework, these relationships seem logical since the ability to identify and access relevant information is influenced by the ability to maintain networks to source information from the environment.

Similarly, the ability to combine new and existing information requires the willingness to listen to external sources and reconcile their insights with existing information.

In the case of the NPPs investigated in the case studies, the analysis produced contradictory results about their 'readiness to listen to scouts and external sources.' At first sight, the case studies reveal a high degree of openness towards external sources, as is illustrated by the great efforts that these organizations undertake to bring in external knowledge and to promote learning from sources in the environment.

For example, it is common practice for people to visit other plants and to welcome personnel from other stations in attempts to foster the exchanging of knowledge. One utility company in the case studies went to even further length to enable learning across organizations:

> "A unit's operators are usually licensed only for that unit (sometimes at the same station for two units, if they are identical). At extra cost, Overton's utility deliberately built stations about 100 miles apart with the same reactor technology to maximize exchange of operating experiences and ideas. But over the years, all agree, disappointingly little occurred." (Case 1 , S. 61: 1375)

Despite organizational structures specifically designed to bring in external expertise, instances for this exchange to happen seem to be rare. This appears to be rooted in a far-reaching resistance to apply knowledge obtained from outside sources in daily operations as one incident at Arrow station illustrates:

> "All review team members knew that backseating[2] this brand and size of valve had been problematic previously, at this station and in the industry generally: studies found the stem vulnerable to embrittlement and cracking under high temperatures and to excessive force (overtorqueing) when putting it on its backseat. Although managers had added details about its perils to the station's conduct of operations and warnings about backseating the valve when hot, procedures for the backseating task did not incorporate them. The Conduct of Operations, a document required by the Nuclear Regulatory Commission, translates into a "chain of command" the design basis and its defense-in-depth strategy. This document defines the enveloping accountability structure of each function and its assigned responsibilities and authorities and specifies how the operations department is expected to relate to other departments. Each Conduct of Operations is unique to each station—Arrow Station's runs fifty pages." (Perin, 2007, p. 46)

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[2] Putting a valve on its internal backseat is a procedure to stop liquid from flowing through. A stem at the valve's top connects to a disc at its bottom; turning the stem drops the disc into the valve's intake opening as a pressure boundary.

In a process driven organization like a nuclear power plant, information must be integrated into the written rules and procedures that govern day-to-day operations. In this case, something prevented this piece of information from being translated from industry insight into operations.

A possible explanation for the failure to integrate and apply external knowledge may lie in an organization-specific mindset. The following excerpt points to an industry-wide perception of organizational singularity. Because NPPs are extraordinarily complex, organizational members may frequently view their organization as a unique assembly of social and technical systems. Such a perception makes it hard to make comparisons to other stations and appreciate insights generated in a subsequently ostensibly different environment. The following excerpt speaks of this clanship which often obstructs learning in NPPs:

> "We're too different to learn anything from them." I have heard peers from the Institute of Nuclear Power Operators at a workshop for about twenty-five operations managers plead with them repeatedly to get and read copies of an international operating experience handbook that INPO prepares on a regular schedule." (Perin, 2007, p. 95)

Even though industry reports on operating experiences are part of the fabric or nuclear regulation, each station considers itself unique.

A very own operating philosophy embedded in unique conduct of operations, a unique history of modifications, remarkable operating experiences, a history of distinguished managers, and relations with regulators, vendors, and contractors, make each plant incomparable to any other station.

Oddly, the case studies also point out that although comparisons among NPPs are highly contested in the industry, there is a pattern of managers listening to outside experts and trusting their recommendations over insiders. This can lead to dissatisfaction among organizational members that don't feel sufficiently valued:

> "When giving evidence its due, there is a pervasive industry pattern of taking the word of "credentialed" outsiders over that of insiders, a practice that frustrates and demoralizes the home team when managers, after hearing their recommendations, take action only if outsiders agree." (Perin, 2007, p. 178)

The evidence from the case studies suggests that 'readiness to listen to scouts and external sources' is contingent on the context in which the outsider information arrives. In the case of industry comparisons, insightful listening seems difficult to achieve; however, knowledgeable experts seem to be associated with a form of credibility that may even overvalue their contribution in relation to insiders. Credibility to the sources of information is of extreme importance in an environment marked by multiple conflicting pieces of information. Receptiveness for external knowledge, therefore, depends not necessarily on its content but the credibility of its source. This implies that ties to external networks exist but are not always used adequately to harness relevant insights.

9.3 Willingness to challenge basic assumptions

The coded results suggest a relationship between the foresight factor 'willingness to challenge basic assumptions' and the foresight capability 'transformation.' These findings seem coherent because, in order to transform knowledge through the combination of new and existing information, organizations need to be able to challenge basic assumptions. If basic assumptions cannot be challenged, this implies that new knowledge is continuously disregarded in favor of existing knowledge, effectively making it impossible to transform foresight insights.

The analyzed data suggests that the NPPs in the case studies struggle considerably to create a culture of openness that allows organizational members to challenge assumptions. A problem that, Chuck, a senior engineer at Arrow Station, attributes to a lacking willingness to accept opposing opinions by top-management:

> "In a situation like this, my feeling as a shift manager is when my boss asks me to do something, my first question, even if it's not outright, but in my mind, "Is it safe? Is what we want to do safe?" That's the first question. The second question is, "Is it legal?" OK. Not that I think my boss would ask me to do something illegal, but he may ask you to do something, and you may turn around and say, "These are the technical specifications and it doesn't fit. We can't do that." If I think it's safe and I think it's legal, then I have to ask if it's the best thing to do or not. Then my responsibility is to give my opinion whether I agree it's the best thing to do or it's not. Unfortunately, what I think you have right now is a high-level management structure that tends to not want to listen to people it doesn't agree with. In other words, they come up with something and if you say, "No, I think it's this..." they say, "Why are you disagreeing with us?" Instead of the open listening. I don't really think that's there right now.
>
> *What do you think it takes for it to get there?*
>
> (sigh) The right people in management, the people with the right philosophy, the high-level management that will listen to people. At least listen to them and then say, "OK, I understand what

> you're saying. I disagree with you. This is what I want done." And through the process that I've just described, if my boss did that and it was safe and it was legal and I just didn't think it was the best thing, I'd say, "OK, I'd do it." But I think it's my responsibility to give my opinion. I think we're in a situation now where it's hard to give your personal opinion or even your professional opinion right now on an issue if management is leaning a certain way and you disagree with it. I think you're frowned upon right now." (Perin, 2007, p. 82)

Even though it is Chuck's conviction that raising concerns and voicing his opinion is part of his responsibilities, the unwillingness to be challenged on the side of superiors, suppresses knowledge that is potentially valuable to the organization. This unwillingness to be challenged may also be rooted in clanship, similar to the deficiencies in listening to scouts and external sources. Questioning organizational assumptions is perceived as turning on the organization, constituting a form of betrayal. This "Us-vs-Them-Logic" promotes hostility towards any behavior that deviates from the group. Challenging assumptions is then perceived as a threat instead of a valuable contribution to organizational objectives.

The same kind of reluctance to tolerate dissent within management is all too common to personnel at Bowie Station:

> "Along with the technical side of it, the soft open-ended things we're sliding backwards on also… In the past we had a culture here where you'd shoot the messenger for the problems identified... Now we're kind of backsliding once again to a point where it's a little more difficult to speak up, a little more difficult to bring that up because everyone is working under pressure, people are stressed out or whatever. It starts to show with the simplest request you may make—you may get more negative feedback than you did in the past." (Perin, 2007, p. 119)

In an environment as demanding as a nuclear plant, contradictions add to an already heavy workload. Managers, strapped for time and resources, react in an expectably hostile manner to undesirable information. Such an attitude by management personnel breeds a culture that is dismissive of contradictions and prevents staff from bringing concerns to the attention of superiors.

Even when superiors actively try to encourage people to speak up and voice their concerns, people may not feel comfortable to do so due to the punitive culture. Doug of Charles Station recalls the intense atmosphere in management conference rooms when consequential decisions have to be made:

> "When you have a meeting and you have very senior people called in on a holiday and you hold it in a big conference room, and everybody's focused on, "What can we do to prevent having to shut

> the plant down?" and that's the aura of the room, that's the environment. It sort of chills anybody bringing up something that says, "We've got a bad problem and we've got to shut down and explore it." It's the production bias as opposed to safety bias, whether it's nuclear safety or industrial safety. Even though the ops manager—a very senior manager in our pecking order and in our credibility and how we respect that individual in the organization—promoted over and over again in that meeting, "Can anyone else tell me anything that we're not doing right, anything we should be doing industrial safety-wise?" Still, people won't speak up because there's that chill or whatever in the room so you're not going to raise the issue. I've been in that room many times and it's a very uncomfortable, tense atmosphere. It's not welcome and warm and exploring" (Perin, 2007, p. 180)

In light of the economic costs that a shutdown of the plant would incur, economic concerns overrule safety considerations. People are so intimidated by the corporate aura and logics of profitability that no-one dares to speak up against it. A 'corporate aura' silences concerns and creates a false impression of unanimity.

Especially with regards to contingencies, an open discussion seems hard to come by. Because management is ultimately measured in terms of profitability, it is in the management's interest to avoid costly worst-case scenarios. Suppressing their discussion altogether may be an unconscious strategy to avoid undesirable economic outcomes.

Doug recalls an event where management shut down the discussion with particularly harsh tone:

> *"So would the alternative be for him to be the devil's advocate himself. To show that he was able himself to dream up this other scenario and have people tell him it wasn't going to happen that way?*
>
> Right. You never hear our senior management doing that. As soon as it starts to go in that direction—I've been in the room when the chief nuclear officer said (shouting), "I don't want to hear about that. I want someone to call the vendor right now and get an expert to tell us that that's not true." It's just not an open dialogue, what the worst possible case could be." (Perin, 2007, p. 180)

This exchange suggests that management is less interested in reconciling its assessment of the situation but instead wants to seek confirmation for its predetermined course of action. The excerpt also speaks to the function of outside experts, which was discussed in detail in the previous section. Here, outside knowledge is brought in, not to introduce a novel perspective and challenge assumptions, but as a seemingly neutral voice to legitimize management decisions.

In summary, the case studies suggest that these organizations have difficulties to challenge underlying assumptions openly. These problems' main root seems to lie in contrasting logics that dominate at the different hierarchical levels. While at the worker's level, safety concerns may be considered more intensely, management personnel are measured in terms of profitability and efficiency, which is why they more frequently base their decisions in economic rationality. Because management is positioned higher in the hierarchical order, they tend to overrule inferior working levels; hence, they more easily dismiss safety concerns in favor of business acumen.

9.4 Attitude towards the periphery

The coded results point to a relationship between the foresight factor 'attitude towards the periphery' and the foresight capability 'acquisition.'

'Attitude towards the periphery' refers to the level of curiosity that personnel display towards the periphery. Periphery here means the edge of organizational sensemaking. Day and Schoemaker describe the periphery as "the blurry zone at the edge of an organization's vision" (2005, p. 1). Organizations are often surprised by environmental changes that seem to come out of the left field. These challenges often begin as weak signals at the periphery that are hard to see and interpret but can become vital to organizational success or failure. Because managers are trained to interpret data set before them, they often have difficulties seeing what is beyond or at the periphery of organizational vision (Ibid.).

Against this background, it seems plausible that the coded results establish a link between 'attitude towards the periphery' and 'acquisition' because identifying and acquiring relevant information requires organizations to be attentive towards changes in the environment and to channel these insights.

In an ideal state, this skill is not restricted to management but incentivizes continuous scanning of the environment by all organizational members.

In the nuclear plants analyzed in the case studies, different organizational habits seem to obstruct a proactively curious attitude towards the periphery.

Operations at NPPs are subject to enormous time pressures. These time pressures can lead people to believe that looking beyond the ordinary is just a waste of time. The maintenance department at Bowie Station exemplifies this attitude as Brian, an oversight specialist, explains:

> "Just go in there and repack the valve, it's a normal job." And that was the mentality almost all the way through it. "What is the big deal, we do this all the time?" And it wasn't until the packing started coming out that they realized that they could lose all of this. Even at that point, my opinion was that they didn't consider this one of the barriers being breached and that this put it in a higher contingency... It's like, "It's a waste of time to put all these contingencies in place for something where we just go in and tighten down on the packing." (Perin, 2007, p. 61)

Economic efficiency demands resourcefulness from people working under conditions of strapped resources. In a nuclear plant, workload routinely exceeds capacity. This forces workers to be particularly deliberate about their division of time, constantly balancing safety and economic efficiency. Looking beyond what is directly in front may seem too resourceful, as well as offering unknown benefits.

