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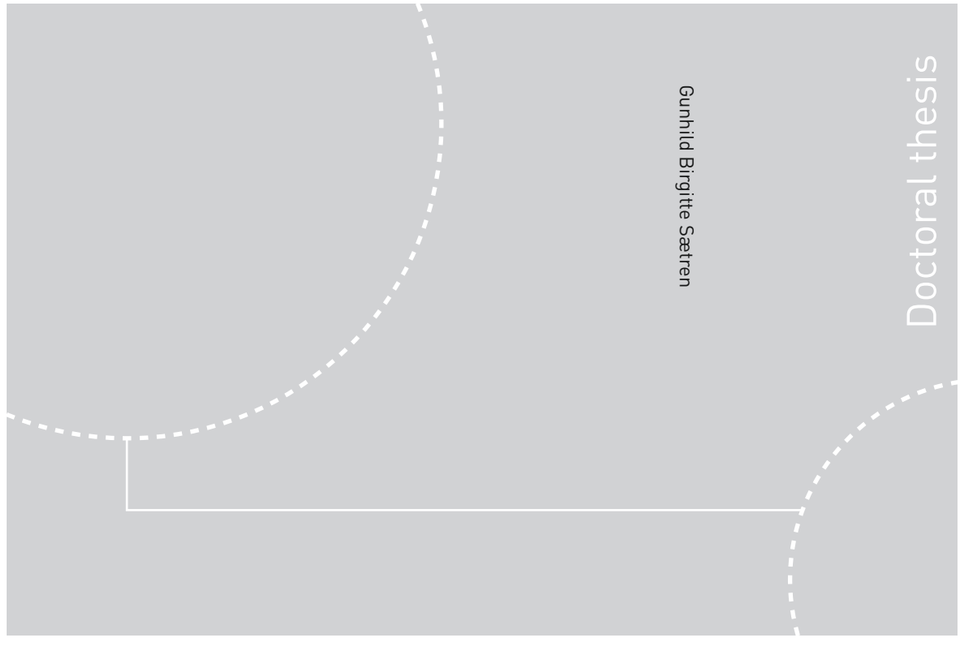

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Development and implementation of automated technology in a high-risk organization

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Preface and Acknowledgements

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This thesis represents my view and does not necessarily reflect any position or policy of the above mentioned.

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Thank you!

Abstract

This thesis aimed to explore safety during changes and, more specifically, safety in managing the development and implementation of automated technology in a high-risk organization. A longitudinal case study of an implementation process for new technology on an offshore oil and gas installation was carried out in addition to a survey. A crew and supervisors of an offshore oil- and gas-producing installation were followed prior to, during, and after the implementation of new technology. The interview data was collected in four rounds. Additionally, a 2-day observation was conducted onshore as the crew were introduced to the new technology, as well as a 3-day observation offshore a few months later. Subsequently, after the data had been analysed, findings suggested that the project would benefit from an additional qualitative study that involved interviewing the engineers who were developing the technology as well as members of the project group.

The findings of this paramount study were presented in the three papers that were guided by the following goals:

1. To investigate a drilling crew's acceptance of a modification of drilling technology and how this process would affect the perceived safety of their drilling activity. (Paper I)
2. To investigate the safety aspects of the project teams' work processes and the outcome of the development process. The specific research question was, How are safety through human factors and human reliability ensured during a development and implementation process of automated technology in a high-risk industry? (Paper II)
3. To make a theoretical evaluation based on the question, Are traditional change management theories adequate for organizational changes where safety is an issue? If not, could the HRO theory be used to ensure safety in a change process? (Paper III)

The findings reported in the first paper indicated that according to the readiness to change theory of Armenakis and Harris (2009), the implementation process had been a success. These findings, however, further indicated that the trust from the crew members was too high, and a nonquestioning culture contributed to a change process that ended in a hazardous incident, according to the theory of high reliability organizations (HRO) (Weick & Sutcliffe, 2007).

The second paper found that the development phase of the product could have benefitted from more thorough human factors and human reliability analyses. Mishaps that occurred due to incorrect use of the product were found to be partly because the developers did not have a sufficient understanding of whom they were developing their product for. Insufficient human factors and human reliability analyses were, in part, the reason the product became more costly than necessary and not as user friendly as requested. These insufficiencies further resulted in end users lacking an appropriate knowledge of safe usage and potential risks of the technology.

The third paper presented a critical review on traditional change management theories and how they were considered to be insufficient in regard to ensuring safety. Organizational change literature has, to a large degree, adopted a leader-centric focus on change processes (e.g., Armenakis & Harris, 2009; Cummings & Worley, 2015; Kotter, 1996; Oreg, 2003). The focus of the literature is mainly on transformational leadership and inspiring visions. In addition to the leader-centric focus, the literature does include an employee-centric focus that represents how employees weigh whether to embrace or reject the change. Based on the findings in the two previous papers, however, whether these theories' focus is sufficient in high-risk industries where safety should be a main focus could be questioned. For this reason, instead of focusing on the acceptance or rejection of the change from employees, this paper argued that successful changes are due to the capability of the organization to organize for

change. The paper presented a model that, based on both theory and practice, gives step-by-step guidance on how to focus on safety while conducting changes within organizations.

In conclusion, the findings of this thesis showed that the term trust should be nuanced and that too much trust could be considered a safety hazard. In order to ensure safety during the design and implementation process of automated technology in high-risk industries, mindfulness of HRO (Weick & Sutcliffe, 2007) amongst the change recipients could therefore be beneficial. Additionally, the findings showed that sufficient human factors analyses in the early stages of product planning could result in a safer product and a safer implementation process by giving insight into who the end users are, what training they need, and how to make the product user friendly. Further, potential improvements can be made to how change processes are conducted to ensure a safety focus in regard to managing change processes. Ensuring safety through change management could for instance be done by encouraging scepticism and questions throughout the change process rather than striving for willingness to change. The conclusion of this thesis is that HRO and human factors should be intertwined elements in change processes within high-risk organizations.

List of Papers

Paper I:

Sætren, G. B., & Laumann, K. (2015). Effects of trust in high-risk organizations during technological changes. *Cognition, Technology & Work*, *17*, 131–144. DOI: 10.1007/s10111-014-0313-z

Paper II:

Sætren, G. B., Hogenboom, S., & Laumann, K. (2016). A study of a technological development process. Human factors – the forgotten factors? *Cognition, Technology & Work,* DOI: 10.1007/s10111-016-0379-x

Paper III:

Sætren, G. B., & Laumann, K. (Submitted to Safety Science Monitor; the paper was resubmitted after revisions in May 2016). Organizational change management theories and safety. A critical review.

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1.0 Introduction

The petroleum industry is considered a high-risk industry, where the consequences of an accident can be disastrous. For this reason, safety is a main focus. Because major accidents within the oil and gas industry are extremely rare despite the dangerous work environment, the companies within this industry can be identified as high reliability organizations (HRO) (Weick & Sutcliffe, 2007). Mishaps do occur, however, and drilling is one of the industry segments in which mishaps have led to major accidents. Blowouts, such as Piper Alpha in 1988, Snorre A in 2004, and Deepwater Horizon in 2010, are all examples of major accidents due to drilling that the industry strives to prevent. For this reason, drilling is considered one of the most hazardous segments in this industry. Thus, offshore drilling has a very high focus on safety in order to prevent mishaps that could potentially lead to major accidents. Regarding the development and implementation of new technology in the drilling segment of this industry, incorporating strategies that ensure safety in managing any change are of uttermost importance.

This thesis emerged out of the assumption that changes in organizations have the potential to be successful in high-risk industries in that they can be accomplished without unnecessary hazards during the change process. The general objective of this thesis, therefore, was to investigate how changes in high-risk organizations can be conducted with a focus on safety. The paramount research question in this doctoral thesis was as follows, *How can changes in high-risk organizations be as safe as possible?*

In order to answer this question, a longitudinal study was conducted of an offshore oil and gas installation in Norway where new automated drilling technology was being implemented.

Three papers are included in this thesis. The first is a study on how trust affects the safety outcomes of a change process, particularly in the case of implementing new automated

drilling technology for offshore drilling operations. The second paper is a study on how human factors analyses could have benefitted the development of the new automated drilling technology in order to ensure safety in use by the end users. The third paper is a theoretical discussion on the aspect of safety in change management theories, or more precisely, the lack of focus on this topic. This third paper also provides a new model for how change processes in high-risk industries can be managed with a focus on safety.

The introduction of this thesis aims to provide theoretical aspects and discussions on safety in general, safety in high-risk organizations, and safety in managing change in high-risk organizations. Additionally, a human-centred approach, including how human factors can contribute to safety in the development of new technology, is presented and discussed. Subsequently, a methodological review of the current scientific work is presented. After this review, a description of the three papers is given. Finally, a discussion, including contributions and suggestions for future research, is presented prior to the conclusion of this thesis.

1.1 Safety

The aim of safety can be claimed to be understanding and managing unwanted incidents, but as a scientific field, it has few established normative criteria. Additionally, safety is often characterized within the boundaries of other fields such as psychology, management, engineering, and so forth (Le Coze, Pettersen & Reiman, 2014). The many perspectives within safety science could make it difficult to clearly understand what safety science actually is, and therefore the definitions of safety are many. For example, Civil Aviation's definition of safety is "the state in which harm to persons or of property damage is reduced to and maintained at or below an acceptable level through a continuing process of hazard identification". A definition such as this demonstrates that the focus of what defines safety lies in elements that can go wrong. Another way to define safety is based on when

something is absent rather than when safety is present. For example, "safety is marked by the absence of accidents and incidents" (Hollnagel, 2014a, p. 22). This definition demonstrates an understanding of safety as an epiphenomenon rather than a phenomenon—an epiphenomenon is something that has no effects of its own. By this definition, safety has no effect of its own but is defined out of an absence of other elements, in this case accidents and incidents (Hollnagel, 2014a). This understanding of safety often links safety to risk, or more precisely, to low risk (Aven, 2014). Definitions such as, "the condition of being safe; freedom from danger, risk, or injury" (Tdf, 2015), or "safety as the absence of accidents, where accident is defined as an event involving an unplanned and unacceptable risk" (Leveson, 1995), or "a condition such that risk is acceptable" (Sheridan, 2008), are further examples of this view. This simple view of safety as an autonomy from risk has its advantages, even though the view is challenged (Möller, Hanson & Peterson, 2006), because it leads to simple and easy definitions of *safe* and *safety* (Aven, 2014). During recent years, a new way of looking at safety science has arisen. In this new perspective, safety is defined as something that is present rather than something that is missing, such as risk. According to this view, safety should be defined by its presence and the focus should be on things that go right. In order to do things the right way, an understanding of how this happens is required. This shift is referred to safety I and safety II, where safety I is looking at how things go wrong and safety II is looking at how things go right (Hollnagel, 2014b). Both views are important, however, and are needed in high-risk industries.

1.2 Safety in high-risk organizations

Reason (1997) referred to three approaches that explain safety in organizations: the person model, the engineering model, and the organizational model. *The person model* emphasizes how people conduct unsafe acts and are, for this reason, responsible for their actions. In other words, people can choose to engage in safe or unsafe behaviour. In this

model, if people care and are attentive, alert, and motivated, errors will be prevented. According to this rationale, the way to prevent errors from happening would be punishment and reward for individual actions because people are free agents and choose how they act. *The engineering model*, on the other hand, focuses on how safety must be engineered into the system. This approach does not view human error simply as a choice of behaviour by individuals, but rather that errors emerge from human-machine mismatch or poor human engineering. The third approach, *the organizational model,* views human error as a consequence and a symptom rather than a cause. In this model, human error is linked to the presence of latent error (Reason, 1990), and the emphasis is on the need for continual reforms of the system at large. This thesis mainly uses the organizational model mixed with the engineering model as a basis for understanding safety in high-risk organizations.

In complex high-risk organizations, accidents such as blow outs on oil and gas producing installations or meltdowns at nuclear power plants, fortunately, occur very rarely. Studies show, however, that when they do occur, interaction of factors in various system levels, including technical, human, social, organizational, managerial, and environmental, often are a triggering cause (DHSG, 2011; Ghosh & Apostolakis, 2005; Rasmussen, 1997; Reason, 1990, 1997; Turner, 1978; Wilpert, 2005). Over the years, various theories and perspectives have been presented on organizational safety and major accidents. How we understand safety in high-risk organizations has developed over the last decades, which is demonstrated by a progression of theories that include Turner's (1978) man-made disaster theory, Perrow's (1999) normal accident theory, Reason's (1990) human error and latent failures theory, Rasmussen's (1997) decision-making theory and boundaries of human performance, the theory of high reliability organizations (Weick & Sutcliffe, 2001; 2007; 2015), and the more recent perspective of resilience engineering (Hollnagel, Woods, & Leveson, 2006).

1.2.1 Man-made disaster theory

Turner's (1978) model of man-made disaster is considered the first model to describe disasters in complex systems based on "normal" processes in everyday organizational operations. Through analysing 10 years of British accident inquiry reports, Turner found that large-scale accidents were not based in chance events or "acts of God", nor could they be described in technical terms alone. Rather, he discovered that the interaction between human and organizational features within a sociotechnical system made to manage complexity led to disasters. The main contributor to disasters, according to this theory, is "a significant disruption or collapse of the existing cultural beliefs and norms about hazards" (Pidgeon & O'Leary, 2000, p. 16). Such cultural beliefs and norms are tacit, taken-for-granted practices embedded in everyday work practices. Turner (1978) labelled the period from when preconditions begin occurring and continue through a chain of concealed errors until an accident occurs as the disaster incubation period. Disaster incubation is defined as a discrepancy between the actual state of affairs and the assumed conditions taken for granted by the workers.

1.2.2 Normal accident theory (NAT)

According to Perrow's (1999) normal accident theory (NAT), accidents are the result of production systems that are both interactively complex and tightly coupled. In this theory, interactions are described as going from linear to complex, where linear interactions are referred to as expected and familiar sequences while complex interactions are unfamiliar sequences that are neither planned nor expected. Couplings, on the other hand, are described as varying from loose to tight: a loose coupling has flexible performance standards and can include failures, delays, and changes without facing destabilizations; a tight coupling has no buffer or slack between its two items, so what happens to one directly affects what happens to the other.

In this theory, Perrow claimed that when system interactions are complex and the couplings are tight, an accident could represent a "normal" outcome because it represents two incompatible demands. In other words, accidents are inevitable in contexts where people are working with complex interactions and tight couplings.

1.2.3 Human error and latent failures

The theory of human error (Reason, 1990) employs cognitive psychology to account for the nature, varieties, and the mental sources of human error. How errors occur is understood in relationship to how our knowledge is stored, selected, and recalled in response to a given context. In this theory, Reason divides human error by intended actions and unintended actions. Slips and lapses are related to unintended actions, while mistakes and violations are related to intended actions. Further, slips and lapses are connected to how an action is performed and attention is given to the task, whereas mistakes are related to the planning of an action and how the problem is solved. Violations are deliberate deviations from procedure; however, such deviations are not necessarily reprehensible if they do not involve an intention of system damage. If they do, the action is labelled sabotage. Human error, from a system disaster perspective, is divided in two aspects: active errors and latent errors. Active errors refers to errors in which the effects are felt at once; latent errors' consequences may lay within the system for a long time and become evident only in combination with specific factors. This combination leads to a breach in the systems defence barriers and could potentially lead to an accident. Further, active errors are generally related to the performance of front-line personnel, such as drilling crew, pilots, air traffic controllers, and so forth, who operate systems. Latent errors, on the other hand, are associated with the work of people, such as engineer designers, high-level decision makers, managers, and maintenance personnel, who are more removed from the day to day operations.

Regarding latent errors and system disasters Reason (1990) provided a model to illustrate the human elements of accident causation. In this model, the term *fallible decisions* refers to decisions made by designers and high-level managerial decision makers. Decisions made on this level are influenced by many factors, including safety and production goals, resources, and feedback during the process. The next level in the model is *line management*. Line managers' everyday work and decisions in regard to safety are affected by the decisions made by their supervisors. Further, the interaction between line management deficiencies and psychological preconditions of unsafe acts is very complex. Elements such as training, workload, time pressure, inappropriate perception of hazards, and so forth, are all examples of preconditions that potentially could contribute to failure. *Preconditions for unsafe acts* are latent states produced by many complex elements such as tasks that are performed, environmental influences, and which hazards are present. Not all unsafe acts originate from fallible decisions; however, they could be a direct cause of human conditions. Such human conditions, including stress, motivation, hazard perception, and so forth, could directly cause an unsafe act. These conditions also includes life events that occur outside the workplace, for instance, sickness in the family or marriage breakdowns. When it comes to the commission of *unsafe acts*, this model refers to the slips, lapses, mistakes, and violations that are made in connection with an individual's information processing within a social and technical environment. The unsafe act, however, must be committed where a hazard is present. For example, not wearing a helmet in itself is not a dangerous act, yet in an environment where falling objects is a known hazard, not wearing a helmet is considered an unsafe act. In this model, the term *inadequate defences* describes an aspect of safety that can be made up of many different elements, ranging from protective personal equipment to engineering solutions such as automated technology.

The model was later illustrated by Swiss cheese, and it has evolved over the years to be seen as slices without labels because distinguishing between productive and protective systems can often be very difficult. The Swiss cheese illustrates the dynamics of accident causation arising from interactions between latent failures and a variety of local triggering events. In real life, very few unsafe acts actually result in accidents and damage, thus, this model illustrates the degree of unlikeliness that all elements will coincide and end in a system accident. In each layer of local triggering events, the loophole for an accident to occur must be hit, and the probability for this to happen on all layers is very low.