Another challenge stems from the process driven approach that NPPs take to organizing. The host of processes and procedures that are in place for all sorts of eventualities may turn any intervention into a standard procedure. Such routinization can lead to limited attention to detail and create a false sense of security.

Intensity and time pressure are significantly increased during plant outages, leaving even less room for discovery. Everyone is well aware that surprises will occur during an outage, which cause problems that require additional attention. As Vince of Charles Station explains, however, these surprises are not considered in the planning process for those outages. Subsequently, outages are strapped for time by design:

> *"But outages are supposed to be for discovering new problems as well.*
> No, no, no, no. Don't think that. 'Cause they'll run you right out of here. Outages, well there's no time built into it for that. It always happens. You're talking about theory and reality here, that's the other thing. You're always going to find something unanticipated.
> *I thought that was the point.*
> No. The point is to change the fuel, fix what you know that needs to be fixed, and start it back up. That's the point. And there are certain things you're doing—disassemble, inspect, repair—but you're not supposed to find anything new, which you doubtless do." (Perin, 2007, p. 193)

Outages are intentionally designed with a tight schedule to keep downtime, and subsequently, economic losses minimal. The time constraints induced by dominating economic rationality promote an attitude that does not value the benefits of looking outside the immediate environment.

At Charles Station, the attitude towards the periphery furthermore seems to be obscured by an overestimation of the organizational scanning capabilities, leading many to mistake luck for skill.

> "Now it's interesting because when I first heard about the GSU the next day, my first thought was, "Good catch, we really did this well." Because, what I'm thinking is, on first blush, "Here's a serious condition, overheating on the transformer, and we found it using a testing technique of infrared thermography before it became a failure." So I thought, "That's pretty good." And we shut down to fix it. So on the surface, you know, it looked pretty good. And as a matter of fact, Doug and Miles—I think they will also tell you that—when they first heard it, I know Miles in particular, thought, "Hey, good job!" But then we got digging a little more and thinking about it a little more, and that's where we kind of came around to, "You know, we didn't use the thermography because it's a normal thing to do thermography out there, we happened to be getting some baseline data, so we found it by luck. We found it late Wednesday afternoon and we didn't shut down until twenty-seven hours later. How come?" (Perin, 2007, p. 159)

NPPs can´t effort large scale failures due to their potentially catastrophic consequences. Therefore, they have to operate at very high levels of reliability. A plant with a track record of frequent severe near-misses or failure would likely lose its license. Subsequently, most NPPs are more used to success than failure. However, the absence of mistakes or instances of failure can generate complacency. A sense of infallibility due to past success can decrease people's curiosity towards the environment.

Overall, it seems that the organizations in the case studies exhibit low levels of curiosity toward the environment. Most organizational members are incentivized to focus on their immediate tasks instead of looking to the periphery. It seems that the ongoing struggle to balance safety and efficiency does not leave much room for reflection and scanning outside the familiar.

9.5 Formalization

Formalization describes the extent of standardization of processes and procedures. Exerting a sufficient level of standardization increases efficiency; however, this has to be balanced against a need for creativity. Standardization and routinization bear the danger of leading to tunnel vision and diminished creativity, which impairs organizational abilities to access and use information. To establish ideal conditions, strategic foresight should be formally incorporated in organizational processes. This allows for efficient dissemination of future insights and facilitates harnessing signals from all over the organization. At the same time, processes need to admit appropriate levels of freedom to allow for reflection and environmental scanning.

The results from the coding that refer to the foresight factor 'formalization' are relatively few. Therefore, equally weak links to all of the foresight capabilities can be observed from the coded results. By a narrow margin, the most intersections occur with 'acquisition.' From the perspective of the foresight framework, most intersections would be expected to exist with 'transformation' and 'exploitation.' This is because formal procedures for processing future insights should enhance the organizational ability to combine foresight insights with existing information and integrate foresight knowledge into operations.

From the case studies, it can be observed that the extraordinarily high levels of formalization in NPPs often instill tunnel vision in people. Because written processes almost entirely govern the work, people develop very high levels of trust for these procedures. This contains the danger that people put such high faith in formalized procedures that they rely on them without reviewing their outcomes. The following account by one of the mechanics at Arrow station is an example of this behavior:

> "When I went in, they [operations] had depressurized and basically reduced the temperature, and said, "Go ahead and repack it." And by our procedure, OK?, it tells us to place it on the backseat and make sure it's on the backseat. In the prejob brief the operations manager said it was already placed on the backseat, nobody had touched it. And when we went in, he gave us permission to go ahead and see if we could turn it in open position to make sure it was on the backseat. And Chuck did that, and he felt that it was on the backseat, OK? And by the procedure, it said to verify that the backseat was holding, so we loosen up all our bolts. And we had no water coming on out. We just followed our procedure, and the water appeared after several minutes. I don't know the exact amount of time. We had the bolts unloosened and everything unloosened and we didn't see any water. So we assumed that from following the procedure it was holding.

But then it didn't?

Then it didn't." (Perin, 2007, p. 43)

Instead of relying on their expert knowledge and experience, the mechanics in this example assumed that following the procedures would lead to the expected result. Highly standardized procedures can magnify the significance of unexpected disruptions to the working routine. Formalization creates the illusion that everything is planned and accounted for, so when things take an unexpected turn, that can leave people clueless about the appropriate response. Another example illustrates how small changes to routines in a highly formalized environment can cause confusion and leave people overwhelmed by what appears a relatively minor disruption to the expected order of things. At Arrow station, a few subtle changes to the routine accumulate into a 'departure from the familiar':

> "Managers took a piece of work out of its place on a schedule, long the frame of reference for all other activities. Why would managers slot this valve repair ahead of its scheduled time? Perhaps because of the backlog of maintenance work, which drives managers to be on the lookout for a system configuration favorable to checking off more of the year's 15,000 work orders. Then, a different repair team replaced the one originally scheduled for the second repair… On top of that, the work scope was different from what operations had originally expected: only adding packing, not picking out existing packing. Steven characterizes the entire context as a departure from the familiar: "This was an attempt to do maintenance that we had performed in the past in an environment that was probably less settled than what we had been exposed to in the past, meaning a lot more things going on, a lot more intensity." (Perin, 2007, p. 81)

Can such highly skilled people who are trained to operate one of the most sophisticated technologies that currently exist, really be overwhelmed by slight changes to the schedule and work orders? It seems like the omnipresence of rules and procedures governing most aspects of everyday work, may have deprived workers of their ability to react flexibly to changing conditions.

The case studies imply that NPPs struggle with balancing demands for efficiency through the formalization of procedures, and the need for creativity, flexibility, and innovation. Data from the case studies suggest that these organizations allow little room for autonomy. This is rooted in a command and control approach to organizing based on the desire to minimize risks of individual wrongdoing. However, this poses significant challenges for the development of foresight capabilities as it curtails the scope of available information and restrains creativity.

9.6 Accessibility

Enabling information to flow across units and functions is a critical prerequisite for strategic foresight. Establishing practices that facilitate the combination of new and existing knowledge presupposes well-functioning information flows that foster cross-fertilization of knowledge from various units and functions.

The coded results suggest that 'accessibility' is strongly linked to the foresight capabilities 'transformation' and 'exploitation.' However, there are also significant overlaps with 'acquisition' and 'assimilation.' These results emphasize the importance of the unobstructed internal distribution of insights to develop foresight capabilities, especially concerning the ability to combine new and existing information and integrate derived knowledge into operations.

The findings from the case studies reveal a picture of fragmentation within the investigated nuclear power plants that frequently prevent information from reaching the right places. This creates lapses in communication and misunderstandings among organizational members.

For example, during the valve repair effort at Arrow Station, adequate contingency plans are not put into place because the working level and the management level fail to exchange information:

> "I think there's some communication problem in that the actual work performed may have been different than the work scope that was presented. But in any event, no freeze seal equipment had been ordered. 'Cause at the working level they never considered [the freeze seal] a contingency, whereas at the management level that was presented as a contingency…" (Perin, 2007, p. 67)

The fact that a critical contingency was discussed at the management level, but not at the worker level, with the people with actual "skin in the game," is testimony to the deficiencies regarding the accessibility of information at the plant.

However, the issues of accessibility are not restricted to miscommunications between management and working level. The same problems persist regarding the exchange of information between design engineering and operations, "the people with the nuts and bolts knowledge" and "those on the theoretical side." To a group of design engineers who switched from the corporate engineering department to work as systems engineers at the plant, the change of perspectives is a revelation:

> *"CARL: In design engineering, unless you brought yourself out here on a weekly trip and really buried yourself into it, you'd have few meetings with operators. There was no formal educational process or assigning you out to the plant for three months and let you see how it goes, like writing procedures and seeing how operators deal with signing things on the schedule and what happens in a daily status meeting. We were never offered that opportunity. At one time there was a discussion of rotation, but only a limited amount. The general population of design engineers are not trained as to what's going on out here.*
> *BART: I used to come down about twice a month and on an as-needed basis. It used to be like we were consultants about the long term. I'm now in the plant every day, and it's really been enhanced for me working with the shifts and the craft instead of making two trips a month.*
> *JOE: The change was devastating to me—it took me a year to feel I was making significant contributions.*
> *ANNE: You get thrown from an office environment to a plant environment. It's a lot different. We used to do a minor mod and never knew what kind of problem it was for plant people to actually get it done.*
> *ANDREW: Tasks were so different. I'm dealing with a whole set of different facts. Now you're not concerned so much with the concept of what's going on or what needs to be going on as to the actual operation of the plant. As a designer you're putting it on paper so someone can go build it. You're incorporating your safety requirements and all this into your design so it's going to be what the plant needs, or what your concept is of what you think they need. And then you come out here and all of a sudden it's a day-to-day business. "Hey I just blew this fuse and I need you to help fix this" . . . so you went from an overall long-term focus to having to deal with something on a day-to-day basis."* (Perin, 2007, p. 114)

Though both functions operate in interdependence, there is minimal exchange among them. Therefore, the perspectives of the respective other side are almost entirely unknown to each other. Once an exchange of views comes about, however, it is associated with an enormous increase in information.

The difficulties of enabling information to flow across organizational units and functions are further complicated because different functions receive varying internal recognition. Not all units are viewed as equally important in achieving organizational outcomes. Activities that are perceived exceeding costs over benefits, or that are blamed for slowing down output are met with ambivalence. Scott, the senior manager for business services at Bowie station, sees a persisting negative bias towards support groups as a legacy of naval order. Speaking about 'access authorization,' a unit responsible for conducting background checks and administering security clearance for all personnel accessing the plant, Scott notes:

> *"I think in this business—I don't think, I know in this business—that because most of the management has come out of the nuclear navy, there's a strong negative bias toward support organizations, and this is a support group. So those groups tend to take an awful lot of flak whether they deserve it or not. They're sort of on the ventilation path."* (Perin, 2007, p. 138)

An open disregard for certain organizational units and functions can hamper accessibility in two ways. Either, by silencing the specific group altogether, or by merely dismissing any insights they bring forward. In both cases, the organization is prevented from fully accessing its knowledge base.

A similar difficulty to receive recognition and attention from other units is voiced by the 'safety group' at Charles station. The 'safety group' oversees industrial safety on the site. Its task is to prevent injuries to employees working on the industrial site, which includes all departments. Industrial safety has to be differentiated from nuclear safety, which is not responsible for preventing harm to employees but with ensuring the safety of nuclear operations. Dom works at the safety group. He comments on the frustration of getting through with industrial safety concerns to the nuclear side:

> "I can't say that there have been any incidents that have made me nervous or made me feel that we need more people or less people [in our group]. Other than maybe getting some help from the technical people that can fix {rising tone] what the plant people see as a need. Sometimes we have a breakdown because people who are [assigned] somewhere else, it's not their priority.
>
> *And your group is in a position of intermediary, really.*
>
> Exactly.
>
> *You're just transferring the request. So, you have no lines into these other organizations directly?*
>
> We're trying to develop them. We're trying to get more weight with the engineers. But no, the things we can fix ourselves, we try to. Someone needs a better pair of safety glasses or a better kind of hard hat, we work on those, but the harder issues are kind of, let's say, outside my control. I feel like a little bit of a victim when I say that, you know. I mean I can control a lot, but I can't move pipes or design things. We kind of put it to the next group and hope that they move with it as well." (Perin, 2007, p. 169)

Harnessing the benefits of accessible information across units and functions requires opening up the many barriers that seem to separate the numerous units and functions in NPPs. The case studies draw an image of organizations that consist of fragmented clusters of closed silos. Be they of hierarchical, functional, or even technical nature. Silos pose a significant obstacle for flows of information. Strategic foresight depends on the accessibility of information to enable the combination of different insights and perspectives to develop future insights, and to disseminate those insights within the organization.