1.2.4 Decision making and mitigation towards boundaries

Another perspective on safety in complex organizations involves examining decision making and how organizations might migrate toward failure (Rasmussen, 1997). Rasmussen (1983) divided decision making into three categories: skills, rules, and knowledge. Skill-based behaviour refers to sensory-motor performance in which information leads to direct response without conscious control. Rule-based behaviour refers to recognition of situations in which stored rules or patterns of behaviour are applied. Knowledge-based behaviour is employed in new and unknown situations and refers to a higher conceptual level in which the situation must be evaluated and interpreted, and the person subsequently selects between patterns of behaviour based on functional reasoning. Rasmussen (1997) stresses how decisions are not made in isolation, rather they are made in the social context and established practices in the work environment. Thus, the interaction of the effects of decisions made by actors in their normal work context must be taken into consideration. For instance, in a world where commercial success often benefits from operating along the boundaries of acceptable safety practices, decisions will be affected by the competing goals of production and safety.

The boundaries mentioned above include (a) perceived acceptable performance and an error margin, (b) unacceptable work load, and (c) economic failure. These boundaries are

essential elements of organizations' production and safety. All work and decisions need to be made within these boundaries to uphold both production and safety. In order to prevent accidents, Rasmussen stated that the focus should be on "control of behaviour by *making the boundaries explicit and known* and giving opportunities to develop *coping skills at boundaries*" (Rasmussen, 1997, p. 191). In this way, safety will be maintained through an understanding of the specific organizational work context.

A high-risk organization operates in a dynamic society—the personnel must continuously adapt to changes, and the management must adapt to dynamic markets. These adaptations and modifications of behaviour appear continuously and seem rational in the contexts in which they occur. Furthermore, these adaptations lead to continuous small changes that could cause a drift towards the boundaries, which if crossed might lead to a drift into failure. In order to manage this risk, Rasmussen (1997) focused first on the importance of identifying the controllers, or more specifically, the decision makers who could contribute to an accident regardless of their location in the system. Second, he emphasised the need to identify work objectives, which often simply involves weighing the competing objectives of production and safety. Third, risk is managed by focusing on information about the actual state of affairs, which relates to how the measurement channel reflects the situation in the organization. In other words, the measurement methods need to be optimal to get the best possible picture of what is really happening within the organization. Fourth, Rasmussen focused on the importance of decision makers being capable and competent. Here, formal knowledge in addition to heuristic know-how and practical skills are relevant to control the requirements of relevant hazard sources. Finally, identifying the decision makers' commitment to safety is essential for managing the risks in an organization. These five factors reveal the context within which safe choices are made.

1.2.5 High reliability organizations (HRO)

For this thesis, the theory of high reliability organizations (HRO) (Weick & Sutcliffe, 2007) is used as the main safety theory. Safety in high-risk organizations is of primary importance, and HRO researchers have studied high-risk organizations with good safety records (Roberts, 1989; Rochlin, 1999; Weick, Sutcliffe & Obstfeld, 1999). HRO focuses on the culture in organizations and the relationship between culture and safety. The studies by Roberts (1989), Rochlin (1999), and Weick, et al. (1999) explored what was done right in high-risk organizations in order to understand how safety was maintained. Research within HRO offers explanations as to why systems with high complexity experience fewer accidents than are expected. Further, HRO is based on organizations that excel at maintaining function and structure when facing changes and challenges. These organizations perform well in settings where the potential for error and subsequent major accidents is substantial, including nuclear aircraft carriers, air traffic control systems, nuclear power generation plants, and so forth. Additionally, the theory of HRO is based on practical advice that should be feasible for most organizations. As a safety aspect the perception and cognition of the personnel is seen as a key factor to obtain high reliability. Five cognitive techniques are employed to ensure faster learning, greater alertness, and better relationships with customers. These organizations, however, are not stable, safe units. What they do is organize for high reliability by continually focusing on avoiding complacency and hubris (Weick & Sutcliffe, 2007).

According to Weick and Sutcliffe (2007), the five collective cognitive techniques or principles in HRO that constitute having a mindful infrastructure in the organization are tracking small failures, resisting oversimplifications, remaining sensitive to operations, maintaining capabilities for resilience, and taking advantage of shifting locations of expertise. The first three principles are concerned with human anticipation, while number four and five refer to containment. In other words, the first three collective cognitive techniques are related

to preventing an incident while the last two are related to the ability to prevent unwanted outcomes after an unexpected event has occurred.

By *tracking small failures*, personnel in HROs treat any unwanted incident or small error as a symptom that something within the system is not up to the desired standard. For this reason, personnel face, analyse, and respond to the incident or error. The reasoning behind these acts is the scientific knowledge that when separate small errors happen to coincide, they can lead to major accidents (e.g., Rasmussen, 1997; Reason, 1990). Acting on small errors could, therefore, prevent major accidents from happening. An example of a common way to do this is to report any unwanted incidents and get an overview of the situation within the organization, and from there, the organization can track how and why these incidents happen. Further, they continue to articulate errors and assess strategies to avoid them.

Another important technique for achieving high reliability is to *resist oversimplifications* of interpretations. This technique includes creating images and scenarios that help personnel understand the complex context in which they operate. Personnel tend to have more alternative possible scenarios and can spot unexpected events earlier because of their active and creative work within creating a more nuanced picture of the complex work context. An important factor necessary for achieving this ability to resist oversimplification is avoiding homogenous thinking. For this reason, HROs seem to appreciate diverse experience, scepticism, and negotiating tactics that reconcile differences of opinion. Within this principle, recognizing an event as something that has been previously experienced is also a factor, which in some cases would be a source of concern rather than comfort. This is due to the knowledge of how people interpret new data and assimilate it into already created schemas. According to cognitive psychology, people are biased and seek confirmation, which could be a reason for human error (Reason, 1990). However, in order to spot signs that an episode

might not be equivalent to something experienced in the past and finding errors that correspond to it, diversity and sceptical thinking are necessary. For this reason, even in the middle of an operation, personnel in HROs should have room to step back and assess the situation.

The third principle is *sensitivity to operations*. This principle is linked to the previously explained 'latent failures' (Reason, 1990), which refers to imperfections in elements such as supervision, reporting, and safety training that might lead to loopholes in the defence barriers of the system. For this reason, Weick and Sutcliffe (2007) emphasized that by integrating the front-line workers into the mindful culture and developing situational awareness in the working environment, HROs might be able to prevent errors from evolving into accidents. In other words, attentiveness to the front-line workers, who are engaged in the real work, helps prevent unwanted incidents. This level of engagement with front-line workers demonstrates how HROs focus more on situational features and less on strategic features. Further, to be able to have this kind of contextual focus on features, situational awareness is important. Situational awareness means that personnel are aware of their context and are able to discriminate amongst details, which makes them sensitive to smaller variances in their work conditions. Such awareness helps personnel make adjustments that prevent errors from accumulating (Endsley, Hansman, & Farley, 1999). Additionally, sensitivity to operations is closely linked to sensitivity in relationships. This linkage is due to the fact that personnel must trust that their scepticism is valued. If they do not believe their insights are valued, they may not speak up for fear of reprisals. Scepticism should be rewarded since it enables decision makers to gain important information necessary for them to make the best possible decisions. In contrast to rewarding such behaviour, reprisals can undermine the system because important information might be left out that enables the organization to

effectively handle situations. A trusting, open, and good work environment is, therefore, a key to safe operations.

The fourth principle is *maintaining capabilities for resilience*. Resilience is defined as "the intrinsic ability of an organization (system) to maintain or regain a dynamically stable state, which allows it to continue operations after a major mishap and/or in the presence of a continuous stress" (Hollnagel, 2006, p. 16). This principle does not imply that personnel view the organization as error-free, but rather that they manage errors by learning from failures. Additionally, the personnel's perceptions of the context are provided so that errors are not permitted to disable the organization. In order to accomplish this objective, resilience demands a deep knowledge of the system, the technology, the people one works with, and oneself. Additionally, having a rich imagination of possible scenarios, including the worst case, is important for training and gaining cognitive skills (Weick, 2005). Training, in combination with personnel who possess both deep and varied experiences and skills, is for this reason viewed as important (Weick & Sutcliffe, 2007).

The fifth technique presented by this theory is *taking advantage of shifting locations of expertise*. By empowering those closest to an incident, HROs make use of the expertise in the organization. A tight hierarchy creates vulnerability, and to avoid this, HROs push decision making down and around. Decision making is placed on the front line and the focus becomes listening to those with the best expertise, regardless of their rank. Experience, however, is not the same as expertise. The person with the longest experience is not necessarily the one who has the best expertise. Businesses today deal with greater complexity, and because of this, HROs use diversity in expertise and skills as a strategy. Businesses use this strategy because it helps them notice more in an increasingly complex environment. Additionally, by changing location of expertise, organizations could avoid deference (Sætren & Laumann, 2015; Weick & Sutcliffe, 2007). Deference could be a hazard, for instance, if one person's expertise leads

to another's unnuanced trust. For example, if the personnel trust the leader's ability to spot everything, the leader's expertise could hinder someone else from being alert and noticing something the leader missed. For this reason, HRO stress the importance of making good use of personnel, appreciating their opinions, and training them to look for and spot errors (Weick & Sutcliffe, 2007).

1.2.6 Resilience engineering

A resilient system is, according to Hollnagel (2009), "able effectively to adjust its functioning prior to, during, or following changes and disturbances, so that it can continue to perform as required after a disruption or a major mishap, and in the presence of continuous stresses" (p. 117). A practical method for resilience engineering is called the four cornerstones. These are knowing what to do (the actual), knowing what to look for (the critical), knowing what to expect (the potential), and knowing what has happened (the factual) (Hollnagel, 2009).

The *actual* refers to being able to respond to what happens, and such a response must help gain the desired outcome or change. The resilient system adjusts how it is functioning to match new conditions. Additionally, a resilient system's actions diminish unwanted outcomes and prevent the effects of adverse events from leading to further deteriorations. In order to prevent such a series of events, a resilient organization must be able to detect, identify, recognize, and respond to incidences when they occur. Detection stems from knowing what to look for by using predefined threats, and therefore the ability to address such threats relies a great deal on whether threats can be imagined or not. If these threats are not recognized, the organization could face vulnerability when facing unexpected events. Furthermore, if situations are recognized as threats when, in reality, they are not, the system could likewise be vulnerable and waste important resources. Deciding which response is appropriate depends

on cultural, organizational, and situational factors in addition to the competence of the people involved.

The second cornerstone, the *critical*, is related to knowing what to look for as in monitoring what is happening in order to cope with what might be critical in the near future. This element is crucial in the sense that by using a system's indicators to properly monitor the system, the organization will have a warning of what is likely to happen before it happens. To efficiently monitor a system, attention must be paid to any elements that may become crucial in the short term while focusing on the right indicators and symptoms.

Potential is the third cornerstone and focuses on threats that are further ahead, as opposed to the second cornerstone, the critical, which focuses on short-term threats. In order to focus on long-term threats, employees must be able to imagine key aspect of the future and how they can affect outcomes. This practice could be a challenge because it requires a combination of both individual and collective imagination.

The fourth, and last, cornerstone is the *factual*. This aspect relates to knowing what has happened in the past in order to learn from such experiences. The ability to learn is considered the basis for responding, monitoring, and looking ahead. Learning from experiences requires that certain elements must be taken into consideration since learning depends on how events are analysed and understood. Additionally, learning from experience requires an understanding of which events should be chosen for analysis. This discernment concerning the choice of events is based on the presumption that "what you look for is what you find" (Lundberg, Rollenhagen, & Hollnagel, 2009).

1.2.7 Theoretical discussion on system failure in complex high-risk organizations: similarities, differences, and critiques

All of the above-mentioned theories are concerned with how normal, everyday practice can contribute to major accidents in complex organizational systems. For instance,

the man-made disaster theory states that an incubation time occurs in which everything seems to be normal; normal accident theory claims that when tight couplings and complex interactions are normal in everyday work, accidents are more or less bound to occur; and according to Rasmussen (1997), everyday practice and the social context in decision making are what is relevant when decisions seems to drift towards boundaries that could lead to disaster. These explanations seem to be equal to what Reason (1990) called latent failures. The third principle of HRO (sensitivity to operations) is directly inspired by this phenomenon. For instance, latent failure could be related to periods of time during which things seem to be quiet and stable while they actually are not. Based on this knowledge, HRO is a theory in which personnel are trained to be sceptical of quiet periods and suspicious of success as an absence of symptoms. This suspicion is rooted in an assumption that an absence of symptoms could be related to danger (Perrow, 1999; Rasmussen, 1997; Reason 1990; Turner, 1978; Weick & Sutcliffe, 2007).

The theories and perspectives described in the theoretical background do, however, separate in how they view accidents as inevitable or not. As already described, HRO assumes that high-risk organizations can possibly exist without accidents (Rochlin, 1999; Weick & Sutcliffe, 2007). The resilience engineering perspective agrees with HRO regarding a proneness to accidents in high-risk organizations (Hollnagel, et al., 2006). The normal accident theory (Perrow, 1999), on the other hand, claims that accidents in these organizations are rare but nevertheless inevitable over time. In other words, Perrow's theory does not share the positive outlook of HRO and resilience engineering regarding the probability of accidents in high-risk organizations; instead, he provided a technological deterministic view. This aspect of Perrow's work has been criticized, and research indicates that elements such as poor management decisions and cost pressures might be the leading causes of major accidents in high-risk organizations (Hopkins, 2014; Perrow; 1994). HRO research has, through the five

mindful cognitive techniques, provided explanations of why some highly complex systems with tight couplings experience fewer accidents than expected (Weick & Sutcliffe, 2007).

HRO (Weick & Sutcliffe, 2007), the main safety theory in this thesis, seems to have several similarities with the more recent concept of resilience engineering. First, they are both concerned with safety as something an organization *does* on a more regular basis rather than something an organization *is* at any moment. Second, both HRO and resilience engineering aim to describe the conditions that lead to safe performance rather than the conditions that lead to accidents. Due to this shared aim, both HRO and resilience engineering could be considered science within a safety II focus (Hollnagel, 2014b). Furthermore, the two perspectives have been treated as essentially the same in a case study of HROs (Le Coze & Dupre, 2006). Another similarity between the two is how resilience is defined. Weick and Sutcliffe (2001; 2007) emphasized that resilience is commitment to learning from experience. Additionally, they stated that resilient organizations are not disabled by errors but rather mobilise, for example, by shifting locations of expertise when such events occur. This definition is largely the same as what Hollnagel (2006) presented as his definition of resilience: "the ability of a system or an organisation to react and recover from disturbances at an early stage" (p. 16). Actually, in the 2015 edition of their book, Weick and Sutcliffe use Hollnagel's (2009) definition of resilience, among others, to describe the fourth principle of HRO (maintaining capabilities for resilience).

Hopkins (2009; 2014) argued that resilience engineering and HRO have so much in common that separating them would be difficult and this resemblance of definitions seems to be one of the reasons why Hopkins (2014) stated that "Hollnagel's four cornerstones are central features of HRO theory" (Hopkins, 2014, p. 10). There are argument that supports this view. For instance, the first cornerstone, the actual, emphasizes that threats need to be recognised by being imagined, which is very much in accordance with HRO. HRO stresses

the importance of a broad range of competence and experience to widen the imagination. This widening of the imagination is done to build a wide spectrum of scenarios in order to prepare for unexpected events. Arguments regarding the second cornerstone, the critical, is related to short-term monitoring of threats, and it bears resemblance to for instance tracking small failures as a way of monitoring daily work processes for threats on a short-term basis.

An argument of why Hollnagel's cornerstones are central features of HRO regarding the third cornerstone, the potential, relates to dealing with threats that are more distant in time. This cornerstone seems to very much include the concepts of latent failure (Reason, 1990) on which HRO bases its third principle (remaining sensitive to operations). Further, this third cornerstone stresses that looking for potential requires a combination of individual and collective imagination. This aspect could be said to be in accordance to individual imagination and shared situational awareness, which are important elements in HRO. Additionally, the fact that the human mind uses simplifying heuristics, which is mentioned by Hollnagel (2009), is one of the main reasons that resisting oversimplifications is such an important aspect of HRO. Finally, the fourth cornerstone, the factual, is about learning from experience, which is also one of the most important aspects of HRO. In other words, HRO and resilience engineering seem to share similarities related to what resilience engineering calls the four cornerstones.

One difference between resilience engineering and HRO, however, is that resilience engineering is not defined as a theory in the way HRO is, but rather as concepts and precepts (Hollnagel et al., 2006). This could make the transfer to a practical setting challenging because the concepts and precepts are not specified clearly enough. Another aspect that is relevant when discussing HRO and resilience engineering is that HRO was based on empirical studies (Roberts, 1989; Rochlin, 1993) and further developed into practical advice in the form of five collective cognitive techniques (Weick, et al., 1999, Weick & Sutcliffe, 2001; 2007;

2015). Resilience engineering, on the other hand, does not have this empirical scientific foundation in which studies have been conducted to provide a theoretical and empirical foundation for resilience engineering as a concept. In HRO, empirical scientific work was conducted to explore this phenomenon by analysing what those organizations did to provide safety. The scientific basis of resilience engineering, however, seems to be based more on safety research that had already been conducted in a broader setting. That being said, for HRO to be as similar to resilience engineering as it seems to be is not necessarily considered a downfall for either of the two, but rather suggests that both are based on a thorough and relevant theoretical foundation that draws upon decades of safety science in complex high-risk organizations. Furthermore, since they both came up with similar results using different approaches, the similarities between the two could be seen as a strength of both perspectives.

Even though HRO could be viewed as a very good theory, and the implementation of the five collective cognitive techniques could improve the level of safety in organizations, elements of this theory should be evaluated. For instance, HRO is a theory about what an organization should do to accomplish safe operation on one hand, but on the other hand, it is impossible to test, according to Hopkins (2014). He states that this inability to test HRO is because empirical examples of testing and refining are impossible to identify. To be able to do scientific research on a subject, one must be able to define what the subject is. He therefore questions how a research site can be identified as an HRO. By definition, an HRO is an organization operating with hazardous technology in a "nearly-accident-free" manner, or with fewer accidents than might have been expected. According to his critique, however, formulations such as these are not precise enough to identify an HRO when one sees it. To complicate the issue further, HRO could be described as not being a theory as HRO scientists La Porte and Consolini (1991) made quite clear. They stated that HRO aimed to describe features that the organizations had in common, not to make prescriptions for safe

organizations. Additionally, they stated that the scientific work on HRO was not done to constitute a theory on how to become an HRO (La Porte & Consolini, 1991). Further, based on the original literature, Rochlin (1993) stated that "no truly objective measure is possible" (p. 17). The five mindfulness categorisations were not found until Weick and Sutcliffe (2001) organized the empirical data, though they do not describe in depth how the empirical findings were analysed. Their HRO model is, however, more of an ideal for which organizations can strive to reach rather than actually measure up to.

If it is impossible to be certain whether an organization is an HRO, it is likewise impossible to demonstrate whether an HRO is safer than a non-HRO, according to Hopkins (2014). On the other hand, the question is if such analysis is necessary. As mentioned, the idea of the theory of HRO could seem to be to create an ideal that organizations could reach for. The description of the ideal organization based on the five mindful cognitive techniques is founded in broad cognitive psychology and empirical science within high-risk organizations and could therefore be seen as a goal to reach. Thus, organizations can be HROs to different degrees based on their distance from the ideal. Certain elements could be scientifically investigated, and perhaps the theory is best used to describe where an organization is according to the five techniques in order to know what that organization should work on to become even better rather than to define an organization as an HRO or not. It could, for instance, be possible to evaluate to which degree an organization is an HRO based on the degree to which the organization conforms to each of the five principles. Safety is never absolute, but rather it is a continuous work on a day to day basis. The theory of HRO falls within this safety categorization. In other words, an organization perhaps should not be categorized as an HRO or not, but rather perhaps should be analysed to determine what work is done on a scale based on the five HRO principles.

1.3 Safety in change management in high-risk organizations

In order for an organization to survive in a competitive environment, changes are inevitable. The need for change is also present within high-risk organizations. According to Burnes (1996), organizational change models can be divided in three main categories: planned models, emergent models, and contingency models. *Planned models* are influenced by Lewin's (1958) model of organizational change, which involves three steps: unfreeze the current level, change, and then refreeze the new level. These models, therefore, often generate steps or stages that changes are to follow, and these models provide a recipe of "one best way for all" by moving from one state to a future desired state (e.g., Blake & Mouton, 1976; French & Bell, 1984). The *emergent models*, on the other hand, are more occupied with the fact that changes in organizations are never linear events but rather are a continuous process of adaptation within the organizations' conditions and circumstances (e.g., Armenakis & Harris, 2009; Cummings & Worley, 2015; Dawson, 1994; Kotter 1996; Wilson, 1992). For this reason, change models from the emergent perspective are less prescriptive and more analytical in order to achieve a broader understanding of the facing problems and to manage change in a complex environment. According to Burnes (1996), four key organizational activities necessary for success with change processes based on the emergent perspective are: information-gathering about external and internal factors, communicating the analysis and discussion of information, learning and the ability to develop new skills, and identifying responses in addition to drawing knowledge from previous experiences. As a third alternative, the *contingency models* focus on the uniqueness of every organization and, hence, the organizations' change processes. Here, the organizational structures are dependent on situational variables that are unique for that organization. In this regard, rather than the "one best way for all" the focus shifts towards a "one best way for each" and organizational structure should depend on the organization's degree of stability and how dynamic the

organization's external environment is (e.g., Dunphy & Stace, 1993; Lawrence & Lorsch, 1967).

Over the years, many theories regarding how to manage, prepare for, and follow through with organizational changes have been formed. Change management has been defined as "the process of continually renewing an organization's direction, structure, and capabilities to serve the ever-changing needs of external and internal customers" (Moran & Brightman 2001 p. 111). Some of the most commonly used theories are those of Kotter (1996) and Armenakis and Harris (2009). Further, Cummings and Worley (2015) looked at the diversity of practical advice for managing change in change management literature and organized this advice into five major activities. These theories will be presented next.

1.3.1 Kotter's eight steps

Kotter's (1996) eight steps to transform an organization are well known within organizational change management theories. The steps he recommended were as follows: step 1, establishing a sense of urgency; step 2, forming a powerful guiding coalition; step 3, creating a vision; step 4, communicating the vision; step 5, empowering others to act on the vision; step 6, planning for and creating short-term wins; step 7, consolidating improvements and producing still more change; and step 8, institutionalizing new approaches.

In step 1, Kotter (1996) stressed the importance of establishing a sense of urgency to gain cooperation because few people are interested in working on a change problem. Further, creating a high sense of urgency is crucial for establishing a group with enough power and credibility to follow through with the change. In this case, complacency is an important concept. Kotter described a situation in which a change group exists within a culture of complacency:

> Sooner or later, no matter how hard they push, no matter how hard they threaten, if many others don't feel the same sense of urgency, the momentum for change will

> probably die far short of the finish line. People will find a thousand ingenious ways to withhold cooperation from a process that they sincerely think is unnecessary or wrongheaded. (Kotter, 1996, p. 38)

Kotter (1996) recommended nine basic means to increase the urgency level: first, create a crisis, for instance, by allowing a financial loss; second, eliminate obvious examples of excess; third, set revenue, income, productivity targets, etc., so high that they cannot be reached by conducting business as usual; fourth, insist that more people are being held responsible for broader measures of business performance than previously; fifth, send more data concerning weaknesses in customer satisfaction and financial performance to more employees; sixth, insist that people talk regularly to unsatisfied customers; seventh, use various means to force more relevant data and honest discussion into management meetings; eighth, put more honest discussions of the firm's problems in company newsletters and senior management speeches; and ninth, bombard people with information on (a) future opportunities, (b) the rewards that come from following those opportunities, and (c) the organization's current inability to pursue those opportunities.

In step 2, Kotter (1996) emphasised the importance of creating a powerful guiding coalition because major change is so difficult. Such a strong coalition needs the right composition, level of trust, and shared objectives. To be able to have these components, the coalition should consist of people with power, so that decisions cannot easily be blocked; people with varied expertise, so intelligent decisions can be made; people with good credibility, so pronouncements will be taken seriously by other employees; and people with leadership skills who will be able to drive the change process.

Step 3 concerns developing a vision and strategy. According to Kotter (1996), a "vision refers to a picture of the future with some implicit or explicit commentary on why people should strive to create that future" (p.71). A good vision serves three important

purposes within a change process: first, a good vision clarifies the general direction of the change; second, it motivates people to move in the desired direction; and third, it helps coordinate the actions of different change actors. An effective vision is further characterized by being imaginable, desirable, feasible, focused, flexible, and communicable.

Step 4 involves communicating the change vision. Having the right strategy in this matter is important because a shared sense of a desirable future helps motivate and coordinate actions that promote the transformation to come. Kotter (1996) provided seven principles intrinsic to communicating the vision in an optimal way: keep it simple, use metaphors, use many different forums (e.g., meetings, memos, newspapers, posters, informal one-on-one talks, etc.), repeat often, behave and lead according to the new vision, explicitly address inconsistencies, and have two-way communication. Having two-way communication implies that one should listen in addition to being listened to in order to make sure that others have understood the new vision.

In step 5, Kotter (1996) stressed empowering employees for broad-based action. Empowering employees is important because internal transformation will be hard to achieve without assistance from many people. In order to accomplish such transformation, employees need to feel empowered in their everyday work. For this reason, " the purpose of stage 5 is to empower a broad base of people to take action by removing as many barriers to the implementation of the change vision as possible at this point in the process" (Kotter, 1996, p. 106). The four most important barriers referred to are structures, skills, systems, and supervisors. Structural barriers might include, for example, independent silos that do not communicate or a lack of the necessary tools to follow the vision. Skill-level can be a barrier if the competence and attitude amongst employees is not at the desired levels. Systemic barriers could include, for instance, measurement scales that are not consistent with the new

vision. Finally, supervisors could act as barriers if they do not communicate the new vision through their behaviour and how they lead.

In step 6, Kotter (1996) emphasized the importance of generating short-term wins. To keep the spirit up amongst the employees, short-term wins should have at least three characteristics: they should be visible, unambiguous, and clearly related to the change. The reason for these short-term wins are to provide evidence that sacrifices are worth it, to reward change agents, to help fine-tune the organization's vision and strategies, to undermine cynics and self-serving resisters, to keep bosses on board, and to build momentum. As an example, Kotter (1996) states, "as a general rule, the more cynics and resisters, the more important are short-term wins"' (p. 127).

Step 7 involves consolidating gains and producing further change. This step is important in order to keep progress from slipping. By this step in the process, change agents can feel like the organization is headed in the right direction and, as a result, slow down; however, it is crucial not to let this happen. For this reason, five factors are relevant for this step: more change, not less; more help with the changes; leadership from senior management to maintain clarity of the shared purposes and to keep the urgency level up; project management and leadership from lower ranks in the hierarchy in order to provide leadership for specific projects and manage those projects; and a reduction of unnecessary interdependencies to make the change easier.

In the final step, step 8, Kotter (1996) stressed the importance of anchoring the new approaches in the culture. Culture refers to "norms of behaviour and shared values among a group of people" (Kotter, 1996, p. 156). Culture is important because it has a great influence on people's behaviour. The way to anchor change in a culture is (a) to remember that cultural change comes last, not first; (b) to be aware that anchoring change in culture depends on the results; (c) to know that this process requires a lot of communication, such as verbal

instructions and support; (d) to remember that anchoring change may involve turnover and changing key personnel; and (e) to be aware that decisions made concerning succession are crucial because promotions must be compatible with the new vision.

1.3.2 Armenakis and Harris' readiness to change

Armenakis and Harris (2009) developed a model around readiness to change that consists of five key components and seven strategies. The five components are as follows: Discrepancy, which is related to how the change recipients perceive the necessity of the change. Efficacy, which is related to how the employee's perceive their own ability to follow through with the change. Appropriateness, which is related to how one sees the planned change as the right change according to a future optimal result. Principal support, which refers to the support the employees are given during the change process. And finally, personal valence, which is related to the question, "What's in it for me?" which at least needs a partially positive answer in order for those involved to commit to the change. Additionally, seven change management strategies are intended to transmit and reinforce the five components during the change process. These seven strategies include management of information, persuasive communication, formalization activities, diffusion practices, human resource practices, rites and ceremonies, and active participation.

1.3.3 Cummings and Worley's five major activities

Cummings and Worley (2015) organized the diversity of practical advice in change management literature into five major activities. These five activities are motivating change, creating a vision, developing political support, managing the transition, and sustaining momentum.

The first activity is *motivating change.* A change process is a transition from the known to the unknown, and as Cummings and Worley (2015) stated, "Because the future is uncertain and may adversely affect people's competencies, worth, and coping abilities,

organization members generally do not support change unless compelling reasons convince them to do so" (p. 181). This first activity consists of two related tasks: creating readiness to change and overcoming resistance to change. *Creating a readiness to change* involves creating a felt need for change that includes "making people so dissatisfied with the status quo that they are motivated to try new work processes, technologies, or ways of behaving" (Cummings & Worley, 2015, p. 181). Three methods are recommended to generate dissatisfaction and produce change: sensitize organizations to pressure for change, reveal discrepancies between current and desired states, and convey credible positive expectations for the change. The second task is *overcoming resistance to change*, which can come from three different sources: technological resistance, political resistance, and cultural resistance. In order to deal with these resistances, Cummings and Worley (2015) offered three major strategies for positively overcoming the resistance to change. The first is empathy and support, which involves actively listening in order to learn how people are experiencing the change. Such empathy creates less defensiveness and is more likely to open relationships that could benefit working on problem solving, which is needed to overcome the barriers to change. The second strategy is communication, which relates to the aspect of people's resistance due to uncertainty about the consequences. In order to hinder rumours, gossip, uncertainty, and to help people realistically prepare for the change, adequate communication of information is vital. The third major strategy is participation and involvement, which is viewed as the most effective strategy to overcome resistance to change.

The second activity presented by Cummings and Worley (2015) is *creating a vision.* This involves creating a vision that reflects the members' views on what they want the organization to become. "Generally, a vision describes the core values and purpose that guide the organization as well as an envisioned future toward which change is directed" (Cummings & Worley, 2015, p. 184). This vision should be created in a way that guides leaders' and

employers' activities during change processes by describing the core ideology and constructing the envisioned future.

The third activity is *developing political support.* This activity is related to power and influence—how the power balance can be adjusted in change processes and how this might affect the outcome. Assessing the change agent's power, identifying key stakeholders, and influencing stakeholders are all important activities for managing the political dynamics within change.

The fourth activity is *managing the transition.* This involves activity planning, such as citing specific events and activities; commitment planning, which involves identifying key people and groups where commitment is needed; change management structures, which includes using people who are capable of following through with the change process; and learning processes, in which those involved are learning the new skills and behaviours that are necessary.

The fifth and final activity, according to Cummings and Worley (2015), is *sustaining momentum.* In this activity, ensuring the commitment and energy needed to implement and complete the changes is important. "A strong tendency exists among organization members to return to old behaviours and well-known processes unless they receive sustained support and reinforcement for carrying the changes through to completion" (Cummings & Worley, 2015, p. 199). In order to follow through with the changes, five specific activities are described. First, resources for change must be provided. These resources include elements such as training, feedback, and meetings. Second, a support system for change agents must be provided. This support system involves a network of people who can give emotional support to help the change agents cope with problems that might arise due to their role in the change process. Third, new competencies and skills must be developed because changes might not be possible unless members gain new competencies. For this reason, training, coaching, and

simulations might be provided to help change agents learn new, necessary technological and social skills. Fourth, new behaviours must be reinforced by rewarding the preferred behaviours. Fifth, change agents must stay the course in order to complete the change process.

1.3.4 HSE on how to manage organizational change and major accident hazards

The above-mentioned change management theories focus on changes in organizations on a more general basis, and they do not specifically focus on high-risk organizations. When an organization has the potential for a major accident, however, safety should be a focus during any changes within the organization. The HSE (2003) in the UK provided an information sheet in regard to how to manage organizational change and major accidents hazards. This informational sheet provided a three-step framework: get organized for change, assess risks, and implement and monitor the change.

The first step, *getting organized*, includes five factors. First, have a strong policy for managing organizational change. The focus in this stage is that principles, commitments, and accountabilities regarding health, safety, and the environment must be clear from the beginning of all changes, both large and small. Second, make senior-level managers accountable and demonstrate a clear commitment to safety by their actions. Third, have a clear change-management procedure. Such a procedure is necessary due to the fact that all changes should be planned in a thorough, systematic, and realistic way. In order to develop clear procedures, certain actions are important: (a) identify the processes and activities that are to be carried out, (b) establish the protocols to be followed, (c) identify who is accountable and who is responsible for these activities, (d) determine who else is involved and how, (e) find what potential risk factors are to be considered, and (f) identify who reviews the change process as well as when and how. Additionally, each stage of the process should be adequately recorded due to the importance of ensuring transparency and traceable decision-

making processes. Fourth, communicate and include all members of the staff because they all have unique knowledge about what their work is really like and how it is performed. This knowledge can be crucial in order to prevent major accidents in relation to changes in high-risk organizations. Because of each staff members' unique perspective, changes should involve all members that are concerned from an early stage. This involvement of staff further generates active participation in decisions. Fifth, review and challenge the process both by internal and external experts.

The second step is *risk assessment*, which involves five factors. First, identify the people involved, including those in the existing and proposed organizations that will be affected. Here, the accuracy of the information is important in addition to registration of all the roles involved. Second, identify all changes. This step is necessary because the complexity of change processes could be viewed as a hazard. Further, in larger organizations, simultaneous changes could hinder smooth processes. Third, assess the risks within the change process. Fourth, consider human factors, competence, and workload for instance by investigating whether tasks or responsibilities could have been overlooked, what training is required for new tasks, and whether the accumulated workloads for individuals are within reasonable levels. Finally, test scenarios that are realistic and structured in order to train for any incidents and emergencies that might occur.

The third and last step of the HSE (2003) framework is *implementing and monitoring the change.* This step includes considering safety during the transition and also consists of five factors. First, provide adequate resources to make the change safely. For instance, the need for training should not be underestimated and staff should not be reduced until the required actions are completed. Additionally, enough staff should be maintained to ensure that the change can be properly planned and monitored and that experienced support is available during the transition. Second, monitor risks during change. Third, keep the plan

under review and track actions. Fourth, monitor performance after the change and be ready to change or reverse decisions if significant risks are discovered. Finally, review the change policy to amend the organization's change procedures.

1.3.5 Theoretical discussion on how to organize change processes in high-risk organizations to promote safety during changes

In the third paper, Sætren and Laumann (submitted) presented a thorough discussion regarding how a selection of traditional change management theories (Armenakis & Harris, 2009; Cummings & Worley, 2015; Kotter, 1996) have shortcomings related to changes in high-risk industries by comparing the change management theories with the theory of HRO. In order to add a broader view on the topic on organizational change theories and safety, a more paramount theoretical discussion will therefore follow here.