9.7 Reach, Scope, Time Horizon

Focusing on certain information leaves organizations vulnerable to neglecting other relevant information. Therefore, organizations need to make efforts to gather information with different reach, scope, and time horizons.

The coded results suggest that ‘reach, scope, and time horizon’ is a particularly crucial factor for the ‘acquisition’ capability. To identify and acquire relevant information, organizations need to be able to access information with different reach, scope, and time horizons, because they are otherwise likely to neglect or miss important information.

The case studies suggest that NPPs operate predominantly on relatively short time horizons. Operating principles and incentive structures are designed to encourage workers to focus on immediacies and leave little room for long-term deliberations:

> “Despite cartons of printouts of daily, weekly, and monthly schedules showing “work windows” to meet restrictions imposed by technical specifications and despite frequent “look ahead” meetings, most of what matters to risk reduction and to line managers’ assigned goals and expected rewards occurs in the here and now…. The experts who carry out testing, repair, and surveillance activities earn hourly wages, overtime extras, and, for some (like managers), bonuses based on production levels. As employees who cannot claim “careers” often do, nonsalaried employees are likely to think about putting in a good day’s work one day at a time. Operational responsibilities devolve to line managers and supervisors, each with a technical specialty, whose goals and the rewards for meeting them are also tied to immediacies: “action plans” chunk their work. Each order works from its own time horizons and its agenda of concerns and commitments.” (Perin, 2007, p. 86)

Working under constant time pressure, NPPs continuously try to maximize efficiency. In an environment of chronic time constrain, it seems rational to avoid tasks that are perceived as not contributing to the short-term success of the organization. Therefore, gathering long-term data might be regarded as resource-intensive with little apparent benefit. The same logic seems to apply to the analysis of what-if scenarios. An event report produced in response to the hotspot incident at Charles station elaborates on a pattern of opting for the most convenient solution to arising problems:

> "When we are faced with a problem, we strive to take the least expensive, least intrusive way out of the situation. We tend to avoid the more labor intensive and more difficult, "what if" analysis. In this instance, if it were circulating currents, it would allow us to remain generating electricity and to correct the problem at a reduced cost. We have seen this before; for example, [naming three previous events], the organization focused on production at the expense of prevention. The Management Team needs to be deliberate and conscientious in asking the tough questions. Management also needs to create the environment that welcomes the questions and comments of those who are bringing them bad news or difficult issues. There are other events out there waiting to happen and the organization, overall, needs to be accomplished at asking the questions in the right way when they get here" (Perin, 2007, p. 189)

The case studies suggest that NPPs are firmly focused on the near-term future. This applies to the majority of activities that organizational members engage in. The short time horizon stems from the intense workload that usually doesn't permit much reflection. Schedules are intentionally kept tight to cut costs and increase economic efficiency. This predicament leads to a very narrow focus that reflects on organizational scanning activities. It appears as though the NPPs in the case studies neglect a large part of the signals in their environment for the benefit of meeting short-term operational demands. This context confronts strategic foresight with the challenge to free up organizational capacities, as well as to alter mental models to expand reach, widen the scope, and extend time horizons of gathered information.

9.8 Patterns of Organizational Struggles in NPPs

The previous section explained how certain foresight factors translate into foresight capabilities and then used excerpts from the case studies to illustrate how developed these foresight factors are in the NPPs examined in the case studies.

Applying the foresight factors and capabilities framework to the case studies revealed several themes that pointed at organizational struggles that NPPs face. These challenges can act as barriers to the development of strategic foresight capabilities. In the forthcoming section, these challenges are explored in more detail, and their impact on the development of foresight capabilities is examined.

9.8.1 Silo Mentality

During the analysis of the case studies, a recurrent theme points to the prevalence of a strong silo mentality in NPPs. Organizations are structured by horizontal and vertical layers. Horizontal hierarchical order structures organizations from top to bottom by levels of power and influence. Vertically, organizations differentiate between functional areas of specialization (e.g., human resources, marketing, operations). Hence, the vertical and horizontal differentiation creates silos in the minds of organizational members (Cilliers & Greyvenstein, 2012). As an image of the organization-in-the-mind, silos have their unconscious patterns of relations between individuals, and therefore, influence work (Diamond et al., 2004). Silos don't physically exist. They only appear in the shared impressions of the reality of organizational members (Diamond et al., 2004). They manifest as invisible boundaries based on a 'us and them' mentality. Establishing such clearly defined affiliations provides employees with safety and comfort. At the same time, it can become challenging to overcome these barriers, leading to a delineation of organizational parts. This delineation can have substantial consequences. For example, people inside a silo can feel threatened by those outside of it, and they can exhibit a general skepticism towards people on the other side of the invisible barrier, even developing fear and disdain towards the outside (Diamond et al., 2004). A pronounced silo mentality within groups also leads to constrained systemic thinking, and an incomplete or even absent vision of the larger organization (Cilliers & Greyvenstein, 2012).

In the NPPs under investigation in the case studies, silo mentality is a recurring theme associated with an unwillingness to exchange knowledge, obstructing collaboration and learning, and interfering with overall organizational performance. In an organization structured by hierarchical order and functional specialization, every unit has its place in an institutionalized ranking of respect, influence, and authority. In NPPs, this order sees design engineering on top, in the middle operations, and maintenance at the bottom. Interestingly, the silos don't play a massive role in the everyday routines at the "worker-to-worker level," but mostly in the rather "philosophical areas." Richard of Arrow Station explains:

> "The silo effect is much less, actually, in the day-to-day work, because at the worker-to-worker level and the first-line level, there is a lot of talk just to keep the stuff moving, going back and forth and having handoffs from department to department. And those are pretty formal and proceduralized also. The silos occur in more philosophical areas. For example, a shift manager deciding he's just not going to allow any [repair or testing] work on that shift because he's too busy, and doing that in isolation from the effect of that on the rest of the unit. Or maintenance deciding, in the case of the leaking valve, "Here's where we're going and we'll defend our position" and "I think I'll keep everybody else out of it so we can do what we want." That's where I come to see the silos. And they exist at my level too, at the level of busyness that most of the managers are at. Talking to another manager becomes a real challenge." (Case 1 , S. 42: 1366)

On the level of everyday operations, formalization ensures that information is exchanged smoothly among departments. Like in a well-oiled machine, the different functions interlock and keep the plant running. However, in roles where the scope of work is not grounded solely in the here and now, the silo unfolds its adverse effects. The invisible barriers of position and function prevent people from considering the impact of their decisions on the larger system. Management personnel that is typically expected to keep an eye on the bigger picture seems to be particularly vulnerable to falling trap to a trained incapacity to take the broader context into account.

How drastic the consequences of an ingrained silo mentality can be, is illustrated by the disaster of the Fukushima nuclear reactor and its operating company TEPCO. In 2011 a tsunami knocked out cooling water and led to a meltdown of the three reactors at the Fukushima Dai-ichi nuclear plant. As the subsequent investigations revealed, a profoundly entrenched silo mentality significantly contributed to the Accident at Fukushima Dai-ichi, because it restricted the focus of TEPCO personnel to their respective expertise and prevented them from comprehensively realizing the overall situation. In its final report the Investigation Committee on the Accident at Fukushima Nuclear Power Stations of Tokyo Electric Power Company, who was appointed by the Japanese government as an independent investigation body, outlines how silo mentality captured TEPCO and paralyzed the organization in the moment of crisis where flexibility and quick collaboration would have been of utmost importance:

> "TEPCO has structured its organization with an Emergency Response Center and other relevant departments in its Disaster Management Operation Plan and Accident Management Guide, under which functional teams are formed, including power generation teams, recovery teams, and engineering teams, etc. with the aim of providing an organizational, unified response in the event

> of a nuclear disaster. However, these functional teams certainly made efforts to fulfill their respective scopes given, but did not perform sufficiently well in capturing the situation from a comprehensive point of view, positioning the roles of their own teams within the overall picture, and carrying out the necessary support operations based on such perspectives. TEPCO personnel, just like as those of other nuclear operators, categorize themselves by their specialty areas from normal times such as an "operating guy," a "safety guy," an "electric guy" or a "machine guy," and their roles are segmentalized. While some personnel take an official career path by experiencing various fields widely and shallowly, some remain in one specialty for long periods. Such personnel might have abundant knowledge of his/her own specialty, but in contrast it is hard to say that he/she has sufficient knowledge of other areas, even closely related matters. If an organization is structured with these kinds of personnel, the individuals might have a narrow view of things, and, even if the organization seems to function without any problems under normal conditions, it results in exposing weaknesses of the organization in an emergency like the latest accident. "(Investigation Comittee on the Accident at the Fukushima Nuclear Power Stations of Tokyo Electric Power Company, 2012, p. 473)

The analysis was echoed and taken even further in the final report by the Fukushima Nuclear Accident Independent Investigation Commission. The report concludes that the nuclear industry in Japan, as a whole, has a historically siloed mindset that prevented it from learning critical lessons from past incidents in the global nuclear power industry, and contributed to adopting a practice of resisting regulatory pressures and covering up small-scale accidents, which finally resulted in the disaster at Fukushima Dai-ichi (Fukushima Nuclear Accident Independent Investigation Commission, 2012, p. 9). Astonishingly, these challenges still seem to persist at TEPCO, even well after the accident itself and its following aftermath. In 2017, Tomoaki Kobayakawa, then newly appointed president of TEPCO, publicly raised concerns over the prevalence of closed-off silos at TEPCO, and its nuclear division in particular, pointing to repeated failures to learn (Harding, 2017).

Silo mentality poses significant problems to organizations that want to make use of strategic foresight as it contradicts several of the cultural factors that underlie strategic foresight capabilities like the 'willingness to share across functions,' the 'willingness to challenge basic assumptions,' and the 'readiness to listen to scouts and external sources.'
As demonstrated in the examples above, a siloed approach to organizing obstructs the internal flow of information. Thereby, it deprives an organization of the basis of strategic foresight.

Not only does silo mentality hinder the accessibility of information, but it also limits the scope of available data by confining scanning activities to the boundaries of the silos.

Concerning foresight capabilities, silo mentality particularly impacts the ‘acquisition,' ‘assimilation,’ and ‘transformation’ capabilities of organizations. As mentioned before, silos promote a walled-off understanding of the division of labor which leads to a neglect of broader contexts. As such, a siloed organization is less capable of identifying and acquiring relevant information, as its attention is primarily focused inwards. Even if pertinent information is picked up upon, assimilation of information is restricted to boundaries of silos. Hence, analysis and interpretation are likely incomplete in the sense that it fails to take into account the organization as a whole. The capability to combine existing with new knowledge is also made significantly more difficult in siloed organizations because units have only limited access to the knowledge of other parts of the organization.

9.8.2 Economy vs. Safety

Nuclear power plants face an existential dilemma stemming from a goal conflict between organizational reliability and economic efficiency. In the case studies, NPPs often seem to dissolve this problem in favor of efficiency at the expense of reliability. At Bowie station, Jay works in the corrective action program and is responsible for conducting event reviews. Contemplating an incident in the access authorization group, where security-sensitive information was missed, he alludes to the conflict of efficiency and safety. He concedes that more often than not economics overrule safety:

> "The way access works at a nuclear power plant is probably based upon economics more than anything else, a purely economic decision. I'll give you an example. We saw that there were problems in a number of areas of how they do their business [at the top] in general. And so I thought that they should just stop work and reassess everything they were doing. First of all, to determine what are our critical functions and our critical points and reassess those, make sure that we had all the bells and whistles in place to make sure that we were going to make the right decisions. And I thought they really needed to stop work. I think if we had a similar breakdown in the plant in a program related to operating the reactor, we wouldn't restart until we did a stop-work and reassessed everything. So I offered that up to the senior manager. It was a decision of the other senior managers and the site vice-president not to do that. What they did is they got an outside consultant to augment the direct oversight in the interim. He's a very competent man. And I thought the most conservative thing to do was to stop work. We'd had a previous event and had barely averted a level-three violation on it. It was a little different, but not different enough. And

> that was what I thought we should do. And just punt and think and stop, and if it costs us money, oh well. The decision was, "We've got a refueling costing money and a major repair, and that's probably too much, going too far." And so they did other things. Whether or not those things were totally apt, I couldn't answer that. But you could see that we're a conservative plant, but the economics of stopping an outage, putting the badging on hold, it was too big. It was their decision to make and they said they couldn't do it. So I think it's pure economics. You want people in, when you want 'em in, you want 'em in in a timely manner, but you want them processed in correctly and sometimes the two ideals conflict." (Case 2, S. 37: 2035)

Because management is ultimately measured in economic parameters, managers are likely to prefer options that are less time and money consuming when a situation pitches market order versus regulatory safety. A senior engineer at Arrow station similarly observes a tendency within management, in particular, but also the organization as a whole to do things quickly instead of meticulously:

> *"So if you say that management is "leaning a particular way," would it be possible to say they would be leaning toward schedule issues and cost issues?*
>
> Definitely. I definitely think we' re—as hard as we say we're not—and we try not to be—I think we are schedule-driven. They tell us not to let the schedule drive you. Unfortunately, schedule is part of life, you have to work to one. The thing is you can't let it become the almighty creature out there that drives everything." (Perin, 2007, p. 83)

However, this mindset is not only restricted to management personnel. As a member of the human resources department at Overton station remarks, it is a trained incapacity that affects everyone at the station: "Everybody is trained to consider production goals first- work should be fast and efficient, and safety only slows it down" (Perin, 2007, p. 9).