Changes in organizations happen all the time, and for the most part, changes are smaller and not planned (Burke, 2002). This view of change could be seen in connection with Rasmussen (1997), who stated that small changes on a continuous basis could be a safety hazard. As normal, everyday practices change, the operations could drift into failure. Furthermore, even though most changes are smaller and unplanned, this element of change is not often seen in change management theories as most organizational change management theories focus on large-scale, planned changes (Burke, 2002). Such large-scale, planned changes are the focus of this thesis as well. Even though the presented safety theories do not focus on change processes in particular, HRO and resilience engineering, for instance, are preoccupied with adjusting an organization's functioning in order to continue working within the complexity of changing environments and disturbances during operations. For this reason, the safety theories could be discussed in regard to which paramount change management model (presented in section 1.3) should be used: *planned*, *emergent*, or

contingency (Burnes, 1996). Such a discussion would focus on which model could be appropriate to use from a safety perspective.

At first sight, planned models does seem to be coordinate well with a safety focus. Detailed planning might hinder major accidents from occurring during change processes, and such planning is also a main element of HSE's (2003) model. Planned models in organizational change theory, however, do propose change from a top-down perspective where the stages are preplanned (Burnes, 1996). Such top-down change does not, for instance, involve making those closest to the changes experts in their own operations, which is, for example, emphasized by Weick and Sutcliffe (2007). The planned models could further be argued as based more on rational thinking in which economic efficiency is the ultimate criterion. In high-risk organizations, the production goals must be seen in connection with safety goals since they are two goals that often seem to be competing (Rasmussen, 1997; Reason, 1990); nevertheless, focusing on both is important. Furthermore, planned theories could seem to be grounded in normative rules and preplanned system designs and focus more on training, instruction, and punishment more than real involvement, elements of which Rasmussen (1997) argued could be viewed as hazards in high-risk industries. Additionally, many traditional theories for managing organizational change usually present steps or phases to implement the change. A real life organizational change, however, is never linear; changes do not proceed exactly as planned, and unanticipated consequences occur. For this reason, planned change models are critiqued because they are based on an assumption that organizations operate under stable conditions and can move from one condition to another (Burnes, 1996). If organizations organize for change on more of an everyday basis and obtain organizational change competence (Ingstad & Finne, 2009), they might have a foundation to handle different types of changes in a more efficient way. The theory of HRO (Weick & Sutcliffe, 2015) does take into consideration the aspect of managing the unexpected, and by

implementing the five principles in the work culture, an organization might be prepared for unexpected incidents during both normal operations and change processes. This understanding of change is in line with an emergent perspective of organizational change.

The emergent approach views organizational changes not as a series of linear events but rather as a continuous process (Burnes, 1996). An emergent approach could further be consistent with safety theories in the way that it emphasizes a bottom-up perspective in which employees should be involved in those change process that concern their work practices. This approach is in line with HRO, which emphasizes taking advantage of shifting locations of expertise and including the front-line workers in the change process since they are closest to the occurrences. Some of the elements within the emergent approach, however, are not in agreement with safety management. For example, the emergent approach states that "the role of manager is not to plan or implement change, but to create or foster an organizational structure and climate which encourages and sustains experimentation and risk-taking" (Burnes, 1996, p. 15). In high-risk industries, experimentation and risk taking are not viewed as strengths in that matter, especially not in the context of the development and implementation of new automated technology. Additionally, the emergent approach is not preoccupied with detailed plans regarding the change, but rather it focuses on understanding the complexity and identifying a range of available options (Burnes, 1996). Safety theories are also concerned with understanding complexity by gaining in-depth knowledge of elements such as coworkers, work operations, and organizational strategies (Weick & Sutcliffe, 2007). Such an understanding is also in agreement with the HSE (2003) recommendations for implementing changes in high-risk industries. An example of a strategy in order to cope with complexity and discover what options are available, is to establish an open and questioning culture (Sætren & Laumann, 2015). Sætren and Laumann (2015) argued that this cultural aspect should be created before the change takes place. This does not agree with Kotter's

(1996) theory which is described as an emergent model. He claimed that the cultural change should come last, not first.

Safety theories do not, however, correspond with emergent models regarding detailed plans, which emergent models are not preoccupied with. A preoccupation with details is of uttermost importance when implementing new technology in high-risk industries. As Haavik (2012) stated, "The devil is in the (normal) details" (p. 34) referring, of course, to the saying, "the devil is in the details". This thesis states that extra attention must be given to the details because overlooking important details in planning carries the potential to overthrow projects. Periods of change, by definition, are not normal operational periods, and therefore the planning and flexibility throughout the change process should be valued because the normal details that normally are paid attention are now changing. Such changes could represent a hazard because they could promote a drift into failure (Rasmussen, 1997; Dekker, 2011). One does not necessarily know which new details to pay attention to. Elements such as sticking to the change and following through with it regardless of what incidents might happen during the process (Cummings & Worley, 2015) can therefore be viewed as minimally flexible. If an organization needs to change, the flexibility of the organization should be valued as such flexibility could benefit the process. This flexibility includes the ability to assess the status quo and evaluate whether the process is leading the organization in the right direction or if it should be corrected or even reversed (HSE, 2003; Sætren & Laumann, submitted).

Contingency models are preoccupied with diversity within changes and organizations, and they focus on how organizations must adjust change processes according to situational factors. In a way, this model type agrees with the arguments that Sætren and Laumann (submitted) made when they discussed how many change management theories are insufficient when it comes to establishing safety during changes. Contingency models consider aspects such as leadership styles, which changes are needed in order to bring the

organization to the desired state (Dunpy & Stace, 1993), and organizational structures (Lawrence & Lorsch, 1967). Because organizational structure and performance are dependent on situational variables, contingency models could offer an argument for why high-risk organizations might take into account other considerations beyond organizations in other industries. Handling contingencies is an important aspect of safety in high-risk organizations, and the five principles in HRO are a way to handle contingencies. For this reason, organizing operations in a more decentralized way as contingency models suggest for organizations with rapidly changing environments (Lawrence & Lorsch, 1967) could cause such organizations to be more resilient and prepared to handle changes.

Contingency models are criticized, however, for the difficulty inherent in defining main situational variables such as environment, technology, and size, in addition to difficulty relating structure to performance (Dastmalchian, 1984; Warner, 1983). These difficulties do not, however, necessarily mean that situational factors should be brushed aside. Rather, it could be argued that such models have the potential to be adjusted and more industry dependent to match high-risk industries.

Change management theories, for the most part, concern types of change other than large-scale technological change. To a large degree, these theories handle larger organizational changes such as a new mission or changes in strategy, leadership, and culture. These theories, however, are among the main theories in the field of change management, and elements from these theories often seem to be used in smaller changes as well as larger changes (Ghoshal, 2005). Furthermore, theories on how to manage changes in organizations are arguably just that: theories. The academic literature on management has questioned the influence of management theories on management practice (e.g. Donaldson, 2002; Pfeffer & Fong, 2002). Theories such as the change management theories presented above are taught in management classes for future managers, and for this reason, the theories' underlying

philosophies are very important for management as a practice as well (Ghoshal, 2005). Unlike physical theories, social theories can change the behaviour of the recipients (Gergen, 1973). This means, for instance, that a theory on subatomic particles, regardless of whether it is right or wrong, does not change the behaviour of those particles (Ghoshal, 2005). In contrast, social sciences tend to be self-fulfilling as people can change their behaviour based on the theories that are being taught. This concept has relevance to the discussion of safety because organizations adopt management regimes based on theoretical management principles, including change management principles, which influence reporting lines and regulations (Almklov, Rosness & Størkersen, 2014). Thus, theories on safe organizational changes are of relevance for high-risk industries. If change management theories such as those above are taught to future managers, they probably will be implemented and used during periods of change. The aspect of safety in managing change for high-risk organizations should, for this reason, be a part of the academic change management discussion.

1.4 Human-centred approach in development and implementation of new technology in the oil and gas industry

Today, new technology is, more or less, being constantly developed, and this technology should be designed for its expected users. For this reason, human-centred design emphasizes both the active and systematic participation of end users, and stakeholders in the technology development processes (Pascal, Thomas, & Romme, 2013). In other words, both the technology and the users should be within focus during development, or as Norman (2013) stated, "Good design starts with an understanding of psychology and technology" ("Human-centered design," para. 3). A lack of the connection between technology and psychology has the potential to result in human error (Reason, 1990). For instance, a person with an incorrect understanding of how to use the technology is likely to err when using it

(Sheridan, 2008). For this reason, when designing new technology for industrial processes, certain principles concerned with human performance and human reliability, or "rules of thumb" are relevant. Examples of such principles are allowing for human variability, providing information in a way that is compatible with how the human brain represents and thinks about the world, and ensuring that the status of equipment is visible where and when users are likely to interact with it (McLeod, 2015). Factors such as these, in addition to organizational factors, are regarded as so important that the Petroleum Safety Authority (PSA) has articulated that human and organizational conditions must be paid proper attention, and that the interaction between humans and organizations must be optimized with technical solutions (PSA, 2011). For this reason, ensuring a project is properly planned and that the development of the project includes these aspects in high-risk industries is of great importance.

When designing technology in the oil, gas, and process industries, human factors analyses, such as function analyses, task analyses, and job analyses, are recommended in order to provide for human reliability (Jernæs et al., 2005; McLeod, 2015; Norsok, 2004; PSA, 2011). Reports indicate, however, that even though such human factors analyses are conducted, they tend to be conducted in a late phase of the process (Jernæs et al., 2005). Furthermore, these findings indicate that in general, a strong focus is placed on technical safety in technological development projects, and technical analyses are seen as essential. Analyses regarding human factors and human reliability do not seem to be an equally natural part of the risk analyses performed within the offshore oil and gas industry (Aas & Skramstad, 2010; Skogdalen & Vinnem, 2011; Sætren, Hogenboom, & Laumann, submitted; van de Merwe, Øie, & Gould, 2012).

The Norsok standard S-002 (2004) applies to the design and modification of equipment for offshore drilling and is therefore applicable to this project. This standard

presents the requirements for design and systematic management within project development and design processes related to work environment. Further, the standard is intended to serve as reference in the authorities' regulations and replace oil company specifications. It consists of several aspects in regard to the design, modification, and upgrading of installations for offshore drilling production such as experience transfer, job hazard/risk of occupational injuries, ergonomic/human factors in work systems, human-machine interfaces/human factors, and so forth. The Norsok standard S-002 specifically recommends human factors analyses, such as functional analysis and task analyses, as part of the design process to ensure a human-centred approach that provides for human reliability and minimizes human error. The standard uses ISO 11064-1 as a normative reference in the section of the standard concerned with ergonomics and human factors within work systems in the driller's cabin. ISO 11064-1 (2000) is part of an international standard developed for designing control centres and optimal systems by focusing on human centred design, integrating ergonomics in engineering practice, user participation, error tolerant design, feedback design, and task analysis at every step of the process.

The design process described in ISO 11064-1 is divided into five main phases from A to E: *Phase A – Clarification*: at this stage, the purpose and background material should be clarified; these elements include the context, resources, and the constraints of the project. *Phase B – Analysis and definition*: at this stage, an analysis of the functional and performance requirements of the system is advised. *Phase C – Concept design*: in this phase, how to develop initial designs, such as displays and communications interfaces, should be described in order to meet the needs identified in Phase B. *Phase D – Detailed design*: at this stage, detailed design specifications necessary for the project's construction, its content, its operational interfaces, and its environmental facilities should be developed. *Phase E – Operational feedback*: at this stage, a postcommissioning review should be conducted to

identify successes and shortcomings in the design in order to positively influence subsequent designs. Throughout this process, human factors analyses are recommended as tools to achieve a human-centred approach.

1.4.1 Human factors in design

Human factors in design could be defined as follows: "the influence the design of technological systems and the working environment has on the ability of people to behave and perform safely and reliably without putting their health and safety at risk" (McLeod, 2015, "Introduction," para. 3). Another way to see human factors is to say that human factors are concerned with the development of novel systems in areas such as usability and safety (Boring & Bye, 2009). Several analyses are alternatives in such development, and choosing the best analysis requires an understanding of what the specific goals of the analysis are (Leonard, Jacko, & Sainfort, 2004). Many human factors issues require a basic methodological intervention; however, a higher level of sophistication and complexity requires some preparation and planning in regard to deciding which methods should be used in combination. Additionally, a technological development project probably needs to undergo several iterations of the method selection processes (Stanton et al., 2013). In most standards and guidelines, such as the Norsok standard and the PSA regulations mentioned above, conducting a minimum of function and task analyses are regarded as important. A function analysis can be defined as "an analysis of the basic functions performed by the 'system' (which may be defined as human-machine, human-software, human-equipment-environment, etc.)" (Wickens, Lee, Liu., & Becker, 2004, p. 38). In other words, a function analysis seeks to understand the scope of the system or the product (Leonard et al., 2004). A task analysis, on the other hand, is one of the most important tools in human factors and can be defined as "the study of what an operator (or team of operators) is required to do, in terms of actions and/or cognitive processes, to achieve a system goal" (Kirwan & Ainsworth, 1992, p. 1). In

the world of task analyses, several options are available (Kirwan & Ainsworth, 1992; Stanton et al., 2013); however, a few basic elements are essential to any task analysis, which include defining the purpose of the analysis and the type of data that will be required, collecting data about the task, have the task's data summarized, and analyse the task data (Kirwan & Ainsworth, 1992; Stanton et al., 2013; Wickens et al., 2004).

1.4.2 Theoretical discussion on how human factors analyses could promote safety or if such analyses are superfluous in complex high-risk environments

Human factors is concerned with the interaction between humans and systems, and this field provides many analyses that give insight and understanding into how to develop good systems for humans to operate within (Leonard et al., 2004; Stanton et al., 2013). Human factors methods, however, do not seem to reveal some elements. For instance, human factors analyses might not be appropriate when seeking to understand the complexity of the systems since such analyses do not necessarily provide thorough information regarding how functions and entities in a complex sociotechnical system interact and depend on each other. Information that human factors analyses provide concern end users, tasks, interface, function, mental workload, and so forth. Aspects such as management, organizational elements, and interactions are less ensured. Most human factors methods focus on the operator and the operator's interaction with the system. The methods do not take into consideration the complexity of the systems, such as interorganizational cooperation, technological complexity, dynamic complexity, and so forth (e.g., Hollnagel, 2012; Salmon, Walker, Goode, & Stanton, 2016). For this reason, human factors analyses have been criticized for being linear and designed for a stable environment, and that when used in a complex, dynamic system, the findings might not be relevant for long as environmental factors have the potential to change (Dekker, 2011; Hollnagel, 2012; Rasmussen, 1997). If safety and maximizing human and system efficiency on an operational level is what one wants to more closely examine,

however, human factors methods could still be recommended. The different analyses of human factors methods are developed for different purposes, and so choosing a method or set of methods that are relevant for what is being examined is important. Another aspect of human factors analyses is that human factors problems can be unpredictable, and the systems within which these problems come into being might be complex (Stanton, 2013). Therefore, such analyses are never 100% reliable. The roles of such analyses, however, seem to be misunderstood by system designers and managers. The tendency amongst these designers and managers is that they trust the results of the analyses too much and fail to recognise potential limitations, such as unanticipated behaviours that have the potential to lead to system breakdown (French & Niculae, 2005).

Furthermore, human factors analyses have been criticized for being sequential and, for this reason, not appropriate to use in complex contexts because major accidents do not happen sequentially (Dekker, 2011; Hollnagel, 2012; Rasmussen, 1997). However, even though major accidents do not happen sequentially, human factors analyses are arguably important in high-risk organization. First, human factors can be considered tools that could prevent the most probable hazards. For example, using task analyses could provide a safe basis because they can help predict what actually can be predicted even though unexpected incidents might occur. Second, the analyses put the operator in the centre, and by this the analyses can be said to provide a bottom-up element that enables the end user to be the expert, which is an important aspect in HRO (Weick & Sutcliffe, 2007). Third, human factors analyses could increase the anticipation on which unwanted incidents that may potentially occur; such increased anticipation is due to making people focus on elements of human factors analyses. For this reason, the analyses could be seen as a means of broadening the perspectives of personnel, training them to see unwanted incidents, and enabling them to be alert and mindful throughout the workday, all of which is in accordance with HRO.

However, human factors analyses will perhaps not be appropriate to complete the last two HRO principles regarding containment. Further, achieving operator anticipation will probably not help awareness of latent failures that could be a product of management decisions, for example (Reason, 1990). It could for this reason, be argued that the different levels of analyses in organizations, such as culture, complexity, and operator levels, should co-exist to maximize the safety level. The solution should not be leaving one level out (e.g., human factors) simply because the analyses for this level do not cope with all relevant aspects on all levels. For this reason, additional analyses should be conducted to ensure safety on other levels in a high-risk organization. In other words, human factors analyses could help track small failures, resist oversimplifications, and become sensitive to operations, which could lead to human factors analyses serving as a tool to achieve anticipation in everyday work situations which are in accordance to the first three principles in HRO.

2.0 Methods

This PhD project has evolved and changed over time as different aspects have influenced it. In the beginning, for instance, this PhD project had a slightly different plan regarding data collection and what data was needed. For this reason, a survey concerning organizational change was conducted twice in addition to observations and interviews. As the project developed, I realized that the aspects I wanted to explore more in depth required a pure qualitative approach. For this reason, the analyses of the data are qualitative analyses using grounded theory based on interviews, observations, and the change project's documentation.

2.1 My professional background

In order to provide transparency in this qualitative study, I frame my background and experience next. My in-depth education in qualitative psychological research was received while working on my master thesis in organizational psychology on organizational change

processes as well as during the work committed in the current PhD project. After finishing my master degree, I gave lectures in qualitative research, mainly in the field of grounded theory and organizational psychology at the university where I worked as an assistant professor. Additionally, I supervised students pursuing master degrees in psychology mainly on qualitative master projects. Before entering the world of qualitative research in organizational psychology and safety psychology, I did my bachelor degree in organizational psychology based on quantitative work using a survey. Prior to this, I completed a bachelor degree in hotel management using quantitative research methods and worked for some time at different hotels in different roles, including management.

2.2 The (eLAD) project

The eLAD project was the paramount project of which the current PhD project is a part. The eLAD project is financed in part by the Norwegian Research Council and in part by the oil industry. Three parties collaborated in this project: International Research Institute of Stavanger (IRIS), Christian Michelsen Research (CMR) in Bergen, and Institute for Energy Technology (IFE) in Halden. These institutes are linked through "Energialliansen", with the intention to utilize complementary competences. The objective of the eLAD project was to build laboratories and facilities that could be used as tools for developing, designing, evaluating, and optimizing future e-centre based working processes, software tools, and automation processes and thus to provide a unique environment for safe experimentation throughout the planning and execution of drilling operations. This project expected PhD candidates to conduct research concerning human performance and factors that typically influence human performance, and that this research was specified and defined in theoretical and operational terms. Situational awareness, workload, trust, and teamwork are examples of relevant variables and measures in human-machine system environments, in addition to the consideration of organizational characteristics, and operating conditions.

2.3 The context of this case study

Yin (2009) defined a case study as "an empirical inquiry that investigates a contemporary phenomenon in depth and within its real-life context" (p. 18). By following an implementation process on an oil- and gas-producing installation over several years, this project falls within the category of a case study. The process was followed both in depth and within its real-life context. As a case study, the context of this project is important.

This study was conducted within the context of the development and implementation process of a new automated drilling technology. The geographical location for this study was an offshore oil- and gas-producing installation where the implementation took place. In addition to offshore observation, the study involved onshore meetings and observations. For a thorough description of the context, see Paper I (Sætren & Laumann, 2015) and Paper II (Sætren, Hogenboom & Laumann, submitted).

2.3.1 Description of the technology

The technology that is the focus of this study was a modification of previously manually driven technology that was automated. Additionally, this complex technology was intended to be used to reach targets that were, when using conventional drilling technology, previously undrillable. For the end users, this new technology meant a shift in cognition, routines, and procedures compared to the conventional drilling techniques they were used to. Regarding the technology, I am prohibited from describing it in more detail since doing so would reveal the specific technology in question. If the technology were disclosed, the study's informants could possibly be revealed.

After the technology was implemented and used a couple of times, the platform was evacuated due to an incident that occurred while this particular new technology was in use. The reason for the incident leading to the evacuation was investigated, and nothing was found to be wrong with the technology in itself. The incident was, however, found to be linked to

the use of the new technology. In other words, the investigation indicated that the use of the technology was at least part of the reason for the serious, unwanted incident that resulted in an evacuation of the platform. This incident was regarded as rather hazardous and had the potential to result in a major accident. Again, due to confidentiality, I cannot refer specifically to the incident in question.

2.4 Data collection

The data collection took place over a period of approximately four years, and a triangulation of interviews, observations, and documentation concerning the development and change process was used. The documentation mainly involved internal reports such as safety analyses. The reports cannot be described more closely due to confidentiality.

2.4.1 Interviews

All interviews were either carried out face-to-face onshore, via video conference, or on the telephone. The interviews were conducted with only the informants and interviewers present; no one else could listen to the conversations. The interviewers were the authors of the papers. Additionally, some master students were present at some interviews for projects related to their master degrees. In all, 43 in-depth, semistructured individual interviews (Kvale, 1997) were completed for this project. All of the interviews lasted approximately 1 hour and were recorded for transcriptions and further analysis.

The interview guides were semistructured with open questions. This format allowed the informants to freely tell about different aspects of their daily work as well as the change process on a more concrete level; they were also able to speak about how they perceived the change.

The interviews for Paper I were divided into different topics, such as general questions concerning their work processes and what they talk about during breaks, details of the changes, how these changes would affect their work situation, how the team worked, and how

they explained the new technology with its advantages and disadvantages. For example, the questions included the following: Can you describe the changes that are to come? What are your expectations? How will the changes affect your work routines? Are there any benefits/disadvantages? How did you feel when you were told about the changes? Why? Do you see any safety hazards that could be a result of going from manual technology to this new automated technology?

The participants were selected based on their relevance to the project. In order to provide in-depth information, the study resulting in paper I followed one crew prior to, during, and after the implementation process of the new technology. Additionally, insights from other crews and the perspective of management was considered an important component of the study. For this reason, drillers and assistant drillers from the other drilling crews at the platform as well as managers, both onshore and offshore, were also interviewed. This strategy was chosen in order to obtain the best possible insight into the processes at different levels.

The interviews for Paper II included topics such as the informants' work processes with regard to developing the new technology, safety aspects, and how the engineer designers worked regarding the end user to whom they were developing the technology. Questions included in this paper included the following: How was a typical workday during the development phase of the new technology? How did you receive information? How were decisions made? How did you receive feedback on your work? Which analyses were performed in relation to safety? What was tested in respect to safety? How did you include user friendliness in your work?

Participants in this study were selected based on their relevance to the project. For this reason, those interviewed were engineers developing the product and members of the project group who were responsible for the development process and the final product.

Participation was voluntary for all informants, and those who accepted the invitation to participate were interviewed. Most of the interviewees were male due to the vast predominance of males in the offshore drilling segment.

In the first and second round, 15 informants were interviewed. These two rounds were conducted during the introduction of the new automated technology but prior to the implementation. Data was first collected at the 2-day introduction meetings where the crew were taught how to rig the equipment and later via video-conference from an onshore location when the crew were at work offshore. For the first data collection, the informants were situated at a hotel for 2 full days for this training. My co-interviewer and I were staying at the same hotel. We attended the meetings and had the opportunity to mingle with them during the stay as well as conduct interviews when suitable. The second round of interviews was conducted approximately 4 months later while the informants were waiting to use the technology in real life. This round of interviews was conducted via video-conference while the crew was working offshore.

For the third round of interviews, seven of the end users that had already been interviewed were chosen since they were considered the most relevant candidates for further interviews. Their relevance was due to the fact that they had worked with the technology once. Additionally, one new informant was included in the third round. The third round of interviews was carried out just after the technology had been in use in real life, approximately 8 months after the introductory seminar for the new technology.

The fourth round of interviews was carried out over a period of 5 months and began shortly after the evacuation of the platform had taken place. For this round, some informants were called at home during their off-period in order to talk to them as close to the time of the incident as possible. In this round, 13 interviews were conducted, and all of the informants had previously been interviewed.

The fifth and final round of interviews was of the engineers developing the product as well as the project group responsible for the development process and final product. These seven interviews were done over a period of 2 months.

In all, the data collection was conducted over a period of approximately 4 years.

Table 1

Numbers of interviews conducted and with whom during the five rounds of data collection

	Drillers / asst. drillers	Crew members	Management	Developing engineers / project group
Round 1 and 2 introduction and prior to implementation	4	6	5	
Round 3 after implementation	3	5		
Round 4 After evacuation	8	4	1	
Round 5 technology development				7
In all	15	15	6	7

Transcriptions of the interviews were performed mainly by me. The transcriptions of the seven interviews for the second paper, however, were conducted by one of the coauthors. These were the seven interviews in round five. I did read the transcribed manuscripts while listening to the interviews as a quality check, and we were both present during all of the seven interviews. All transcriptions were made based on an assumption that the meaning of the interviewees' statements were the essence of the content. For this reason, the transcriptions did not include sounds such as "ehh", but instead the transcribed content focused on the words that were spoken as well as the sentences. Where found relevant, however, sounds that demonstrated moods (e.g., laughs) were included to show the atmosphere and tone of the interviews.

2.4.2 Observations

Because I wanted to gain knowledge based upon direct contact between researchers and the informants' daily work situation, participant observations were conducted (Brannan & Oultram, 2012). Participant observations were performed by one of my coauthors and me, located onshore with the crew attending the 2-day introductory seminar to the new technology. During this part of the observation, the focus was to gain knowledge about how the information concerning the new technology was brought to the end users. Here, we attended the meetings, mingled with the crew during the breaks, and ate all meals with them. A few months later, I conducted a 3-day participant observation on the offshore oil and gas installation. An observation guide was developed beforehand to help me remain focused during the offshore observations. While observing offshore, I followed the crew during their normal work hours, I participated in their normal work, and I ate all meals with them. The focus was generally divided into two parts. One part of the focus was on the work conditions for and within the crew; the other part was more specifically related to the driller and assistant drillers regarding their work situation and workload. The offshore observations, however, were not made while the new drilling technology was in use for safety reasons. This could be regarded as a limitation to this study, but it could also be argued that to get to know the regular working conditions was a benefit because I was able to understand the normality of the crew's everyday work. Offshore contexts are rather different from most onshore work situations, and for this reason, I determined it would be important to experience these conditions first-hand. Even though I was prohibited from travelling offshore more than once, I was able to comprehend the descriptions given during the interviews on another level since I had experienced the offshore conditions.

2.5 Grounded theory

Grounded theory is both a qualitative scientific approach on how to collect data as well a method of data analysis. When conducting a grounded theory study, both how the data are collected and how they are analysed are, therefore, important. Grounded theory does not base the analysis on a particular theory, but instead the aim of a grounded theory study is to generate theories that are grounded in the collected data. Hence the name. For this reason, the researcher's task is not to produce a perfect description of the area studied but rather to develop theories and conceptual explanations that account for much of the relevant behaviour of the informants and topic being researched explored (Kenealy, 2012; Länsisalmi, Peiró, & Kivimäki, 2004; Strauss & Corbin, 1990).

The basis for grounded theory is a scientifically inductive qualitative research approach. This approach is not a linear method, and both data collection and data analysis occur, in part, simultaneously (Strauss & Corbin, 1990). Commonly within grounded theory, the researcher will not conduct a comprehensive literature search beforehand concerning the topic to be explored, and this feature is one of the ways grounded theory differs from other research methods (Länsisalmi et al., 2004; Glaser & Strauss, 1967). This aspect of grounded theory, however, is not entirely agreed upon within grounded theory theorists today. For instance, the importance of knowing the literature in order to stimulate research and recognize contradictions or ambiguities in published studies has been discussed. To know the topic and understand what is needed for further development is also viewed as an important part of grounded theory (Corbin & Strauss, 2015). Furthermore, greater grounding in the literature arguably helps prevent bias because it expands the researcher's understanding of the phenomenon being studied (Morrow, 2005). While an examination of the literature may or may not be a necessary practice in grounded theory, one thing that grounded theory theorists tend to agree on is that in grounded theory, there are most often no hypotheses or theories to

be verified; instead the results are all grounded in data collected from scientists who are exploring the topic (Länsisalmi et al., 2004; Strauss & Corbin, 1990). Another important aspect of grounded theory is that while analyses are conducted, a constant comparison method is used in which the researcher compares incidents in data with other incidents for similarities and differences. Further, triangulation is rather common in grounded theory. The collected and analysed data are often of different kinds, such as interviews, observations, and documents (Corbin & Strauss, 2008). When analysing the data for this project, the software QSR NVivo 9 was utilized to aid in organizing and examining the data that were collected (NVivo 9, 2010a; NVivo 9, 2010b).

2.5.1 The coding process

Three main steps are involved in the coding process of Strauss and Corbin's (1990) grounded theory: open coding, axial coding, and selective coding. The three steps are, however, rather artificial and do not necessarily take place in separate stages. Data are also collected during data analysis and this combination is an example of the unlinearity of grounded theory as a method (Strauss & Corbin, 1990). During the two studies in which I used grounded theory (see Paper I, and Paper II), the coding processes were similar and are, therefore, explained in general.

Open coding is "breaking data apart and delineating concepts to stand for blocks of raw data" (Corbin & Strauss, 2008, p. 198). I performed open coding in accordance to the guidelines of Strauss and Corbin (1990) after initial interview rounds for each study. When conducting open coding, "data are broken down into discrete parts, closely examined, compared for similarities and differences, and questions are asked about the phenomena as reflected" (Strauss & Corbin, 1990, p. 62). This process implies that I labelled smaller parts of the raw data from the transcribed interviews, sometimes no more than a sentence, to keep close to the data. Through this process, the data were defined and labelled as the collected

data were studied. One of the benefits of using grounded theory is that data are analysed simultaneously as they are collected. This concurrent process gave me the opportunity to label conducted interviews using open coding and gain a deeper understanding of the topic, which enabled me to immediately adjust the following interviews in accordance to the findings. The labels that were generated during open coding were compared. This act of comparing the data is the process of axial coding. Open and axial coding go hand in hand because breaking up the raw data to informative parts (open coding) is one part of the analysis process, yet these parts needs to be compared and connected, which is where the axial coding process comes in. Axial coding is: "the act of relating concepts/categories to each other" (Corbin & Strauss, 2008, p. 198). In this stage, I organized the labels from the open coding into categories that I found by comparing data in order to explore the connections between them. This constant comparison of data is a central element in grounded theory analyses. By employing this method, I was able to form a more abstract understanding by linking what was found in the data. During this process of linking labels, I was also elaborating on them as the labels became explanatory descriptions of the higher abstract categories.

The final step of the coding process, selective coding, was conducted at a later stage of the study. Open and axial coding was conducted for the first rounds of interviews; however, I chose to wait to conduct selective coding because of the importance of gaining as much information concerning the phenomenon as possible and letting the data mature while performing lower-level, abstract coding. Through the classification process of axial coding, I discovered concepts that were compared. This comparison is selective coding which is a process not much different from axial coding, but the data has been worked through thoroughly and has matured over a longer period of time. Additionally, selective coding was performed at a higher level of abstraction than the axial coding because it was performed on categories derived from codes that were already interpreted and not directly from raw data.

The final outcome of the process of selective coding is the core category, which is defined as "the central phenomenon around which all the other categories are integrated" (Strauss & Corbin, 1990, p. 116). Additionally, this step involved making the model that showed the relationships between the categories.

2.5.2 Memos, theoretical sampling, and theoretical saturation

Memos are written throughout the research as notes for the researcher to keep track of the process of analysis. I wrote memos, for example, that included my thoughts while collecting and analysing data. Memos facilitate the theorizing part of grounded theory and basically involve writing down ideas concerning the codes and theoretical relationships between them. Recording memos made it easier for me to keep track of the thoughts that arose as I went through the process, developing this study from scratch and ultimately creating the core category (Strauss & Corbin, 1990).

Theoretical sampling is the collection of material in order to further the analysis. Material could, for instance, include additional interviews or observations and could involve reading internal documents and literature. This step could be explained as a "where next" in collecting data, "for what" regarding the analysis, and "why" in the memos (Strauss & Corbin, 1990).

Theoretical saturation is a goal of grounded theory and refers to the point in which the theoretical sample for each category is reached. Theoretical saturation is achieved when three factors become true: (a) no new relevant data emerge, (b) the category development is dense, and (c) the relationship between the categories are interpreted to be well established (Strauss & Corbin, 1990). Regarding the first study, I will argue that theoretical saturation was reached. I had access to interviews throughout the analysis process and was able to go back to informants to discuss preliminary results. In the second study, however, the number of informants I had access to was limited. The group of selected informants did not consist of

many people, and time was a limited resource for the interviewees. This created a restriction on how many times we were able to interview each of the informants, and each of the seven informants were interviewed once for approximately 1 hour. The number of informants could be regarded as a limitation; however, I argue that those chosen were representative. Additionally, the project had been closely followed for years, and the informants were a part of this setting, which I knew well at the time the interviews were conducted.

2.6 Methodological discussion

What grounded theory is, and should be, is contested, and the three primary views on grounded theory are based mainly on three different stages in the development of this method of analysis. This qualitative research method was developed in 1967 by Glaser and Strauss. Since then, this method has developed in different directions. Glaser maintained the basic model theory that was established in 1967, but Strauss connected with Corbin (Strauss & Corbin, 1990) and modified some of the original ideas. Later in the 1990s, Kathy Charmaz entered the scene with yet another way to ground grounded theory in a social science. Already, through the titles of their books, one can see underlying differences in their ontological standpoints. The first book by Glaser and Strauss (1967) is called "The discovery of grounded theory" and indicates an objective reality that is ready to be discovered, explored, and understood. "Discovery" does imply that a stable underlying structure exists and is waiting to be revealed to the scientist examining it. This title also suggests an ontological point of view that simply accepts the existence of an objective reality. In the book by Kathy Charmaz (2006), on the other hand, the title, 'Constructing grounded theory', indicates a different meaning. The title implies no objective reality waiting to be discovered, but rather that the reality is constructed by the individuals interacting with each other. By using the word "constructing", Charmaz takes into consideration that the scientist is a part of the results by being a part of the constructed theory, and the underlying ontological point of view is

constructivistic. The third direction in grounded theory can be said to be somewhere in between the two polarized standpoints of the positivist Glaser (and earlier Strauss) and the constructionist Charmaz. This position is represented by Strauss and Corbin, who are labelled postpositivistic (e.g., Charmaz, 2000; Denzin & Lincoln, 1994; Corbin & Strauss, 2008), and they chose a more neutral title for their book: "Basics of qualitative research".