The struggle to balance efficiency and safety may be rooted in the fact that the nuclear industry for a long time did not have to consider economic dynamics.

Traditionally, electricity was conceived of as a natural monopoly. Utilities held exclusive rights to provide a specified region with electricity at cost-of-service rates that allowed them to recover their operating expenses regardless of performance levels. Because this creates little incentive for firms to run their plants efficiently, the 1980s and 1990s saw the introduction of different forms of regulation, designed to incentivize companies to increase output and reduce costs (Davis & Wolfram, 2012, p. 197). These efforts have mostly been viewed as successful in reforming the nuclear industry. Studies show that deregulation has led to a 10 percent increase in operating performance, mainly by reducing the number of outage days per year (Davis & Wolfram, 2012). However, studies also show that financial pressures stemming from deregulation are linked to declining safety margins in the nuclear power industry (Bier et al., 2003, p. 186).

An imbalance of economic and safety concerns has been an ongoing concern for the nuclear industry on many levels. The Defense Nuclear Facilities Safety Board delivered a report on the safety management of complex high-hazard organizations to the department of energy (DOE). In it, they concede that leaders in the nuclear industry do not always display equal value placed on safety and productivity. They attribute this to a tendency "to be lulled into complacency, and even arrogance, based on past successes" (Defense Nuclear Facilities Safety Board, 2004, pp. 7–2). Furthermore, the report alludes to another challenge that is associated with balancing safety and economy in high-hazard organizations. Namely, the differences in incentives for efficiency versus safety:

> "Although excellence in safety performance is an implicit factor in project success, milestone completion is rewarded while safety is recognized only when failures are punished. Sometimes line managers have to choose between safety and meeting deadlines. Potential for rewards is often a stronger motivator than fear of punishment, so some decisions may not be as conservative from a safety perspective as prudence would dictate. In most cases, the decision to trade safety for productivity does not result in an actual accident. The "successful" outcome of such cases can breed complacency, and the result can be gradual degradation of safety margins to a major accident" (Defense Nuclear Facilities Safety Board, 2004, pp. 7–8)

A tendency to sacrifice safety standards for the benefit of economic efficiency was also observed by the Fukushima Nuclear Accident Independent Investigation Commission as a factor leading up to the disaster at Fukushima Dai-ichi. The report asserts:

> "As the nuclear power business became less profitable over the years, TEPCO's management began to put more emphasis on cost cutting and increasing Japan's reliance on nuclear power. While giving lip service to a policy of "safety first," in actuality, safety suffered at the expense of other management priorities." (Fukushima Nuclear Accident Independent Investigation Commission, 2012, p. 44)

The research on high-reliability organizations has long recognized the relevance of goal conflicts between reliability and efficiency. In this respect, LaPorte (1988), called attention to the fact that the key goals of efficiency and reliability are inextricably linked in the context of high-hazard organizations. Because inefficiencies in the system contribute to hazardous conditions, while unreliability reduces efficiency and increases costs, they are mutually dependent.

Conflicting interests of economics and safety pose a particularly significant challenge for strategic foresight. Measuring the benefits of strategic foresight practices has been a long-time struggle of the field. Organizations that emphasize productivity may be difficult to convince of the usefulness of strategic foresight from the beginning. It seems likely that such organizations may perceive strategic foresight as a time and resource expensive activity with unclear benefits. If organizations are willing to sacrifice safety considerations because they view them as a waste of time, it seems unlikely that they will dedicate resources towards strategic foresight unless it can substantiate how it concretely contributes to improved performance.

Even if organizations can overcome said skepticism, productivity bias, will most likely pose a significant challenge to the ability to employ strategic foresight as it limits the organizational capacity to scan for signals and take cues from the environment.

The qualitative analysis of the case studies supports the impression that difficulties to conciliate safety and economic concerns hamper organizational foresight capabilities.

Challenges to reconcile production and safety goals are detrimental to all stages of the foresight process, but it particularly hampers organizational abilities to identify and acquire relevant information. That is because an economic lens restricts scanning to the economic environment, creating blind spots in other relevant areas.

The capability to combine existing knowledge with new information is also particularly challenged by a surmounting focus on economics. 'Transformation' of insights is highly dependent on the 'willingness to challenge basic assumptions.' If economic assumptions routinely overrule other considerations, this means they are hardly ever challenged, which obstructs organizations from learning through the combination of knowledge.

9.8.3 Shiny vs. Rusty

It is a common understanding in the nuclear industry that there are two sides to a nuclear plant. This is reflected by an assortment of antithetical terminologies that members of the nuclear industry make use of, like 'safety-related' and 'non-safety-related,' 'plant' and 'balance-of-plant,' or 'primary side' and 'secondary side.' These terms refer to a differentiation of a plant's components based on equipment and its consequences. The 'non-nuclear side' of a plant includes the steam generator, turbine, and the switchyard connecting to the regional grid. The 'nuclear side' refers to the reactor itself and its supporting systems. This differentiation is widely accepted by people working in the nuclear industry and associated with a view that values the ‘nuclear side’ over the ‘non-nuclear side.’ This is also reflected in the terminology of 'shiny side' and 'rusty side' that is used by staff in the case studies. The nuclear, the 'shiny,' side is the showpiece of the plant. The appreciation for the 'nuclear side' also finds its way into market order logic, which describes it as the 'moneymaker' (Perin, 2007, p. 164).

In the minds of nuclear workers, the nuclear side is what makes the plant special and distinguishes it from any other organization. As a maintenance department manager at Charles station explains, the 'primary side' is more complex, and equipped with more idiosyncrasies, while the 'secondary side' is just a standard industrial system:

> "Historically the nuclear industry has taken a very structured approach to the nuclear side or the N triple S [nuclear steam supply system] side of the house in terms of construction—it's more standardized in most cases. There's a lot more seismic issues there, there's a lot more built-in safety features, and with that comes tech specs and the NRC's Final Safety Analysis Review, which also is another layer of protection. Those are requirements to assure you're working within the design concept. On the balance-of-plant side, historically it's just a standard old fossil design, fossil mentality, you know, it's a different approach. The steam comes out of the primary side with all its bells and whistles and protection and envelopes. And here comes the steam and you hook up any old turbine and any old secondary system, no matter what power plant you're at." (Perin, 2007, p. 166).

The nuclear and the non-nuclear side of a plant differ significantly from a construction standpoint. The resulting differences in complexity and risks are reflected in the diverging approaches to regulation by governing bodies. The ‘nuclear side’ is much more tightly regulated through written processes and procedures. Whereas on the non-nuclear side regulation does not specify such detailed procedures, but demands from operators to make more independent decisions based on their own assessments:

> “On the nuclear side of the plant you have procedures for almost every contingency and they’re written down. If you have this or that event, you go right to this procedure and the control room can almost act without even having to think just follow the procedures and you’ll get to a safe conclusion. On the electrical side of the plant, basically you’re developing your plan on the fly.” (Perin, 2007, p. 136).

These semantics of nuclear/non-nuclear, plant/balance-of-plant also fulfill the objective to reassure the public that potentially catastrophic impacts of the technology are under control and confined to certain parts of the organization. It serves a rhetoric of normalizing operations at nuclear plants by claiming that the dangers associated with nuclear energy are encapsulated in a concrete containment (Perin, 2007, p. 170).

However, with this split mindset, members of nuclear plants can also deceive themselves by creating a false sense of safety regarding the vulnerability of non-nuclear systems. Especially the terminology of 'safety-related/non-safety-related' seems to obscure the fact that failure on either side can quickly impact the other and force a plant shutdown or cause accidents.

The distinction' shiny/rusty' may also contribute to the productivity bias mentioned before, by inducing organizational members with a sense of pride for the 'moneymaker' part of the plant. This may lead to a reluctance to make safety decisions about equipment on the 'rusty side' that can have costly impacts on the 'moneymaking' side.

This dualistic mindset poses challenges for the foresight capabilities of NPPs in several ways. The ability to analyze, interpret, and understand relevant information and infer consequences requires openness to novelty, attentiveness to differences, recognition of diverse contexts, and ability to adopt multiple perspectives (Baškarada et al., 2016: 422). The shiny/rusty differentiation obstructs these abilities because it diverts focus to one half of the system while neglecting the other.

The problem for foresight capabilities arises not from the assumption of different systems' existence, but that one is perceived as more dangerous, complex, and relevant to performance. Such a view disregards the coherence of the system and hints at discomfort with ambiguity.

Perceiving NPPs, as a composition of separate parts with distinct logics, also makes disseminating information profoundly difficult. Diverging operational logics and procedure mean that each side evaluates information differently and subsequently derives distinctive consequences. Therefore, learnings on one side may not be shared because they are deemed inapplicable to the other side. The competing sets of organizational logics may similarly make it challenging to combine new and existing knowledge, as neither side possesses an exhaustive knowledge base.

The shiny/rusty logic also interferes with organizational abilities to incorporate acquired and transformed knowledge into operations. 'Exploitation' of foresight insights is dependent on their integration with other relevant processes. The lack of integration between the two halves of the organization suggests difficulties in integrating information across this divide.

9.8.4 Neglecting Contingencies

The case studies revealed significant deficiencies in planning for contingencies, especially in considering worst-case scenarios. As was mentioned before, NPPs are highly time constrained. Therefore, they display a notable tendency to avoid time-consuming activities that are perceived as economically unproductive. In this regard, planning for contingencies is often considered a "waste of time", because people don't see why they should prepare for eventualities that, in their mind, will never occur (Perin, 2007, p. 62).

Another factor in the disregard for contingency planning is the fact that the people in most positions at nuclear plants are simply not trained to consider them. Especially in roles below management, workers are expected to precisely follow detailed job descriptions and customize their routinized and standardized skills to the situations any manufacturing order puts them in (Perin, 2007, p. 62). Command and control principles rely on people that simply follow orders, and they don’t leave room to consider much else.

Moreover, despite management paying lip service to forward-thinking, widespread encouragements to adopt a long view, and frequent 'look ahead' meetings, most of what matters to risk reduction and line managers' goals and expected rewards happens in the short-term.

The reluctance to plan for the unexpected is also rooted in a mindset that tends to avoid bad news and is overly optimistic regarding the system's infallibility, as the concerns of an operations manager regarding the absence of contingency planning at Bowie station suggest:

> “In terms of actual reactor safety, this might not have been the world's worst event. I think that one could have calculated that we had something on the order of four days of reserve water, that even with gravity feed we could have continued to maintain plant safety. But none of that was thought of going in up front because it was, "You can't have this failure, so why do you need to plan for it?" So that valve went wrong at my level for a different reason than on some other levels because to us it was presented as a "This isn't a problem, this is below your radar screen. ..." This was part of the discussion of, "You can't have catastrophic failure. Since all you're doing is adding

> packing, you back off on the gland [the repository for packing]. If the gland starts to leak, you retighten the gland." (Perin, 2007, p.68)

These remarks suggest that a mindset existed with these workers that disregards eventualities based on wishful thinking instead of facts and evidence.