The postpositivistic ontology of the work of Strauss and Corbin (1990) (Guba & Lincoln, 1994) is the foundation for the methodology used in this thesis. This work was aimed towards unbiased data collection, yet at the same time was intended to give voice to the informants and to represent them as accurately as possible. The postpositivistic grounded theory direction chosen for this thesis emerged from symbolic interactionism and pragmatism (Corbin & Strauss, 2008). The symbolic interactionism represents, on one hand, the interpretation people have of others' actions and their own reaction to them. In this, the response people have to others' actions is not made by the action itself but rather by the meaning they attach to it. The pragmatic viewpoint, on the other hand, includes an assumption that reality cannot be separated from the "knower" and that acts of knowing embody the knower's perspective. This concept of being open to different interpretations of the "truth" in pragmatism is not close to extreme views such as radical relativism, which claims that no version of interpretation can be proven and therefore no assumption of any of the interpretations can be claimed. One important element of the pragmatic view is that one reality can be assumed in which it is the truth for the time being, as in "this is what we know now" (Corbin & Strauss, 2008).

Generally, it could be said that qualitative research contributes to revision and enrichment rather than verification, which is more a quantitative approach. In other words, qualitative research answers different scientific questions than quantitative research (Elliot et al., 1999), and qualitative research leads to a different kind of knowledge (Morrow, 2005).

All scientific work, however, goes through a process of interpretation, whether the research is quantitative or qualitative. If, for instance, a survey is compared to an interview as a data collection method, the interpretation is more greatly influenced by the respondent in a survey. In an interview, interpretations or even the misunderstanding of questions and answers can be talked through. During a survey, the scientist most often does not have this opportunity in the same way and while the actual data collection takes place. While filling out a survey, respondents tend to interpret the questions, and from a constructive perspective, questions on a survey could be interpreted in many ways since no objective reality exists. The degree to which an objective reality exists is thus an important topic to reflect upon while for instance creating questions for a survey.

Further, the degree of objectivity depends on what the research topic is. Within the social sciences, many topics to some degree are up for interpretation, especially if they concern how people experience certain events. Other topics might be of a more objective nature (e.g., following a process to find out what is happening) and do not necessarily investigate people's experience. How qualitative interview data are collected is also a factor that must be taken into consideration. This factor would involve, for instance, how the interview guide is built and which questions are asked. Arguably, the more concrete the questions regarding what happened during an incident, the more objective the reality, and any questions concerning how the informants felt during the incident reveal a more subjective, and therefore more constructive, ontology. The data used in this analysis consisted of both objectivist and constructivist questions. Some questions were more concrete, such as "What topic did you discuss at lunch with your colleges?" and "What caused the incident?" or "Which mishaps did you have? Please explain the actions of those involved". Additionally, follow up questions were more linked to a constructivistic approach, such as "What did you

think when you realized the platform needed to be evacuated?" and "What did you think when you heard you were to get new drilling technology?"

Another critical part of grounded theory is the principle of induction. Intuitively, the idea that knowledge can be built from the bottom up seems right, and this notion is at the core of grounded theory. Building scientific knowledge based on expressed opinions, however, could be considered problematic from a scientific point of view. As early as the 17th century, Hume demonstrated that the principle of induction is logically invalid: just because something has happened before does not mean it will happen again. The principle of induction cannot, therefore, prove or verify inherent orderliness that has validity for future events (Ringdal, 2007). The assumptions that postpositivistic grounded theory are based upon, though, reflects that the interpretation of the world changes, and that the reality of the here and now is assumed.

2.7 Validity

Several approaches can be used to evaluate the quality of qualitative studies (e.g., Elliott, Fischer & Rennie, 1999; Kvale, 1997; Meyrick, 2006; Yardley, 2000). Yardley (2000), for instance, uses three principles for assessing validity. The three principles are (a) sensitivity to context, (b) commitment rigour transparency and coherence, and (c) impact and importance. Another approach is from Elliot et al. (1999), who refer to seven guidelines shared by both qualitative and quantitative research as well as an additional seven guidelines especially pertinent to qualitative research. The first seven are explicit scientific context and purpose, appropriate methods, respect for participants, specification of methods, appropriate discussion, clarity of presentation, and contribution to knowledge. The seven guidelines more directly related to qualitative research are owning one's perspective, situating the sample, grounding in examples, providing credibility checks, coherence, accomplishing general versus specific research tasks, and resonating with readers.

Within the context of the current scientific work, validity is established as important from several sources (Elliott et al., 1999; Meyrick, 2006; Yardley, 2000) and is connected to establishing a transparent process for the reader. For instance, the first principle of Yardley (2000), sensitivity to context, refers to the need for scientists to show sensitivity to the context in which the scientific work is situated. This principle could be compared to the first factor of both qualitative and quantitative research (Elliott et al., 1999), "explicit scientific context", and the first factor specifically directed towards qualitative research, "owning one's perspective". In the current work, my professional background was described in order to introduce my previous experience and to provide a description of the eLAD project. Additionally, a theoretical background was given to provide a theoretical context and demonstrated an awareness of the existing literature. These elements are viewed as important for allowing the reader to gain an understanding of the theoretical framework in which this scientific work is based. Furthermore, a thorough explanation of the scientific philosophical context was presented, which is mentioned by Yardley (2000), Meyrick (2006), and Elliot et al. (1999) as crucial for interpretation of data.

Additionally, providing a description of the sociocultural context is important. This context involves where the collection of data took place and who the participants were; such context has been provided in this case study. Providing this context is related to the second qualitative guideline of Elliot et al. (1999), "situating the sample". Nevertheless, the trustworthiness of the study could be questioned because of the lack of detailed descriptions of the particular technology that was developed. The technology itself, however, was not investigated in this research project, but rather the process of developing and implementing automated technology in connection to safety. For this reason, I would argue that a detailed description of the technology is not necessary for the results to be applicable for other contexts of technology development and implementation.

Regarding the criteria for thoroughness in data collection, analyses, and reporting, the literature generally agrees on the importance of giving insight into these elements within qualitative projects (Elliott et al., 1999; Meyrick, 2006; Yardley, 2000). Yardley (2000), for instance, mentions commitment, rigour, transparency, and coherence while Elliott et al. (1999) are concerned about grounding in examples and providing credibility checks. Regarding the current research, I have been personally involved in this PhD project from the earliest planning through the finalization of this thesis, which demonstrates what Yardley (2000) calls commitment. Further, the selection of participants was based on the phenomenon the study was intended to explore, and each participant was relevant to the project. Additionally, the data were collected by following the informants over a longer period of time, which enhances the credibility of qualitative research (Morrow, 2005). Information regarding the informants, for instance, how representative the sample is, is also important to reflect upon, according to Meyrick (2006).

As part of analysing the data, providing credibility checks is also considered important (Elliott, 1999; Morrow, 2006), and such checks in this case included asking end users about the preliminary results and verifying the findings through discussion amongst the interviewers. Further, I sought to present the findings in a coherent way using the structures of the findings to map the interactions between the categories, which Elliott et al. (1999) stresses as important. Transparency is related to the descriptions of the scientific process (Meyrick, 2006; Yardley, 2000). In this case, by keeping close to the data throughout the collection and analyses and by providing a thorough description of the methodological processes within this methods section, I believe this thesis has maintained transparency.

Other criteria for validity, such as ethics and contribution to knowledge (Elliott, 1999; Yardley 2000), will be demonstrated in later sections of the current thesis. Ethics will be

presented next within the methods section, and implications and contributions will be discussed later in the general discussion.

2.8 Ethics

Prior to commencing any research activity, the necessary agreements with NSD were arranged to ensure ethical practice during this research project. These agreements were to ensure anonymity and confidentiality of the informants and facilities. When conducting observations or interviews, the sound recordings were only available to me and my fellow interviewers. The written transcriptions were made without any personally identifying elements such as the names of interviewees or the installations, and these transcripts were not available to anyone other than the authors. Furthermore, all three papers included in this thesis were approved by the principal organization. Additionally, all participation was voluntary and the informants agreed on participating in the study projects.

One important ethical consideration of this research, which is admittedly difficult to assess, is whether the scientific process was a source of strain on the participants and whether the change processes were made more difficult as a result (Burke, 2002). As I consider the theme of the interviews, the interviews themselves, and the observations, I believe they were not a strain for those involved. The informants did not show signs of stress in the context of data collection; the conversations were generally easy going, the participants were willing to take part in the data collection more than once, and they appeared reflective. Ensuring that the informants had a good experience during the interviews and observations was important (Kvale, 1997). Over the years, I came to know the informants rather well, and I regard them as trustworthy. I believe they would have informed us if there were anything they thought we should have been aware of. Additionally, the informants were not chosen by the organizations where they worked, and they were not pushed by their organizations to participate. All participation during the project was voluntary and properly arranged for by

the organizations. Such arrangements included providing rooms and time for the employees to be interviewed as well as allowing for offshore observations to be conducted.

All informants agreed to participate in the project after receiving information both orally and written, and those interviewed agreed to allow the interviews to be recorded. Furthermore, all informants were informed that they could withdraw during the project at any time. Additionally, I was available for any questions or comments from the informants and gave all of the informants my contact information. I was not contacted by any of the informants during the course of this project.

3.0 Findings

This section will provide a summary of the main findings of the three papers. For a detailed presentation of the findings, please see the respective papers. After the summary, the findings will be discussed in the context of the theoretical framework presented in the introduction, and then contributions and further research suggestions will be presented. Finally, a conclusion will bring this thesis to completion.

3.1 Paper I: Effects of trust in high-risk organizations during technological changes

The purpose of this study was to investigate a drilling crew's acceptance of a modification to their drilling technology and how this change process would affect the perceived safety of their drilling activity.

In all, 23 interviews were conducted with three drillers, four assistant drillers, 11 various crew members from one crew, one tool pusher, one technology-coordinator, one technology manager, one platform manager, and one drilling operation manager. All of the interviewees were males due to the vast predominance of males in the offshore drilling segment. Interviews were conducted face to face onshore or via video conference when the informants were at work offshore. Semistructured interview guides were used. Additionally,

offshore and onshore participative observations were completed. Grounded theory was used to analyse the data.

This paper reported trust in the change process and how the process affected perceived safety and technology acceptance. The period prior to and during the implementation process was compared to the model of readiness to change (Armenakis & Harris, 2009). This study found that *trust in the change process* was the core category, which was a result of both *general trust* (i.e., trust in management, trust in colleagues, trust in procedures, and trust in technology) and *context specific trust* (i.e., trust in the decision, trust in the competence, and trust in the consequences). Furthermore, the trust in the change process affected two outcome categories: *technology acceptance* and *perceived safety*.

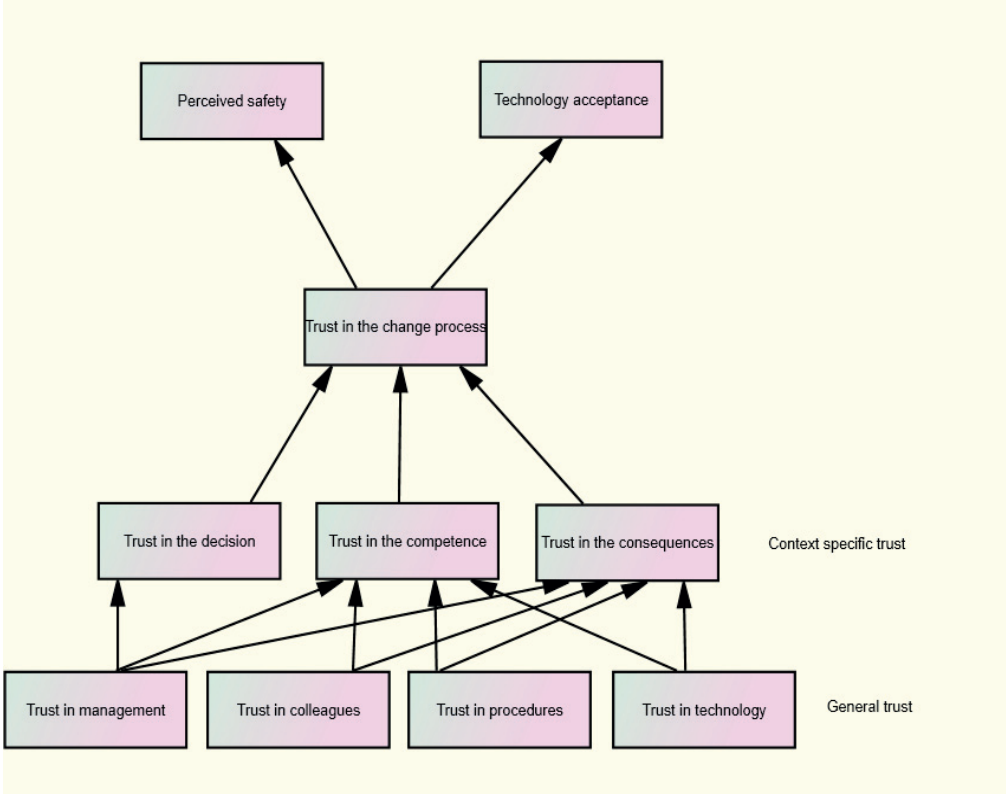

Figure 1. Trust in the change process (Sætren & Laumann, 2015, p. 135).

It was found that there was a match between how the crew were ready to change and their high degree of acceptance of the new technology. However, the crew's positive attitude towards the new technology might have given them a perception of safety that was unfortunate from a safety aspect. This perception of being safe might have led to a loss of the ability to create images that corresponded with the true state of affairs. High trust, in other words, seemed to cause a low-risk perception. Too much trust, which led to a low-risk perception, in conjunction with a nonquestioning culture was found to be inconsistent with HRO (Weick & Sutcliffe, 2007). This finding led to the conclusion that the concept of trust should have a more nuanced perspective regarding safety during changes in high-risk organizations.

3.2 Paper II: A Study of a technological development process. Human factors – the forgotten factors?

The aim of this study was to explore how human factors were taken into account in the development of a new type of drilling equipment. For this reason, the research question was, How can safety through human factors and human reliability analyses be ensured during the development process of an automated technology in a high-risk industry?

In this study, seven informants were interviewed who were part of a project that developed new automatic drilling technology for the offshore petroleum industry. Additionally, the informants were part of the principal project team or the engineer development team of this development process. Semistructured interview guides were used during the interviews, which were conducted via video conference or telephone. For analysis, grounded theory was used.

The theme of this paper was a natural follow-up from Paper I, in which the end users expressed trust in those developing the technology based on the assumption that the developers had in-depth knowledge of the end users' work situation and competence level.

This second paper, however, reported that insufficient human factors analyses were conducted during the development process and that the developers did not have sufficient knowledge of the end users of the technology. The consequences that arose from this lack of sufficient human factors analyses included increased costs, low user friendliness, and insufficient knowledge of safe usage and the potential risks of the technology by end users.

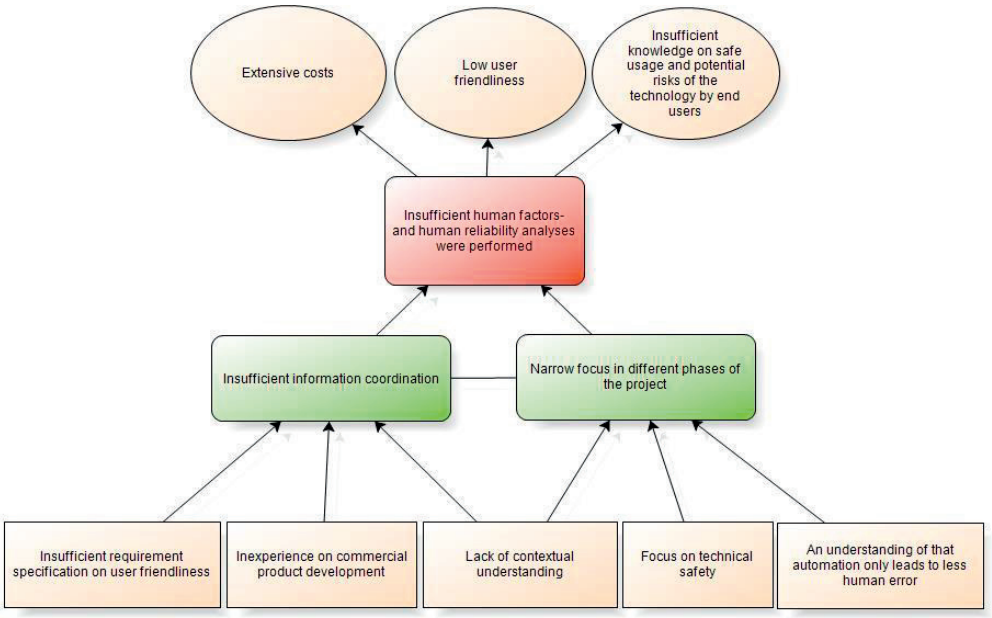

Figure 2. Effects of insufficient human factors and human reliability analyses (Sætren, Hogenboom, & Laumann, submitted).

The reasons that the insufficient human factors analyses were conducted were of interest. As the figure indicates, insufficient information coordination and narrow focus in different phases were found to be the main causes. Insufficient information coordination involved insufficient requirement specifications on user friendliness, which resulted in the engineers not knowing precisely what the customer and end users expected. The inexperience

of the engineers on commercial product development further lead to a lack of discernment regarding what level of detailed information was needed in different phases, and thus they did not ask for more information. The engineer developer's lack of understanding regarding the offshore context and who the end users were was an additional cause found to complicate the development process, and this lack of understanding was another reason the product needed redesign after implementation. The narrow focus during different phases was due to a technical focus and an understanding that automation only leads to less human error. Focus on human aspects, such as a contextual understanding of who the end users were, was found to be lacking.

The conclusion was that homogeneous top competence involving technological aspects contributed to a lack of understanding of the need for human factors analyses. Thus, this paper recommended that human factors specialists should be included from the beginning of development projects. Additionally, guidelines and standards regarding the development of new technology in high-risk industries could benefit from being more specific as to which analyses should be conducted, and why, which would help ensure that proper human factors analyses are conducted.

3.3 Paper III: Organizational change management theories and safety. A critical review.

Paper III was a follow-up to Papers I and II. Paper I looked at how technology acceptance and perceived safety do not necessarily match in the sense that safety was not ensured due to cultural aspects. Paper II looked into the same lack of safety from an earlier stage, namely, the development process. Following this, the natural follow-up seemed to be to look into *how* a change process in high-risk industries could ensure a focus on safety. Paper III was thus a theoretical comparison of selected change management theories and HRO (Weick & Sutcliffe, 2007) developed to explore safety in changes from a theoretical

perspective. The change management theories used in this analysis were Kotter's (1996) eight steps to successful change, Armenakis and Harris' (2009) readiness to change, and Cummings and Worley's (2015) step by step model, which is based on change management literature, in addition to Oreg's (2003; 2006) theory on reistance to change and the HSE's (2003) guidelines regarding changes in high-risk organizations. The change management theories were found to be leader-centric and focused on willingness to change by the change recipients in order to commit a successful change. Resistance was found to be an element that needed to be overcome. Thus, the findings were that the traditional change management theories have a focus that does not necessarily ensure safety. According to HRO, elements such as heterogeneity and a questioning culture are basic elements necessary to provide a safe work environment. Overcoming resistance was, for instance, found to be inconsistent with a questioning culture. Additionally, providing for heterogeneity to ensure a broad spectrum of opinions was found to be contrary to ensuring a willingness to change, which, for instance, included rewarding those who agree with the change and not rewarding those who question it. For this reason, a step by step guide was developed to help ensure safety during changes in high-risk organizations founded theoretically on HRO and human factors.

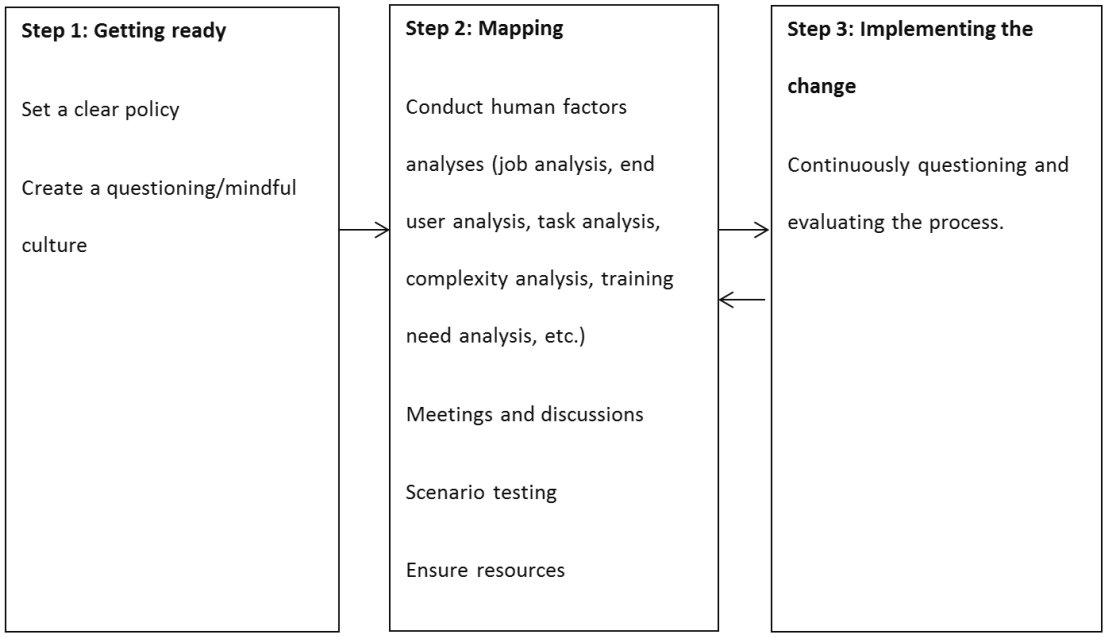

Figure 3. The steps of safe organizational changes.

This figure provides a step by step structure for accomplishing change in high-risk organizations with a focus on how safety can be ensured. Throughout the three phases, getting ready, mapping, and implementing the change, safety remains a focus through human factors analyses and HRO, which is the foundation of the cultural aspects in view.

4.0 General Discussion

The main objective of this thesis has been to explore safety during changes, or more precisely stated, how changes in high-risk organizations could be managed to ensure safety. In this section, I will relate the theoretical framework and main findings of the thesis to the industry and the research question, which is, How can changes in high-risk organizations be as safe as possible?

Through three papers, this question has been approached from different angles. The first two papers were based on empirical research, and the third was a theoretical discussion. As Paper I indicated, the readiness to change theory (Armenakis & Harris, 2009) was

followed and implemented in a positive way that resulted in acceptance of the new technology. The process seemed to be completed with satisfactory results until smaller unwanted incidents and a serious incident occurred while using the technology, which led to an evacuation of the platform. Whether this was a success or not must, in other words, be defined by the given criteria. If the criterion for a successful implementation process had been that the end users accepted the technology, this process would have been considered successful. One of the main criteria in this project, however, was that the implementation process should be completed without hazardous incidents, which was not the case. Several reasons have been given for why this was not the case, and both Paper I and Paper II discuss different aspects of why this process ended in a serious unwanted incident while using the new technology. The conclusion of Paper I was that the end users had too much trust in the change process, which resulted in a low-risk perception. The paper further concluded that the term trust should be nuanced in order to provide for a questioning culture that could have created trained scepticism in accordance to HRO (Weick & Sutcliffe, 2007). Paper II considered why the implementation process ended up in an evacuation of the platform while using the new technology and related this result to the development process, ultimately concluding that insufficient analyses were performed during this phase. Paper III looked at how HRO and human factors combined could provide safety in a model where safety was a main focus during changes in high-risk organizations.

In order to discuss how this current change process could have been as safe as possible, this discussion will first examine how behaviour on several levels resulted in a serious unwanted incident before discussing how the competing goals of production and safety might have affected the change process. Additionally, a discussion about how a more human centred development process could have contributed to a more successful outcome is presented before a discussion on whether change management theories are good enough for

high-risk industries. Finally, contributions and further research is presented prior to the conclusion.

4.1 Unwanted incidents causations

In order to understand how unwanted incidents could occur in connection with the change process, one must look at the mechanisms that generated the behaviour that led to the serious unwanted incident. In this section, I have chosen to demonstrate how different theoretical perspectives, namely Rasmussen (1997), Reason (1990), and Turner (1978), explain the causation of such unwanted incidents.

Rasmussen (1997) explained that decision making is not an isolated phenomenon, but rather that decisions are made within a certain context. Even though most work in high-risk organizations have thorough procedures, regulations, and instructions regarding how work should be done, all work situations have degrees of freedom concerning how to conduct the work. Rules and instructions are often designed for an isolated task while the real work is performed in local contingencies of the work context. As a result, each employee must adjust and modify his or her actions, even if they are not according to the instructions, in order to fulfil the task according to the local context. Such adaptations could result in a violation of formal rules that appear rational to the operator in the given context. The reason for the error might therefore not be the person, but rather the system (Dekker, 2006; Rasmussen, 1997; Reason, 1990). Within this system lie the culturally accepted behaviours as well. Acts become normal and part of a culture even though they might migrate closer and closer to the boundaries of safety. In this case, the acts seen in Paper I, such as not asking questions and not being pessimistic, were not considered dangerous because up to a certain point, they did not cause serious unwanted incidents. Until they did. In other words, a low-risk perception in the change process could be a result of several smaller decisions on how to act that had been normalized over time and therefore not considered dangerous. In reality, however, some of

these acts were close to the boundaries of safety partly because they did not reveal the importance of the end user in the implementation process. This observation could also be stated regarding the results of Paper II, where the development team conducted insufficient human factors analyses during the development process. Even though conducting human factors analyses is a part of the Norsok standard S-002, the developers had a certain degree of freedom regarding how to conduct the human factors analyses and which analyses to conduct. Furthermore, the development group seemed to assume that the technological component—as in making safe technology, was their main task. As a whole, the outcome of this change process could be seen in connection with interactions between the decisions made by several people on several levels during their normal everyday work.

The outcome could also be seen in regard to the project group's reaction to the unwanted incident. After the incident, it was emphasized that the error that caused the incident was not technological, but human. The project group responsible for developing the new technology stated that the fact that user error caused the incident indicated that the work of neither the engineer development team nor the project group was to be blamed. Their responsibilities were said to be over as soon as the technology was implemented, and user error was not part of their responsibility. Nevertheless, their decisions and insufficient focus on the end users during the development phase could have arguably been an indirect factor contributing to the incident that occurred due to fallible decisions (Reason, 1990), which in turn led to a latent failure or incubation time (Turner, 1978; Reason, 1990). According to Reason (1990), this incident could be seen in connection with latent failure because the decision to not conduct sufficient human factors analyses was a fallible decision that led to a narrow view. Again, this decision resulted in a lack of focus on the end user that propagated during the project until a serious unwanted incident occurred. Thus the technical focus did not cause an accident during the development of the technology, but the decision could have

created a latent hazard as the end users were not familiar enough with the technology to be able to use it safely. The unwanted incidents were due to user errors, which could have potentially been prevented with a more in-depth focus on the end users during the development phase.

Turner (1978) also explained how despite the best intentions of those who are involved, normal processes of organizational operations can end in accidents. Existing cultural beliefs and norms about hazards and the hazards' impacts could result in actions that end in disaster. Such cultural aspects could be both written formalities as well as tacit, taken-for-granted elements embedded in everyday work practices. For this reason, accidents could occur as a surprise for those involved, while investigations might show a divergence between cultural assumptions and the actual state of affairs. In this case, the end users took for granted that this new technology could not be a hazard, which is demonstrated in the results of Paper I. This taken-for-granted attitude could, however, be the result of assumptions made by the end users, who perceived that the development engineers knew whom they were developing the technology for. This perception turned out not to correspond with the actual situation.

Additionally, Turner (1978) revealed that some failures leading to an accident can originate years before the actual accident. This could have been the case here as well. The lack of sufficient human factors analyses to provide a human-centred approach could have been a misconception of the potential hazard of this decision. Again, this misconception could have led to what Turner called a disaster incubation period. In this case, where the actual use of the technology ended in a serious unwanted incident that resulted in the evacuation of the platform, system vulnerability might have been the result of unintended and complex interactions over a longer period of time (Pidgeon & O'Leary, 2000).

Relating all this to the paramount consideration of the current thesis, the findings of Paper I and Paper II substantiate the importance of a questioning culture. This conclusion is

based on the fact that the trust the end users had was not necessarily grounded in reality. The study in Paper II showed that those who developed the technology did not have the expertise the end users perceived they possessed, as described in Paper I. What the end users perceived, partly because of their interpretation of what they were told by coworkers and superiors whom they trusted, seemed to be divergent from the true state of affairs. This situation could also be seen in connection with Rasmussen (1997), who stressed the importance of identifying the capability and competence of decision makers. In this case, the paramount decision makers of the development team seemed to have insufficient knowledge of how to conduct a human-centred technology development. If the culture had been characterized by trained scepticism and questioning, this issue could have potentially come up for discussion. For instance, the end users might have questioned elements of the development and implementation processes, such as why they had little training, or they might have spoken out regarding their perception of receiving too little information. Both of these elements were found to be issues the end users had in the back of their heads during the change process. The findings indicated, however, that even though the end users felt as though they received too little information during the process, they interpreted it to be because the management and developers had everything under control, which is an example of deference (Weick & Sutcliffe, 2007). Building a culture that included trained scepticism could have potentially hindered some of the outcomes experienced during this process. Additionally, the HRO principle of relocating expertise could have been employed by including the end users more during the process; they could have been viewed as experts in their tasks regarding the new technology.

4.2 Competing goals

Another perspective of why this change process resulted in several smaller unwanted incidents before a serious unwanted incident occurred could be to view production and safety

as competing goals. As goals, production and safety are known to be competing in high-risk organizations (Rasmussen, 1997; Woods, 2006). Woods (2006), for instance, argued that accidents represent breakdowns in the processes that produce resilience, and that one cause might be an improper balance between production and safety. Woods further suggested that balancing the competing demands for high levels of safety with real-time pressures for efficiency and production is very difficult.

One result of balancing cost against safety in the petroleum industry is outsourcing tasks such as drilling because a hired company will most often be the most cost effective. For example, a drilling crew might be employed by a different company than the one who owns and runs the installation where they actually work, as was the case in the current project. Even though in this case, the fact that the drilling crew was employed by a contractor company did not seem to have an impact on their trust in the change process, some of the potential consequences this relationship could have should nonetheless be mentioned. For instance, an interorganizational cooperation might add to the complexity and complicate the unified development of safety culture according to HRO. The informants in the current study mentioned that cooperating personnel who had been moved or changed had the potential of being a hazard because they did not know them as well as they thought was optimal. Outsourced tasks where companies other than the operator company are responsible, therefore, have the potential to not fulfil the intentions of an HRO as HRO stress the importance of personnel knowing each other in operations involving risk. Further, outsourcing could result in turnover of crew members, temporary employment, loose attachments, and so forth that could impede a stable work force who know each other well and are confident enough to raise important questions. This element is viewed as important by HRO. With a more unstable workforce, one might question where the loyalties of the employees are strongest and what the consequences might be if they raise a question that is

not regarded as suitable to raise. In the current project, raising questions was generally viewed as acceptable, but even so, certain issues were not regarded as suitable to ask about, and these were perceived to potentially harm individual career development (Sætren & Laumann, 2015). In spite of this, the culture in this case study was based on a general trust as discussed in Paper I.

Further, a higher turnover in high-risk work is considered unfortunate because the workers might not know each other well enough to see warning signals, or they may not trust each other due to a lack of in-depth personal knowledge. In the current study, the work force was rather stable, and most crew members had worked together for a long period of time. This aspect, however, could be an accomplice cause related to how a nonquestioning culture might be created in the industry in general. Insecurity regarding one's future work—for instance, having temporary work contracts or an unstable workforce—has been shown to have a negative impact in high-risk industries (Jorens, Gillis, Valcke, & Coninck, 2015).

Competing goals could also be related to theoretical change management. The change management theories presented in this thesis could seem to come from a management perspective that is leader-centric with a top-down focus. Further, management theories are arguably evolved more often from an economic perspective rather than a safety perspective (Rasmussen, 1997). For instance, Kotter (1996) recommended that management start a change process by creating a sense of urgency, and if the need for change is not actually urgent, he recommends creating urgency to make people understand the need for change. This form of change management could be seen as a demonstration of insufficient trust in the employees who are expected to change. To engineer a false urgency in order to make people change is not consistent with establishing trust. Neither of the safety theories presented (Hollnagel, 2009; HSE, 2003; Rasmussen, 1997; Reason, 1990; Weick & Sutcliffe, 2007, 2015) recommend creating false scenarios. Rather, a bottom-up perspective is recommended

that includes the employees in the decisions being made regarding their work. This perspective sees employees as experts in what they do uses their skills, and draws benefits from their experiences (HSE, 2003; Weick & Sutcliffe, 2007).

Additionally, change management theories are preoccupied with making the senior management committed to the change. Senior management commitment is a factor that safety theories and change management theories have in common; however, an important difference is that the safety theories stress the importance of senior management's commitment to safety (Rasmussen, 1997; Pidgeon & O'Leary, 2000), while the change management theories seem to be more concerned with costs (Ghoshal, 2005; Kotter, 1996). These differences reflect the competing goals: change management theories are preoccupied with cost efficiency but safety theories with safety concerns.

This thesis emerged out of the assumption that changes in organizations have the potential to be successful in the sense that production is maintained without unnecessary hazards during changes in high-risk industries. To this end, how the change process is managed is an important factor. However, when examining change management literature from the last 2 decades (Armenakis & Harris, 2009; Burke, 2002; Burnes, 1996; Cummings & Worley, 2015; Kotter, 1996), safety seemed to be a missing factor. In this case, since the end users seemed to be content with the new technology and how the implementation process proceeded, it seems that the management was content with the willingness to change. In this way, change seems to be the easiest when people agree with the change process. Willingness to change, which change management theories recommend, is not, however, something that the safety literature agrees upon. Furthermore, change management literature seems to agree on what is called getting rid of obstacles (Cummings & Worley, 2015; Kotter, 1996). For instance, in Kotter's seventh step, he recommended that only those in favour of the change should be hired and promoted. The question that arises is, What will happen to those who, for

safety reasons, are sceptical of the change and change process? With statements like those presented by Kotter, a bottom-up perspective in which the workforce's everyday work is part of the change from the beginning is difficult to see. Rather, the overall goals of making the change happen seem to be of main importance in change management theories. By following Kotter's (1996) recommendations, such as putting a group with power together, making a vision, and getting rid of obstacles, the theory has an underlying leader-centric assumption.