Interestingly, and in keeping with the conception of a 'shiny side' and a 'rusty side' to NPPs, this reluctance to consider contingencies is mostly restricted to equipment not categorized as 'safety-related.' As soon as something is classified as 'nuclear safety-related,' a different rationale takes control. A logic that is governed by technical specifications of regulatory oversight:

> "As soon as I say "not nuclear safety" and as soon as everyone else says "not nuclear safety," we don't have to do what-ifs. If I thought that was nuclear safety, as soon as I came out of containment, saying "I saw one thread on one valve and two threads on the others," I would have had to be conservative and issue a condition report, and we would have had to address the issue. Because it was nuclear safety I have to address the issue and I would have to feel conservative." (Perin, 2007, p. 66)

A production logic that is based predominantly on efficiency seduces workers to think only within the predetermined patterns of written procedures and work orders. People's sensemaking capabilities are put aside in favor of those organizational process logics, which even assume control over emotions, as illustrated by the expression "I would have to feel conservative."

A similar disregard to consider contingencies seems to have prevailed among the individuals involved in the disaster at Fukushima Dai-ichi. The report by the Fukushima Nuclear Accident Independent Investigation Commission (2012) asserts that TEPCO displayed a lack of disaster preparedness and a substantial unwillingness to consider worst-case scenarios. In response to the accident, leadership at TEPCO pointed to the tsunami in arguing that it constituted an unexpected natural phenomenon of unforeseeable magnitude. However, records show that TEPCOs administration repeatedly downplayed dangers and ignored warnings about the possibility of a tsunami. A 2007 report by TEPCOs senior safety engineer warned that a tsunami could exceed the determined design height underlying the protection measures at Fukushima. The report estimates the chance for a tsunami to test or overrun defenses of the Fukushima Dai-ichi nuclear plant at around 10 percent within 50 years (Krolicki et al., 2011).

TEPCOs dismissal of warnings over tsunami dangers seems particularly arbitrary when comparing Fukushima Dai-ichi nuclear plant to the nearby Onagawa nuclear plant and how it survived the natural disaster. In similar vicinity to the oceanfront, the Onagawa nuclear power station is located in an area considerably closer to the earthquake's epicenter, where the damage caused by the earthquake and tsunami were much greater than in the region around Fukushima. Remarkably, the Onagawa plant survived the natural disaster virtually unscathed, thanks to the 14.7-meter seawall that was designed to protect it from the worst anticipated tsunami. Meanwhile, at Fukushima Dai-ichi, the seawall only had a height of 5.7 meters. Apparently, because TEPCO wanted to cut costs (Clark, 2012).

A subcontractor who worked at Fukushima for four years testifies to a TEPCO mindset that is reluctant to listen to warnings about low-probability/high-impact events:

> "I have worked in a subcontracted company for around four years—during which time I never once experienced evacuation training for a nuclear accident. TEPCO's mindset was that "there is no possibility that an accident will occur," and "we only need to do evacuation training for fires." (Fukushima Nuclear Accident Independent Investigation Commission, 2012, p. 70)

The Japanese language even has a specific word for this mindset, which was frequently used by TEPCO officials in the aftermath of the disaster. 'Sotei-gai' roughly translates to 'beyond expectations, and therefore to be ignored.' The saying accurately encapsulates the mindset that groomed disaster at TEPCO and can be observed in many NPPs throughout the industry (Labaka et al., 2015). Alluding to this mentality, the Investigation Comittee on the accident at the Fukushima Nuclear Power Stations of Tokyo Electric Power Company concludes in its report:

> "When people see and think about things they tend to view only what they themselves consider agreeable and only the course they are trying to take; they cannot see things they do not want to see or things that are inconvenient. The impact of this kind of human psychology can be glimpsed in TEPCO's natural disaster preparedness, which were not outfitted with AM [accident management] measures for tsunami, and did not provide for a situation involving a simultaneous and complete loss of power at several reactor facilities. To prevent situations like this, there is a need to be constantly self-aware that one's views are biased not only by his/her own interests but by the various influences of the organization, society and the times that surround himself/herself, and to be conscious that something is always overlooked. (Investigation Comittee on the Accident at the Fukushima Nuclear Power Stations of Tokyo Electric Power Company, 2012, p. 524)

By neglecting contingencies, organizations restrict their view to the short-term, which limits their capabilities to identify and acquire relevant information. Acquiring knowledge with different time-horizons is an essential factor for strategic foresight practices. By committing to a short-term mindset, organizations run the risk of neglecting information that unfolds its impacts in the medium- and long-term future.

Naturally, consequences are not always as drastic, as in the case of the Fukushima nuclear disaster. Nonetheless, this mentality creates inefficiencies that jeopardize the long-term success of the organization and can potentially even threaten its existence.

To improve their ability to acquire information, NPPs have to develop the capacity to specifically search for the unexpected, which requires being comfortable with inconvenient information and contradictions.

9.8.5 Formal vs. Informal Information

NPPs are highly process-oriented organizations. This organizational property comes from a strong desire to limit the potential for failure in an environment where mistakes can have disastrous consequences. Therefore, highly formalized operations and procedures are supposed to minimize opportunities for failure by limiting the influence of individuals on the overall system. Adding to the well-known downsides of formalization, like leading to a dearth of creativity, and breeding complacency, the analysis of the case studies points to another relevant disadvantage of the strict reliance on formalized processes and written procedures.

Training people to rely heavily on formalized knowledge may create a disregard for any information that is not conveyed through formal channels of communication.

A maintenance manager at Arrow station ponders why a crucial piece of information that was presented by a colleague was not picked up on:

> "*The reports talk about that. What was running through my mind was, "How did Ray present it? Was it critical when they heard it?"*
>
> It was not formally presented, meaning, in hindsight, what should have happened was we should have written a condition report which would have gone into the formal corrective action program, which would have gotten formal management reviews. This was a {hesitates}
>
> *An aside?*
>
> Yes, and that's exactly what it was. You know, "I know you, you know me. Hey, I was just out there looking at this, and I don't see it's correct." That was probably the closest to a formal—and it was in a sense a formal [recognition] because it was brought to a management meeting where it was

> put on the table as, "Here's what we're seeing, we need to follow up on this," and it was taken by me to my mechanical people. So now you're probably twice removed, in that it traveled from experienced system engineer to manager to second manager— "Here's a condition, I need you to take a look at it, make sure we look at it prior to going in." That was consequently given to a third party, meaning the mechanics that were going in to do the work, and now so far removed with no formal ties, there was no condition report . . . the importance of it diminished as you moved through the handoffs." (Perin, 2007, p. 78)

Because the information was never integrated into formal channels of communication, it was easy to disregard, overlook, or ignore it. Formalization provides information with authority and credibility. In an environment of information overload, credibility is a vital mechanism to filter signals from the stream of environmental noise. At the same time, this process may delegitimize information that is not transmitted through formal channels of communication. Because it is not 'stored' in written organizational procedures it is indistinguishable from all the 'noise' and gets lost in the constant flow of information. The same maintenance manager explains how information has to be entered into organizational communication for it to receive credibility and recognition:

> "I think it could show up in probably three forms and be acted upon. It could show up in the form of a very credible experience-based person, it could show up in the form of the paperwork, the actual CR [condition report], "Here's what we need to address prior to going there," and probably the third phase, that it is formally put together either in a work package description or in a scheduled activity." (Case 1 , S. 45: 44) (Perin, 2007, p. 79)

The content of a piece of information itself is not sufficient to guarantee it is acted upon. For it to become relevant and unavoidable for the organization, it needs further credibility. In organizations operating under a command and control regime, the most obvious sources for this kind of credibility are formalization and reputable advocates.

Formalization is usually perceived as a strength in much of the nuclear industry. Investigations of incidents consistently allude to processes and procedures as a mechanism to prevent accidents and frequently demand stricter adherence to process guidelines in response to organizational errors. In a study of 60 incidents that happened in nuclear plants during the 20th century, the Los Alamos National Laboratory (2000) revealed that insufficiently formalized information significantly contributed to accidents by obstructing communication between operating personnel. Therefore, they conclude that critical instructions, information, and procedural changes should always be captured in writing.

The habit of reacting to incidents with renewed processes may also disguise underlying systemic issues and prevent people from taking responsibility by laying blame on processes. An operations manager at Arrow station is doubtful whether just reinforcing existing procedures will change much about the deeper-rooted issues at his organization:

> "The final IRT conclusions . . . were very generic in nature. "Here's a series of requirements and general procedures. Everybody should review them and see what they say."
>
> *What effect do you think that would have in any case?*
>
> We were already doing that at the time, among the soul searching we were doing. It's valuable stuff, but if what you need is a paradigm shift—if there's some fundamental flaw in our collective way of thinking that led to this—going back and reading the procedures does not correct that fundamental flaw. I don't know what went on internal to maintenance, but I think whatever fundamental failure occurred in this case occurred somewhere in the maintenance organization. That's when—when you talk about omissions—that's what surprised me about the report that, again, some fundamental failure occurred and I don't think we addressed what or where it was." (Perin, 2007, p. 60).

Process-driven as they are, NPPs face the challenge of rivaling tensions between 'machine-like compliance' to processes which standard operations and maintenance demand, and the need for creativity, collaboration, and innovation that solving the complexities of highly coupled, interdependent organizations requires (Mintzberg, 1992).

This tension also reflects on the ability to develop strategic foresight capabilities. ‘Acquisition’ may be obstructed by organizing practices heavily dependent on formalization and process orientation as it may create blindness towards non-formal information.

On the other hand, formalized communication can also benefit the capability to incorporate foresight knowledge into operations. This requires that foresight insights are actively integrated within the formal channels of communication. This way, formal communication can be leveraged to provide foresight insights with the authority and credibility that knowledge in NPPs requires to receive recognition. The case studies illustrate the role that formalization plays for the dissemination of insights on the example of contingency planning on the nuclear versus the non-nuclear side. On the 'nuclear side,' regulation requires contingency planning. This makes planning for 'what-if's' part of the formalized procedures providing it with credibility and acceptance. However, while contingency planning is a requirement at the worker level, its insights are not necessarily disseminated across all levels of the organization. Furthermore, at a management level, those formal requirements do not exist. With the result that contingency planning is often dismissed as too costly and time-consuming.

If integrated adequately across all organizational levels, however, existing channels for formal communication in NPPs can be an excellent opportunity for the exploitation of foresight insights.

9.8.6 Operations vs. Management

It is by no means uncommon for organizations to display difficulties in communication between organizational members in management positions and at the working level. In high-hazard organizations, like NPPs, however, the looming danger of disaster magnifies the importance of untroubled communication across organizational levels. At the same time, the specific circumstances of a high-hazard environment contribute to the emergence of cultures, structures, and practices that increase the complexities of communication. Several examples from the case studies testify to this struggle to enable communication across organizational levels.

At Arrow station, Chuck, a senior engineer, explains his thought process going into discussions with superiors:

> "In a situation like this, my feeling as a shift manager is when my boss asks me to do something, my first question, even if it's not outright, but in my mind, "Is it safe? Is what we want to do safe?" That's the first question. The second question is, "Is it legal?" OK. Not that I think my boss would ask me to do something illegal, but he may ask you to do something, and you may turn around and say, "These are the technical specifications and it doesn't fir. We can't do that." If I think it's safe and I think it's legal, then I have to ask if it's the best thing to do or not. Then my responsibility is to give my opinion whether I agree it's the best thing to do or it's not. Unfortunately, what I think you have right now is a high-level management structure that tends to not want to listen to people it doesn't agree with. In other words, they come up with something and if you say, "No, I think it's this... ," they say, "Why are you disagreeing with us?" Instead of the open listening. I don't really think that's there right now
>
> *What do you think it takes for it to get there?*
>
> (sigh) The right people in management, the people with the right philosophy, the high-level management that will listen to people. At least listen to them and then say, "OK, I understand what you're saying. I disagree with you. This is what I want done." And through the process that I've just described, if my boss did that and it was safe and it was legal and I just didn't think it was the best

> thing, I'd say, "OK, I'd do it." But I think it's my responsibility to give my opinion. I think we're in a situation now where it's hard to give your personal opinion or even your professional opinion right now on an issue if management is leaning a certain way and you disagree with it. I think you're frowned upon right now." (Perin, 2007, p. 82)

Chuck holds the view that the people in management are the ones primarily responsible for establishing open communication. His solution to the problem of troubled communication is to exchange the people in those positions with other people with 'the right philosophy.'
Similar problems seem to plague communication at Charles station. Doug, staff at the corrective actions program, explains how the intimidating atmosphere at management meetings shuts down discussion. He also elaborates that a proposition he had made to counteract this problem, was immediately silenced with renowned force:

> "I've been in that room many times and it's a very uncomfortable, tense atmosphere. It's not welcome and warm and exploring, and that's part of why Miles and I proposed the significance and consequence exercise. That gives you a framework where it's OK to talk about, "What's the worst possible that can happen? What does this mean in the worst-case scenario? What is the [safety] significance? Is this a campaign issue with the regulator or with INPO or ourselves because this has happened a dozen times before? What are the consequences if the worst thing happened?" But that same ops manager that professed to do a stellar job in promoting openness and industrial safety said, "This is ludicrous to think that we have to have something like that to promote discussion. I asked the question, everybody was free to talk."
>
> *So would the alternative be for him to be the devil's advocate himself? To show that he was able himself to dream up this other scenario and have people tell him it wasn't going to happen that way?*
>
> Right. You never hear our senior management doing that. As soon as it starts to go in that direction—I've been in the room when the chief nuclear officer said (shouting) "I don't want to hear about that. I want someone to call the vendor right now and get an expert to tell us that that's not true." It's just not an open dialogue, what the worst possible case could be." (Perin, 2007, p. 180).

Management seems so profoundly unaware of its own behavior that it becomes impossible to overcome this reluctance to listen and unwillingness to be challenged.
In this regard, Flach et al. (2015) allude to the importance of trust for the flow of information and participation in decision-making processes. In their comparative study of the nuclear and fast food industry, they discover that NPPs trust the expertise of technical experts but not the

expertise of workers actually doing the job. A condition, which they conclude, breeds mistrust and ignorance among workers and management.

Another cause for the difficulties of upward communication in NPPs may be its historical development out of the military. After world war II, the federal Atomic Energy Commission was awarded the mandate to promote and privatize the peaceful use of nuclear energy. This meant moving the control over atomic energy from its military origins in the U.S. Army, into civilian hands (Buck, 1983). Since its beginning, ex-nuclear officers, as well as enlisted men and women, have populated the nuclear power industry. Military influence in the nuclear industry has continually diminished over the years due to retirements, cultural change, and shifting regulatory demands. Nonetheless, the mentality of top-down discipline and command and control principles inherent to military order still prevails in the nuclear industry and may contribute to a hierarchical culture that obstructs bottom-up communication. Against this background, it doesn't seem surprising that values like openness and active listening are not easily implemented through an exchange of management personnel or the introduction of new discussion tools.

Troubled communication between management and working level personnel can result in accidents that threaten people and organizations. A study by the Los Alamos National Laboratory discovered that several accidents in nuclear plants could have been avoided if supervisors had a better understanding of the actual work that operators perform in their routines (2000, p. 66). Part of the difficulty of enabling communication across hierarchical levels can be attributed to differences in mindsets. Carroll et al. (2002) analyzed reports of problem investigation teams in three nuclear power plants and thereby discovered that managers often exhibit values and cultural assumptions that emphasize results, short-term financial objectives, and avoidance of doubt and ambiguity. Team members in contrast focused on finding root causes, deep inquiry, and systemic understandings. These diverging mindsets also reflect on expected learnings from investigation reports. For team members, the primary objective of an investigation report was to identify failed barriers and generic lessons. Managers appreciated reports that primarily provided insights on effective corrective actions (Carroll, Hatakenaka, et al., 2002, p. 21).

The differences in thought worlds, professional cultures, and distinct knowledge reservoirs confront organizations with substantial challenges to developing strategic foresight capabilities. Bridging the hierarchical boundaries and communities of practice is particularly essential for the capabilities of 'transformation' and 'exploitation.' Active participation by members from all levels of the organization leads to higher payoffs from foresight processes because it activates more organizational knowledge reservoirs. At the same time, the learning effects of strategic foresight are much higher if people actively participate in the foresight process instead of passively consuming its results. The different perspectives and mindsets of working-level and management can pose a challenge for strategic foresight primarily because of the inherent power imbalance. Strategic foresight has the potential to serve as a boundary object bridging hierarchical boundaries, if it creates a space to negotiate shared meanings openly.

9.9 Summary of Findings

The analysis of the case studies produced insights on several foresight factors that contribute to foresight capability development. Most prominent are the findings concerning 'accessibility,' 'willingness to share across functions,' 'readiness to listen to scouts and external experts,' and 'willingness to challenge basic assumptions.' The examined NPPs display significant struggles to enable internal flows of information that lead to exchanges of knowledge and learning. These problems manifest themselves in rigid adherence to assumptions and reluctance to share and accept diverging perspectives. Speaking in terms of foresight capabilities, this means that dysfunctionalities in the diffusion of insights and unwillingness to challenge basic assumptions hamper transformation capabilities to combine new with existing information.

The roots of these issues are manifold. This analysis has established six themes that repeatedly reoccur within the case studies. Standing out is the omnipresence of silo behavior. It seems as though the environment of existential risk that prevails in nuclear power plants has contributed to a culture that tries to minimize risk by strictly adhering to hierarchy and expertise. Therefore, in organizational members' minds, any situation has someone with the responsibility and the appropriate expert knowledge to handle it. This belief creates impenetrable barriers because everyone operates only in his clearly defined silo of expertise. Furthermore, it is striking how these organizations struggle to dissolve contradictions. Many of the identified themes point to struggles to reconcile conflicting interests, such as reliability versus efficiency, formalized information versus informalized knowledge, or nuclear versus industrial operating logics. Because these organizations are built on compliance with formalized procedures, they tend to struggle with which procedure to follow when there is more than one rule of action available.

Overall, this research project's findings reveal significant challenges for the development of foresight capabilities, especially the ability to combine new and existing knowledge. These are due to strong departmentalization leading to silo behavior and split mental models, which obstruct the effective diffusion of information.

Paradoxically, while the development of strategic foresight capabilities requires organizations to move past these obstacles, strategic foresight can simultaneously serve as a tool to overcome these challenges.

The implementation of strategic foresight practices can serve as a boundary object to negotiate meaning between organizational members. The concept of boundary objects describes objects that are shareable across different problem-solving contexts. Effective boundary objects establish a shared language for individuals to represent their knowledge, provide a concrete means to specify differences and dependencies across given boundaries, and facilitate a process where individuals can jointly transform their knowledge (Carlile, 2002, p. 451f).

Because strategic foresight practices are not occupied by any existing areas of expertise in NPPs, it can constitute a space to enable this kind of learning. However, for strategic foresight to become an effective boundary object, its value has to be understood by all organizational members.

10 Limitations

The results of this research project are clearly exploratory. With only three cases as the subject of the investigation, there is a need for replication to validate the findings. Moreover, the cases were only subjected to secondary analysis. This means that the researcher did not have full access to the primary data. Therefore, the data underlying this investigation had already passed through the analysis and interpretation filters of another researcher. Constance Perin, a cultural anthropologist, conducted the case studies over a period of several years during the 1990s. Because of her background, Perin's case studies mainly focus on the cultural aspects of high-hazard organizations, which explains why analysis of the case studies produced the most data relating to the foresight factor framework's cultural elements. Future studies should, therefore, strive to obtain data related more to organizational structure and its impact on foresight capabilities.

The goal of this research was to understand how the distinct characteristics of high-hazard organizations affect their abilities to develop strategic foresight capabilities.

However, most of the data used for this research stems from investigations of incidents in nuclear power plants. This means that the case studies were conducted in organizations experiencing abnormal conditions. Therefore, the data is biased towards organizational deficiencies and may overstate their relevance.

Another factor compromising the validity of the results is the age of the case studies that underlie the analysis. Perrin conducted most of the case studies during the 1990s. Obtaining data from high-hazard organizations is problematic because of their inaccessibility. Gaining access requires long-term preparation and trust between the researcher and the organization (K.H. Roberts & Rousseau, 1989). Once access is established, these projects usually require immense resources financially and others, with a project, usually lasting several months or years. It is for these reasons that in-depth on site case studies of high-hazard organizations have become increasingly rare.

Therefore, more recent data is urgently needed to validate the results of this research.

The data is not representative because nuclear plants display significant differences in performance, which are linked to management (Bourrier, 1996). Therefore, it seems likely that management styles would also impact organizational abilities to adopt strategic foresight. Accordingly, it could be insightful for future research to compare the readiness to develop foresight capabilities of NPPs that exhibit different performance levels.

Problems of generalization are inherent to qualitative research designs, because "findings cannot be extended to wider populations with the same degree of certainty that quantitative analyses can" (Ochieng, 2009, p. 17). Especially case studies are commonly subjected to claims of lacking scientific rigor and insufficient generalizability (Yin, 2018, p. 56).

Generalization is even more difficult for case studies of high-hazard organization. These organizations are incredibly complex systems in which social and technological systems exist in infinite compositions. The variety of potential configurations makes almost every high-hazard organization a unique composition of structures, cultures, and technologies (K.H. Roberts & Rousseau, 1989). Thus, comparing high-hazard organizations is inherently challenging, especially across different industries. To be able to transfer conclusions from nuclear power plants to other organizations, large-scale, long-term studies would have to be carried out in several organizations.

The enormous complexities of high-hazard organizations are also the root of another limiting factor in this research. As complex as these kinds of organizations are, it takes years of operating experience for the staff at nuclear plants to develop comprehensive levels of expertise. Naturally, it is impossible to develop similar levels of knowledge over only months of explorations, because researchers cannot spend those same amounts of time studying and understanding these systems (K.H. Roberts & Rousseau, 1989). Therefore, future research needs to reconcile these findings with industry experts. Feeding back the insights to people actually on the inside of high-hazard organizations seems the only viable way to verify their relevance.

11 Conclusion

This paper explores how organizational conditions of high-hazard organizations impact their ability to build strategic foresight capabilities. Thereby, this research contributes to furthering the understanding of organizational levers and barriers to strategic foresight. The paper introduces a framework to assess factors for foresight and how they translate into organizational foresight capabilities. This framework's application reveals that accessibility to information across all organizational levels and functions is of elevated importance to build effective foresight capabilities. In the specific, hazardous context of nuclear power, organizational departmentalization and hierarchic structures create substantial obstacles for the development of foresight capabilities. Simultaneously, these obstacles accentuate the need for strategic foresight in high-hazard organizations. The analyzed organizations in this study often exhibit somewhat split mental models. Economic rationality competes with safety, logics of nuclear safety challenge non-nuclear systems, formal communication questions the validity of non-formal communication, and workers and managers struggle to align their objectives. Strategic foresight capabilities could create a space to articulate and negotiate these contradictions, elevating organizational performance. Because the intricacies of high-hazard organizations make them somewhat reluctant to disruptive change, an incremental approach to the development of foresight capabilities, slowly evolving from periodical forecasting exercises into an ingrained organizational practice, seems to bear the most promise.

Bibliography

Ahuja, G., Coff, R. W., & Lee, P. M. (2005). Managerial foresight and attempted rent appropriation: Insider trading on knowledge of imminent breakthroughs. *Strategic Management Journal*, *26*(9), 791–808. https://doi.org/10.1002/smj.474

Amanatidou, E., & Guy, K. (2008). Interpreting foresight process impacts: Steps towards the development of a framework conceptualising the dynamics of 'foresight systems.' *Technological Forecasting and Social Change*, *75*(4), 539–557. https://doi.org/10.1016/j.techfore.2008.02.003

Barriere, M., Luckas, W., Whitehead, D., & Ramey-Smith, A. (1994). *An Analysis of Operational Experience During Low Power and Shutdown and a Plan for Addressing Human Reliability Assessment Issues (NUREG/CR-6093)* ((NUREG/CR-6093)). U.S. Nuclear Regulatory Comission.

Baškarada, S., Shrimpton, D., & Ng, S. (2016). Learning through foresight. *Foresight*, *18*(4), 414–433. https://doi.org/10.1108/FS-09-2015-0045

Battistella, C. (2014). The organisation of Corporate Foresight: A multiple case study in the telecommunication industry. *Technological Forecasting and Social Change*, *87*, 60–79. https://doi.org/10.1016/j.techfore.2013.10.022

Behr, P. (2009, March). Three Mile Island still haunts U.S. nuclear industry. *The New York Times*. https://archive.nytimes.com/www.nytimes.com/gwire/2009/03/27/27greenwire-three-mile-island-still-haunts-us-reactor-indu-10327.html?pagewanted=all

Bier, V., Joston, J., Glyer, D., Tracey, J., & Welsh, M. (2003). *Effects of Deregulation on Safety Implications Drawn from the Aviation, Rail, and United Kingdom Nuclear Power Industries*. Springer US. http://nbn-resolving.de/urn:nbn:de:1111-2011061144

Bilodeau, B., & Rigby, D. K. (2007). A Growing Focus on Preparedness. *Harvard Business Review*, *85*(7/8). https://hbr.org/2007/07/a-growing-focus-on-preparedness

Blackman, D. A., & Henderson, S. (2004). How foresight creates unforeseen futures: The role of doubting. *Futures*, *36*(2), 253–266. https://doi.org/10.1016/S0016-3287(03)00144-7

Bodwell, W., & Chermack, T. J. (2010). Organizational ambidexterity: Integrating deliberate and emergent strategy with scenario planning. *Technological Forecasting and Social Change*, *77*(2), 193–202. https://doi.org/10.1016/j.techfore.2009.07.004

Bourrier, M. (1996). Organizing Maintenance Work At Two American Nuclear Power Plants. *Journal of Contingencies and Crisis Management*, *4*(2), 104–112. https://doi.org/10.1111/j.1468-5973.1996.tb00082.x

Bourrier, M. (2005). An interview with Karlene Roberts. *European Management Journal*, *23*(1), 93–97. https://doi.org/10.1016/j.emj.2004.12.013

Buck, A. (1983). *The Atomic Energy Commission*. U.S. Department of Energy. https://www.energy.gov/sites/prod/files/AEC%20History.pdf

Carayannis, E. G. (2012). Absorptive Capacity and Organizational Learning. In N. M. Seel (Ed.), *Encyclopedia of the Sciences of Learning* (pp. 25–27). Springer US. https://doi.org/10.1007/978-1-4419-1428-6_1620

Carlile, P. R. (2002). A Pragmatic View of Knowledge and Boundaries: Boundary Objects in New Product Development. *Organization Science*, *13*(4), 442–455. https://doi.org/10.1287/orsc.13.4.442.2953

Carroll, J. S. (1995). Incident Reviews in High-Hazard Industries: Sense Making and Learning Under Ambiguity and Accountability. *Industrial & Environmental Crisis Quarterly*, *9*(2), 175–197. https://doi.org/10.1177/108602669500900203

Carroll, J. S. (1998). Organizational Learning Activities in High-hazard Industries: The Logics Underlying Self-Analysis. *Journal of Management Studies*, *35*(6), 699–717. https://doi.org/10.1111/1467-6486.00116

Carroll, J. S., & Cebon, P. (1990). *The organization and management of nuclear power plants* [Working Paper]. Sloan School of Management, Massachusetts Institute of Technology; Sloan Working Papers.

Carroll, J. S., Hatakenaka, S., & Rudolph, J. W. (2002). Problem Investigation in High-Hazard Industries: Creating and Negotiational Learning. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.305719

Carroll, J. S., Hatakenaka, S., & Rudolph, J. W. (2006). Naturalistic Decision Making and Organizational Learning in Nuclear Power Plants: Negotiating Meaning Between Managers and Problem Investigation Teams. *Organization Studies*, *27*(7), 1037–1057. https://doi.org/10.1177/0170840606065709

Carroll, J. S., Rudolph, J. W., & Hatakenaka, S. (2002). Learning from experience in high-hazard organizations. *Research in Organizational Behavior*, *24*, 87–137. https://doi.org/10.1016/S0191-3085(02)24004-6

Cilliers, F., & Greyvenstein, H. (2012). The impact of silo mentality on team identity: An organisational case study. *SA Journal of Industrial Psychology*, *38*(2), 9 pages. https://doi.org/10.4102/sajip.v38i2.993

Clark, G. (2012, December). *The case for nuclear power*. Global Energy Polocy Research. http://www.gepr.org/en/contents/20121217-03/gepr.pdf

Cohen, W. M., & Levinthal, D. A. (1990). Absorptive Capacity: A New Perspective on Learning and Innovation. *Administrative Science Quarterly*, *35*(1), 128. https://doi.org/10.2307/2393553

Daft, R. L. (2013). *Organization theory & design* (11th ed). South-Western Cengage Learning.

Daft, R. L., & Weick, K. E. (1984). Toward a Model of Organizations as Interpretation Systems. *Academy of Management Review*, *9*(2), 284–295. https://doi.org/10.2307/258441

Daheim, C., & Uetz, G. (2008, September 28). *Corporate foresight in Europe: Ready for the next step?* Second International Seville Seminar on Future-Oriented Technology Analy- sis: Impact of FTA Approaches on Policy and Decision-Making.

Davis, L. W., & Wolfram, C. (2012). Deregulation, Consolidation, and Efficiency: Evidence from US Nuclear Power. *American Economic Journal: Applied Economics*, *4*(4), 194–225. https://doi.org/10.1257/app.4.4.194

Day, G. S., & Schoemaker, P. J. H. (2005). Scanning the Periphery. *Harvard Business Review*, *83*(11), 135–148.

Defense Nuclear Facilities Safety Board. (2004). *Safety Management of Complex, High-Hazard Organizations* (Technical Report DNFSB/TECH-35).

Diamond, M., Allcorn, S., & Stein, H. (2004). The Surface of Organizational Boundaries: A View from Psychoanalytic Object Relations Theory. *Human Relations*, *57*(1), 31–53. https://doi.org/10.1177/0018726704042713

Doz, Y., & Kosonen, M. (2008). The Dynamics of Strategic Agility: Nokia's Rollercoaster Experience. *California Management Review*, *50*(3), 95–118. https://doi.org/10.2307/41166447

Eisenhardt, K. M., & Graebner, M. E. (2007). Theory Building From Cases: Opportunities And Challenges. *Academy of Management Journal*, *50*(1), 25–32. https://doi.org/10.5465/amj.2007.24160888

Flach, J. M., Carroll, J. S., Dainoff, M. J., & Hamilton, W. I. (2015). Striving for safety: Communicating and deciding in sociotechnical systems. *Ergonomics*, *58*(4), 615–634. https://doi.org/10.1080/00140139.2015.1015621

Fukushima Nuclear Accident Independent Investigation Commission. (2012). *The official report of The Fukushima Nuclear Accident Independent Investigation Commission*. The National Diet of Japan. https://www.nirs.org/wp-content/uploads/fukushima/naiic_report.pdf

Grim, T. (2009). Foresight Maturity Model (FMM): Achieving Best Practices in the Foresight Field. *Journal of Futures Studies, 13*(4), 69–80.

Hamel, G., & Prahalad, C. K. (1994). Competing for the Future. *Harvard Business Review*, *72*(4), 122.

Harding, R. (2017, June). Tepco's new president vows to shake up Japanese utility's culture. *Financial Times*. https://www.ft.com/content/73ef47e4-50e1-11e7-bfb8-997009366969

Hayes, J. (2013). *Operational decision-making in high-hazard organizations: Drawing a line in the sand*. Ashgate Pub. Co.

Hines, A., Gary, J., Daheim, C., & van der Laan, L. (2017). Building Foresight Capacity: Toward a Foresight Competency Model. *World Futures Review*, *9*(3), 123–141. https://doi.org/10.1177/1946756717715637

Hopkins, A. (1999). The limits of normal accident theory. *Safety Science*, *32*(2–3), 93–102. https://doi.org/10.1016/S0925-7535(99)00015-6

Horton, A. (1999). A simple guide to successful foresight. *Foresight*, *1*(1), 5–9. https://doi.org/10.1108/14636689910802052

Hsieh, H.-F., & Shannon, S. E. (2005). Three Approaches to Qualitative Content Analysis. *Qualitative Health Research*, *15*(9), 1277–1288. https://doi.org/10.1177/1049732305276687

IAEA. (1998). *Modernization of instrumentation and control in nuclear power plants (IAEA-TECDOC-1016)*. International Atomic Energy Agency.

Iden, J., Methlie, L. B., & Christensen, G. E. (2017). The nature of strategic foresight research: A systematic literature review. *Technological Forecasting and Social Change*, *116*, 87–97. https://doi.org/10.1016/j.techfore.2016.11.002

Investigation Comittee on the Accident at the Fukushima Nuclear Power Stations of Tokyo Electric Power Company. (2012). *Lessons learned from Fukushima Dai-ichi—Report*. https://www.cas.go.jp/jp/seisaku/icanps/eng/final-report.html

Jefferson, M. (2012). Shell scenarios: What really happened in the 1970s and what may be learned for current world prospects. *Technological Forecasting and Social Change*, *79*(1), 186–197. https://doi.org/10.1016/j.techfore.2011.08.007

Jissink, T., Rohrbeck, R., & Huizingh, E. K. R. E. (2014, June 8). *Corporate Foresight: Antecedents and Contributions to Innovation Performance*. The XXV ISPIM Conference 2014, Dublin, Ireland.

Kettunen, J., Reiman, T., & Wahlström, B. (2007). Safety management challenges and tensions in the European nuclear power industry. *Scandinavian Journal of Management*, *23*(4), 424–444. https://doi.org/10.1016/j.scaman.2007.04.001

Kondracki, N. L., Wellman, N. S., & Amundson, D. R. (2002). Content Analysis: Review of Methods and Their Applications in Nutrition Education. *Journal of Nutrition Education and Behavior*, *34*(4), 224–230. https://doi.org/10.1016/S1499-4046(06)60097-3

Krolicki, K., DiSavino, S., & Fuse, T. (2011, March 29). Special Report: Japan engineers knew tsunami could overrun plant. *Reuters*. https://www.reuters.com/article/us-japa-nuclear-risks/special-report-japan-engineers-knew-tsunami-could-overrun-plant-idUSTRE72S2UA20110329

La Porte, T. R. (1988). The United States air traffic control system: Increasing reliability in the midst of rapid growth. *Working Paper Institute of Govenmental Studies*. University of California, Berkeley, CA, United States.

La Porte, T. R. (1996). High Reliability Organizations: Unlikely, Demanding and At Risk. *Journal of Contingencies and Crisis Management*, *4*(2), 60–71.

Labaka, L., Hernantes, J., & Sarriegi, J. M. (2015). Resilience framework for critical infrastructures: An empirical study in a nuclear plant. *Reliability Engineering & System Safety*, *141*, 92–105. https://doi.org/10.1016/j.ress.2015.03.009

LaPorte, T. R., & Consolini, P. M. (1991). Working in Practice But Not in Theory: Theoretical Challenges of “High-Reliability Organizations.” *Journal of Public Administration Research and Theory*. https://doi.org/10.1093/oxfordjournals.jpart.a037070

Lelieveld, J., Kunkel, D., & Lawrence, M. G. (2012). Global risk of radioactive fallout after major nuclear reactor accidents. *Atmospheric Chemistry and Physics*, *12*(9), 4245–4258. https://doi.org/10.5194/acp-12-4245-2012

Los Alamos National Laboratory. (2000). *A Review of Criticality Accidents* (LA-13638).

Major, E., Asch, D., & Cordey-Hayes, M. (2001). Foresight as a core competence. *Futures*, *33*(2), 91–107. https://doi.org/10.1016/S0016-3287(00)00057-4

Major, E., & Cordey-Hayes, M. (2000). Knowledge translation: A new perspective on knowledge transfer and foresight. *Foresight*, *2*(4), 411–423. https://doi.org/10.1108/14636680010802762

Mayring, P. (2000). Qualitative Content Analysis. *Forum Qualitative Sozialforschung / Forum: Qualitative Social Research*, *Vol 1*, No 2 (2000): Qualitative Methods in Various Disciplines I: Psychology. https://doi.org/10.17169/FQS-1.2.1089

McKelvey, B., & Boisot, M. (2009). Redefining strategic foresight: 'Fast' and 'far' sight via complexity science. In L. A. Costanzo & R. B. MacKay (Eds.), *Handbook of research on strategy and foresight* (pp. 15–47). Edward Elgar.

Mintzberg, H. (1992). The Effective Organization: Forces and Forms. *Sloan Management Review*, *32*(2).

Naevestad, T.-O. (2008). Safety Cultural Preconditions for Organizational Learning in High-Risk Organizations. *Journal of Contingencies and Crisis Management*, *16*(3), 154–163. https://doi.org/10.1111/j.1468-5973.2008.00544.x

O'Brien, F. A., & Meadows, M. (2013). Scenario orientation and use to support strategy development. *Technological Forecasting and Social Change*, *80*(4), 643–656. https://doi.org/10.1016/j.techfore.2012.06.006

Ochieng, P. A. (2009). An Analysis Of The Strengths And Limitation Of Qualitative And Quantitative Research Paradigms. *Problems of Education in the 21st Century*, *13*, 13–18.

Offstein, E. H., Kniphuisen, R., Robin Bichy, D., & Stephen Childers, J. (2013). Rebuilding reliability: Strategy and coaching in a high hazard industry. *Journal of Organizational Change Management*, *26*(3), 529–555. https://doi.org/10.1108/09534811311328560

Paliokaitė, A., Pačėsa, N., & Sarpong, D. (2014). Conceptualizing Strategic Foresight: An Integrated Framework: Conceptualizing Strategic Foresight. *Strategic Change*, *23*(3–4), 161–169. https://doi.org/10.1002/jsc.1968

Perin, C. (2007). *Shouldering risks: The culture of control in the nuclear power industry*. Princeton University Press.

Perrow, C. (1999). *Normal accidents: Living with high-risk technologies*. Princeton University Press.

Pettigrew, A. M. (1979). On Studying Organizational Cultures. *Administrative Science Quarterly*, *24*(4), 570. https://doi.org/10.2307/2392363

Popper, R. (2008). How are foresight methods selected? *Foresight*, *10*(6), 62–89. https://doi.org/10.1108/14636680810918586

Potter, W. J., & Levine-Donnerstein, D. (1999). Rethinking validity and reliability in content analysis. *Journal of Applied Communication Research*, *27*(3), 258–284. https://doi.org/10.1080/00909889909365539

Pratt, M. G. (2009). From the Editors: For the Lack of a Boilerplate: Tips on Writing Up (and Reviewing) Qualitative Research. *Academy of Management Journal*, *52*(5), 856–862. https://doi.org/10.5465/amj.2009.44632557

Ramírez, R. (2016). *Strategic reframing: The Oxford scenario planning approach* (First edition). Oxford University Press.

Ramírez, R., Österman, R., & Grönquist, D. (2013). Scenarios and early warnings as dynamic capabilities to frame managerial attention. *Technological Forecasting and Social Change*, *80*(4), 825–838. https://doi.org/10.1016/j.techfore.2012.10.029

Rasmussen, J. (2003). The role of error in organizing behaviour. *Quality and Safety in Health Care*, *12*(5), 377–383. https://doi.org/10.1136/qhc.12.5.377

Reason, J. T. (1990). *Human error*. Cambridge University Press.

Roberts, Karlene H. (1990). Some Characteristics of One Type of High Reliability Organization. *Organization Science*, *1*(2), 160–176. https://doi.org/10.1287/orsc.1.2.160

Roberts, K.H., & Rousseau, D. M. (1989). Research in nearly failure-free, high-reliability organizations: Having the bubble. *IEEE Transactions on Engineering Management*, *36*(2), 132–139. https://doi.org/10.1109/17.18830

Rohrbeck, R. (2011). *Corporate Foresight*. Physica-Verlag HD. https://doi.org/10.1007/978-3-7908-2626-5

Rohrbeck, R. (2008). Towards a best-practice framework for strategic foresight: Building theory from case studies in multinational companies. *IAMOT 2008 “Creating and Managing a Knowledge Economy,”* 15.

http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.580.7266&rep=rep1&type=pdf

Rohrbeck, R., Battistella, C., & Huizingh, E. (2015). Corporate foresight: An emerging field with a rich tradition. *Technological Forecasting and Social Change*, *101*, 1–9. https://doi.org/10.1016/j.techfore.2015.11.002

Rohrbeck, R., & Gemünden, H. G. (2008). Strategic Foresight in Multinational Enterprises: Building a Best-Practice Framework from Case Studies. *Emerging Methods in R&D Management*. R&D Management Conference 2008, Ottawa, Canada.

Rohrbeck, R., & Schwarz, J. O. (2013). The value contribution of strategic foresight: Insights from an empirical study of large European companies. *Technological Forecasting and Social Change*, *80*(8), 1593–1606. https://doi.org/10.1016/j.techfore.2013.01.004

Sarpong, D., Maclean, M., & Alexander, E. (2013). Organizing strategic foresight: A contextual practice of 'way finding.' *Futures*, *53*, 33–41. https://doi.org/10.1016/j.futures.2013.09.001

Schulman, P. R. (1993). The Negotiated Order of Organizational Reliability. *Administration & Society*, *25*(3), 353–372. https://doi.org/10.1177/009539979302500305

Schwartz, P. (1991). *The art of the long view* (1st ed). Doubleday/Currency.

Sitkin, S. B., Sutcliffe, K. M., & Schroeder, R. G. (1994). Distinguishing Control from Learning in Total Quality Managment: A Contingency Perspective. *Academy of Management Review*, *19*(3), 537–564. https://doi.org/10.5465/amr.1994.9412271813

Skjott Linneberg, M., & Korsgaard, S. (2019). Coding qualitative data: A synthesis guiding the novice. *Qualitative Research Journal*, *19*(3), 259–270. https://doi.org/10.1108/QRJ-12-2018-0012

Slaughter, R. A. (1997). Developing and Applying Strategic Foresight. *ABN Report*, *5*(10), 13–27.

Slovic, P. (1987). Perception of risk. *Science*, *236*(4799), 280–285. https://doi.org/10.1126/science.3563507

Tapinos, E. (2012). Perceived Environmental Uncertainty in scenario planning. *Futures*, *44*(4), 338–345. https://doi.org/10.1016/j.futures.2011.11.002

Tsoukas, H., & Chia, R. (2002). On Organizational Becoming: Rethinking Organizational Change. *Organization Science*, *13*(5), 567–582. https://doi.org/10.1287/orsc.13.5.567.7810

Tsoukas, H., & Shepherd, J. (2004). Introduction: Organizations and the future from forecasting to foresight. In H. Tsoukas & J. Shepherd (Eds.), *Managing the future: Foresight in the knowledge economy* (pp. 1–17). Blackwell Pub.

Turner, B. A. (1976). The Organizational and Interorganizational Development of Disasters. *Administrative Science Quarterly*, *21*(3), 378. https://doi.org/10.2307/2391850

Vecchiato, R. (2012). Environmental uncertainty, foresight and strategic decision making: An integrated study. *Technological Forecasting and Social Change*, *79*(3), 436–447. https://doi.org/10.1016/j.techfore.2011.07.010

Vecchiato, R., & Roveda, C. (2010). Strategic foresight in corporate organizations: Handling the effect and response uncertainty of technology and social drivers of change. *Technological Forecasting and Social Change*, *77*(9), 1527–1539. https://doi.org/10.1016/j.techfore.2009.12.003

Wack, P. (1985, September). Scenarios: Uncharted Waters Ahead. *Harvard Business Review*. https://hbr.org/1985/09/scenarios-uncharted-waters-ahead

Wahlström, B., & Kettunen, J. (2000). *An international benchmark on safety review practices at nuclear power plants*. Technical Research Centre of Finland.

Weick, K. E. (1976). Educational Organizations as Loosely Coupled Systems. *Administrative Science Quarterly*, *21*(1), 1. https://doi.org/10.2307/2391875

Weick, K. E. (1987). Organizational Culture as a Source of High Reliability. *California Management Review*, *29*(2), 112–127. https://doi.org/10.2307/41165243

Weick, K. E., Sutcliffe, K. M., & Obstfeld, D. (1999). Organizing for High Reliability: Processes of Collective Mindfulness. *Research in Organizational Behavior*, *1*, 81–123.

Whitehead, A. N. (2010). *Adventures of ideas*. Free Press.

Wildavsky, A. B. (2017). *Searching for safety*. https://search.ebscohost.com/login.aspx?direct=true&scope=site&db=nlebk&db=nlabk&AN=1592354

Wilkinson, A., & Kupers, R. (2013). Living in the Futures. *Harvard Business Review*. https://hbr.org/2013/05/living-in-the-futures

Yin, R. K. (2018). *Case study research and applications: Design and methods* (Sixth edition). SAGE.

Zahra, S. A., & George, G. (2002). Absorptive Capacity: A Review, Reconceptualization, and Extension. *Academy of Management Review*, *27*(2), 185–203. https://doi.org/10.5465/amr.2002.6587995

Zheng, W., Yang, B., & McLean, G. N. (2010). Linking organizational culture, structure, strategy, and organizational effectiveness: Mediating role of knowledge management. *Journal of Business Research*, *63*(7), 763–771. https://doi.org/10.1016/j.jbusres.2009.06.005

Appendix A: Theoretical Foundations of the Foresight Factors

Variable	Explanation	Relevance	Source
Reach	Information gathering reach: Are information gathered only from current markets, or extend to adjacent markets and white spaces?	By focusing on certain information, organizations tend to neglect other information in neighboring areas. Increasing the reach of information gathering is, therefore, paramount for successful foresight.	(Rohrbeck, 2008); (Rohrbeck & Gemünden, 2008);
Scope	Areas of the environment: Technologies, political environment, consumers, competitors	Organizations should not only focus on different markets but also different areas of the environment to gather relevant foresight knowledge.	Rohrbeck (2008); Rohrbeck & Gemünden (2008)
Time horizon	What time horizons does the gathered information concern?	Acquiring foresight knowledge requires gathering information from different time horizons and comparing them.	Rohrbeck (2008); Rohrbeck & Gemünden (2008)
Accessibility	How fast and direct can information flow across units and functions?	For foresight to create value for an organization, insights need to flow quickly across functions and units to reach relevant decision-makers that can translate these insights into actions.	Rohrbeck (2008); Rohrbeck & Gemünden (2008)
Sources	What sources of information are used? How many different sources? How much effort is undertaken to access information?	Using various means to access information that is inaccessible to others is crucial to generate insights that can lead to a competitive advantage. Being able to access a variety of sources is, therefore, essential for successful foresight.	Rohrbeck (2008); Rohrbeck & Gemünden (2008)
Willingness to share across functions	What attitude exists towards sharing information (e.g. frequently hoarded or ignored, sharing of information restricted to some functions, ongoing sharing across multiple levels)?	Making sense of weak signals often requires collaborative interpretation. To make collaboration possible it is necessary to foster trust and information sharing on multiple levels.	Day & Shoemaker (2005)
Readiness to listen to scouts and external sources	How do organizational members perceive of external sources of knowledge? Is listening to	Using foresight insights requires making use of external information as insights often have sources outside of the organization itself.	Day & Shoemaker (2005)

	external experts encouraged or discouraged?		
Willingness to test/challenge basic assumptions	How strongly do organizational members hold on to beliefs and basic assumptions (defensive about challenging critical premises, openly questioning and testing assumptions)?	It is important for foresight to challenge basic assumptions as well as the underlying mental models that are used to build consistent expectations about the future. To generate value from foresight, organizations must have an internal demand for decision-makers to make their basic assumptions explicit, track them, and challenge them frequently.	Rohrbeck & Gemünden (2008); (Blackman & Henderson, 2004); Grim (2009)
Attitude towards the periphery	How does the organization interact with the periphery?	In order to be susceptible to signals in the environment, members of the organization need to observe the environment actively. The organization should have an active and curious attitude towards the periphery and scanning being commonplace for all members.	Rohrbeck (2011)
Informal diffusion of insights	What is the role and effectiveness of informal communication?	Informal channels of communication can be crucial for the diffusion of foresight knowledge. They enable insights to spread efficiently and reach relevant decision-makers.	Rohrbeck (2011)
Integration	How is scanning for weak signals integrated with other management functions and processes? (e.g. strategy, innovation, controlling etc.)	To generate value, foresight insights need translation into action. Translating insights into action can be best achieved by integrating scanning for weak signals with other management functions as opposed to viewing it as a separate unit.	(Battistella, 2014); Rohrbeck (2011); (Amanatidou & Guy, 2008)
Responsibility	How are responsibility and accountability to sense and act on weak signals defined (e.g. Confined to technological domain/specific units, all members of the organization)?	Accountability to scan for signals should include all members of the organization. That also applies to incentives to reward a wider vision. By engaging all organizational members in scanning for weak signals, an organization maximizes its scanning capabilities.	(Rohrbeck 2011)

Formalization	How standardized are procedures and processes through guidelines and procedures?	Foresight depends on creativity. While formalization of procedures and processes can help organizations increase efficiency, it also has to allow sufficient freedom for creativity.	Battistella (2014); (Horton, 1999)
People	Does the organization attract the right people for foresight?	Foresight is about smartly channeling the available knowledge. Characteristics of a foresighter include lateral thinking, respected inside the organization, cross-disciplinary oriented, imaginative, communicative. Foresight also requires people to possess expert knowledge without becoming blinded by dominant logics within domains and organizations.	Rohrbeck & Gemünden (2008)
Networks	How is building of informal/formal networks encouraged?	Networks affect SF in terms of available information, chances of finding wild cards, ease of exploring adjacent businesses, white spaces, access to creativity/cognitive diversity	Battistella (2014); Rohrbeck (2011); (Daheim & Uetz, 2008); (Schwartz, 1991)