Safety literature, on the other hand, does not recommend this way of organizing a high-risk organization. Here, diversity and sceptical thinking are important. This emphasis on diversity is illustrated by several safety theorists, for instance, Pidgeon and O'Leary (2000), who stated that the emphasized elements are meant to ensure reflection upon practice through monitoring, analysis, and feedback. Reason (1997) stressed that having work groups made up of diverse people in order to avoid homogeneity is important because if people look for different things, more elements are observed. Dekker (2011) stated the following:

> Diversity is a critical ingredient for resilience, because it gives a system the requisite variety that allows it to respond to disturbances. With diversity, a system has a larger number of perspectives to view a problem with a larger repertoire of possible responses. (p. 173)

In safety literature, a homogenous group could represent a safety hazard due to the potential hazards resulting from group think (Janis, 1982; Weick & Sutcliffe, 2007). According to HRO, to be able to create a desired culture that includes trained scepticism, employees need to expect praise for their acts and to offer praise to others for acting resilient, in this case by asking the necessary questions. As Weick and Sutcliffe (2007) emphasized, not only how people think, but also how people feel, is important. "People need to feel strongly that it's a good thing to speak up when they make a mistake, good to spot flawed assumptions, good to focus on a persistent operational anomaly" (p. 118). The organization should therefore inspire

and reward people to choose one act over another, for instance, choosing safety over production pressure (Dekker et al., 2008). In this case, the informants were generally rewarded for acts that focused on safety; however, the acts were specifically in connection with personnel safety (Sætren & Laumann, 2015). Personnel safety is important in high-risk industries such as offshore drilling operations, but the change process could have benefitted from a trained safety focus of a broader perspective to prevent major risk.

4.3 The human-centred design process

Because technological development in high-risk industries is often driven by demands for safer, more reliable, and more efficient operations, automation in technology is increasing. Automation results in new tasks for the operators who monitor these complex systems, which potentially increase the consequences of both equipment and human failure (ISO 11064-1, 2000). For this reason, when technology in the oil, gas, and process industries is developed, human factors analyses, such as function analyses, task analyses, and job analyses, are required (Norsok standard S-002, 2004). Such a requirement is given in order to provide human reliability (Jernæs et al., 2005; McLeod, 2015; PSA, 2011). According to Jernæs et al. (2005), however, even though such analyses within the petroleum industry have been conducted, they are often conducted late in a project's development. The result, therefore, is that often no actions are implemented based on the findings of the analyses. This insufficient acknowledgement of the importance of human factors analyses is consistent with the findings in this project. In the current project, human factors analyses were conducted, but analyses such as task analyses or function analyses were not found to have been conducted at any stage. This lack of certain analyses is in spite of this being defined as a large technology development project from the operator company. Again, human factors analyses were done, specifically regarding additional noise, new escape routes, and so forth. Analyses regarding

how the end users would interact with the new technology, however, were not found to have been conducted.

Such human factors analyses should be seen as an important part of the puzzle to ensure safety during change processes. The importance of human factors analyses is rooted in the fact that such analyses can provide information regarding the situation that could benefit good decisions at every step of the development process. For this reason, ISO 11064-1 has set up a generic framework for applying recommendations and requirements that relate to human factors in design and evaluation. This framework is intended to eliminate or minimize the potential for human error. Some of the principles in ISO 11064-1 are to conduct situational analyses, task analyses, and function analyses and to form an interdisciplinary design team that includes human factors specialists. In this particular study, neither situational analyses, task analyses, nor function analyses were found to have been conducted. Further, even though the development group was interdisciplinary, human factors specialists were not found to be a part of it.

Another principle in ISO 11064-1 is to ensure user participation. Within drilling in particular, one area that could benefit from improvement related to change management is involvement of operational personnel (Jernæs et al., 2005). An insufficient involvement of end users seems to match the findings in this study as well. User participation was ensured to some degree in this study; however, as argued in Paper II, this participation was insufficient in regard to the scope of the project. If all the end users had been defined earlier in the project, it was argued that the planning and management of the change project would have benefitted. Human factors analyses are tools that could provide some of the pieces needed for a successful change in high-risk organizations. Because human factors analyses involve end users, focusing on such analyses is consistent with HRO, which emphasizes the bottom-up

perspective and the need to empower the sharp end in order for the organization to maintain flexibility (Weick & Sutcliffe, 2007).

ISO 11064-1 (2000) deals with changes in work environment with a particular focus on ergonomic design processes. Additionally, the Norsok standard S-002 uses ISO 11064-1 as a normative reference concerning ergonomics and human factors in work systems in the driller's cabin. ISO 11064-1 was, therefore, seen as a suitable example even though this study is not exploring a development of a control room, which is the scope of ISO-11064. It could, however, be questioned why human factors analyses are recommended since these analyses are not specially designed for complex sociotechnical systems. Even though the design of the control room is a part of larger and complex systems, ISO 11064-1 recommends human factors analyses. One argument for this recommendation is that the identification of the physical, cognitive, and psychosocial dimensions that constitute human factors would be beneficial in order to development safe technological solutions (Carayon, 2006). This being said, human factors specialists would benefit from working with other domain experts to ensure safety in a complex sociotechnical system, but human factors analyses nevertheless provide important information during the development process.

Rasmussen (1997) criticized task analyses for being linear, and for this reason, suggested this form of analysis is not suitable for complex systems. But even though the process in the current study, from design to implementation, was complex and involved interorganizational cooperation, complexity is not the main reason human factors analyses were recommended. The human factors analyses were, first of all, recommended mainly for the sake of the engineer designers, who needed to understand whom the end users of the product being developed were in order to understand whom they were designing for and which tasks the technology would be used for. The recommendation in this case was not for the engineer designers to assess the complexity of the interorganizational cooperation since

this would have been considered outside the scope of their task. Second, another recommendation was to make sure the end users had the expertise necessary to handle the technology. Assumed within this recommendation was the importance of knowing who the end users were and their current competence level, which would determine which training was needed and how for instance the screen should be designed based on the end users' competence level.

Arguably, analyses should not be more complex than the issue to be analysed need. In this case, these particular analyses were not recommended for complex sociotechnical issues. In the end, the project probably could have benefitted from a greater focus on human factors early in the process, and some basic human factors analyses could have provided a more user friendly technology.

An argument against making too many analyses, on the other hand, is that such analyses could lead to deference, or in other words, too much trust (Weick & Sutcliffe, 2007). This result could be considered a pitfall because too much analysis could lead to a failure to recognize potential limitations, such as unanticipated behaviour, that has the potential to lead to system breakdown (French & Niculae, 2005). Certain indications of this sort of false perception of security were present in this study. The thorough technological testing may have given the development group a sense of sufficiency, which again could have led to a failure to recognize how unanticipated behaviour by the end users had the potential to lead to breakdown of the technological system.

According to the results of the first two papers in this thesis, safety must be ensured on different levels, and both HRO and human factors stand out as important. One way to see this issue is to say that HRO ensures safety on a cultural and cognitive level while human factors analyses are the tools that potentially provide for the safest possible development and implementation process, ensuring a bottom-up procedure. The recommendation based on the

findings in this thesis, therefore, is that HRO and human factors should be used in a technological change process in a high-risk organization from the beginning.

4.4 Are change management theories good enough for changes in high-risk industries?

One important factor to consider in this discussion is that this thesis examines changes in high-risk industries; the relevance of the change management theories presented is in accordance to this limitation. Not all of the aspects regarding the change management theories (Armenakis & Harris, 2009; Cummings & Worley, 2015; Kotter, 1996) are insufficient, yet the aspect that is particularly relevant for this thesis is to view these theories in regard to changes in high-risk industries.

The third paper discussed theoretically how some of the most common change management theories have an insufficient safety focus. For this reason, a step-by-step model on how safety could be ensured through a change process in high-risk organizations was presented. The model was based on the theoretical framework of HRO and human factors. This change management model is separate from many others based on the underlying assumptions related to human functions. Economic and management sciences have, to a large degree, tried to imitate physical sciences with casual explanations instead of imitate social sciences with intentional explanations (Ghoshal, 2005). This underlying assumption of many management theories is an important aspect to keep in mind. Williamson (1975) pointed out that theories regarding organization design are grounded in a need for tight monitoring and control in order to prevent opportunistic behaviour. This understanding of successful organizing has been a part of popular management theories that are still being taught to future managers. This understanding is also visible in change management literature through, for instance, an emphasis on the willingness to change (Wangberg & Banas, 2000; Herscovitch &

Meyer, 2002) and conquering resistance (Harvard Business School, 2005; Oreg, 2003, 2006; Thomas & Hardy, 2011).

It should be mentioned that in Norway, other values are important besides tight hierarchies (Bang, 1988; Fischer & Sortland, 2002), but the theories mentioned in this study are taught in Norway as well, and organizational cooperation is becoming more and more global. For this reason, an awareness of this aspect is important in order to promote management theories that result in good management practices. Ghoshal (2005) argued that management theories based on economic principles rather than social and psychological principles have had a significant impact, and he argued that this impact has been negative. He further argued that alternative theories have not gained acceptance because they do not yield sharp, testable propositions or simple prescription. Additionally, he argued that these negative influences "have been less at the level of adoption of a particular theory and more at the incorporation, within the worldview of managers, of a set of ideas and assumptions that have come to dominate much of management research" (Ghoshal, 2005, p. 76).

Rasmussen (1997) pointed out another important theoretical aspect of management theories: "Traditionally, sociological studies at the upper levels are based on analysis of samples of organizations or groups of people with no detailed consideration of the actual processes found at the productive bottom level" (p. 186). Studies on management theories are often based on statistics and industry-wide questionnaires and, as a result, "management theories tend to be independent of the substance matter context of the given organisations" (Rasmussen, 1997, p. 186). Management theories are, in other words, often based on an assumption that management is a profession of its own regardless of which organization one is managing, whether a hospital, bank, or an oil- and gas-producing installation. Theories on managing organizations, or in this case manage changes in high-risk organizations, could

benefit from being based on a context-specific organization. This benefit further assumes that human aspects should be in focus in management theories in addition to economic principles.

4.5 Contributions

This project has contributed theoretically and practically to the literature on safety in high-risk organizations, the relevance of human factors when developing new technology, as well as to the change management literature. Next, relevant contributions will be described.

4.5.1 Nuance of the term *trust*

First of all, this study has provided a nuance to the term trust and has emphasized the role that trust plays in changes in high-risk industries. It might seem obvious that high trust is positive for an organization's safety culture (Cox, Jones & Collinson, 2006; Tharaldsen, Mearns & Knudsen, 2010); however, this project demonstrated that the concept of trust should be more nuanced. Too much trust was found to potentially lead to a state of deference in which questions are not asked because one is certain the experts have dealt with the topic. As a result, too much trust is regarded as a safety hazard (Weick & Sutcliffe, 2007), which is an important aspect this project contributed to understand more in depth. In technological change processes in general, a high level of trust such as this is important to be aware of. Encouraging end users to question technological change processes, therefore, seems to be positive due to the possibility that such questions might reveal important issues. Questions should be asked during all phases of development and implementation of new technology.

4.5.2 Questioning the willingness to change

This project also provided a nuance to the concept of willingness to change within the context of high-risk industries. In this study, high trust and a nonquestioning culture resulted in a willingness to change that would be viewed as beneficial according to many change management theories (Armenakis & Harris, 2009; Cummings & Worley, 2015; Kotter, 1996). Willingness to change based on high trust and without questions, however, was found to be a

potential safety hazard because an expectation that new technology is free of risk can affect the interpretation of how to use that technology. Generally, such an insufficient understanding can contribute to an acceptance of something that would not have been accepted if the complexity and risk had been better comprehended (Torbiörn, 2006). For this reason, this thesis has confirmed the importance of including end users in technological changes in general, both by informing them on the new technology to come and encouraging them to question the changes. Including the end users has the potential for broadening the information pool from which decisions are made and will help enable the best possible decisions to be made throughout the change process. For the safest possible change process, this project has outlined the need to focus on scepticism and questioning rather than striving for willingness to change. This aspect is likely beneficial for any change context in which safety is important.

4.5.3 Human factors and safety in the petroleum industry

This PhD project has sought to expand the scientific knowledge base on human factors and safety in the petroleum industry. First, the project provided explanations regarding why human factors analyses were not sufficiently conducted in the case of a large-scale technological development project, even though standards within the industry (e.g., ISO 11064, 2000; Norsok, 2004, PSA, 2011) state that human factors analyses such as task analyses and function analyses are beneficial for such projects. Because insufficient human factors analyses were conducted during this project, and because literature regarding human factors in the oil and gas sector report the same issues (e.g., Jernæs et al., 2005; van de Merwe, et al., 2012), it would be reasonable to think that the findings concerning why such human factors were not conducted sufficiently could span over contexts, at least within the same industry. Second, in addition to exploring why human factors analyses were not conducted, this study provided descriptions of possible outcomes from insufficient human

factors analyses during a technological development process. Generally, these findings contributed to an understanding that if end users are not defined and included thoroughly, risk of end user error has the potential to lead to major accidents; the potential hazard of technological user error is applicable to high-risk industries (Reason, 1990). Additionally, the study contributed to the understanding of the importance of heterogeneous competence. Because a homogeneous technological top competence contributed to a narrow focus on technological safety, a heterogeneous expertise, including competence on human factors, is anticipated to benefit the outcome of technological change processes in high-risk industries.

4.5.4 Practical change management to provide for safety during changes

Furthermore, the project contributed to the literature by demonstrating how change processes in high-risk industries can be as safe as possible. This contribution was accomplished by providing a practical change management guide on how to carry through with change processes in high-risk industries while ensuring a focus on safety. Change management theories in general seem to lack strategies for ensuring an inclusion of end users' experiences, which can be used to evaluate, improve, and induce reliability or safety in a change process. Furthermore, the HSE model that provides for safety during changes in high-risk industries is lacking a theoretical foundation (HSE, 2003). Based on these factors, the change model provided in this project was developed to ensure a focus on safety during changes in organizations. This model is based on both the theory of HRO (Weick & Sutcliffe, 2007) and human factors (e.g., Wickens et al., 2004) in addition to the structure of the HSE model (HSE, 2003). The project has thus provided a practical change management model that ensures a focus on safety during changes in high-risk organizations.

4.6 Further research

Several aspects of this study are expected to benefit from more in-depth investigation based on this project. First, empirical investigations are needed in future research regarding

changes in high-risk industries. Based on the scientific work in this project, for instance, the model from Paper III should be scientifically and empirically tested for further development. An example for future research for developing the model could be to focus on development of methods to ensure safety during changes in high-risk industries in order to prepare for the unexpected during changes. Second, future research could produce more specific knowledge on the consequences of how the increasing complexity in the petroleum industry will influence safety in change processes. Additionally, conducting research to provide further recommendations for the design, implementation, and integration of work processes with existing practices will be of importance for safety in changes. Furthermore, the effects of high trust on different organizational and safety outcomes should be studied. For example, future research could look into whether high trust, a nonquestioning attitude, and low-risk perception in more populations are highly correlated. As another example, such research could examine how high trust and a questioning and sceptical culture can coexist and, if so, how such a culture can be promoted. Additionally, a more thorough, in-depth analysis of successful change processes could be beneficial in finding factors that contribute to safe change processes in high-risk organizations. A final suggestion for further research would be to explore changes that are smaller and not planned, like Rasmussen (1997) described, which is contrary to the current focus on large-scale, planned change. Such research could also evaluate risks associated with such changes, in addition to develop methods to ensure safety.

5.0 Conclusion

So, how can changes in high-risk organizations be as safe as possible? The conclusion of this thesis is that within high-risk organizations, HRO and human factors should be intertwined elements in change processes. Even though safety is a field of high importance and a focus area in many ways, some elements still have the potential for improvement through the development and implementation of new technology. First, a questioning culture

could benefit safety during changes. Additionally, such projects could, starting at early stages, benefit from involving people with sufficient human factors expertise already from the beginning of the project. This involvement could help ensure operational challenges are handled in a systematic and holistic manner throughout the development and implementation of the projects, including a focus on the end users. Further, in regard to managing change processes, potential improvements can be made to how change processes are conducted to ensure a safety focus. Within change processes, the tendencies in change management theories and practice indicate that the importance is to complete the change rather than to implement it in the safest possible way. In other words, production and safety still seem to be competing goals, and a focus on technological aspects of change are stronger than a focus on human factors. I hope to see a change of focus in the future in this regard to ensure safety during changes.

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Papers I-III

Paper I:

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Paper II

Paper III

Organizational change management theories and safety. A critical review. (Submitted Safety Science Monitor)

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Abstract

In many change management theories, the change recipient's trust and willingness to change on one hand, are viewed as key factors for a successful change process. Resistance to change, on the other hand, is viewed as something the management must conquer to be able to complete the change process. In order to make the change recipients trusting and willing to change, change theories provide useful tools such as making discrepancy in the work situation of those who are to face changes, and using persuasive communication. However, from a safety perspective the importance of trained scepticism, and having the end users questioning the change process, rather than convincing them, seem to be more important. To view the end users as experts, and to bring them in the process from an early stage, with their opinions on how to make changes as safe as possible, seems more important than overcoming their resistance to change. This paper bridges theories of organizational change and the theory of high reliability organizations (HRO) as a safety theory and discusses how a change process can be feasible with safety as a main priority. Finally, a new model of organizational change which includes processes that ensure safety is presented.

Key words: safety, organizational change, high reliability organizations, high-risk industry

Introduction

Given today's business environment as both dynamic and uncertain, benchmarking for the experts when managing the unexpected is important. Organizational change is a process that will clearly handle unexpected situations. However, within the traditional organisational change management literature, a focus on unexpected incidents during change processes is not common. In addition, few studies have presented a critique to the existing change theories such as Armenakis and Harris (2009), Cummings and Worley (2015), and Kotter (1996).

In recent scientific work, such as Sætren and Laumann (2015), the question was raised if traditional change management theories should be used for changes where safety is the focus. These include examples of unwanted incidents due to unexpected episodes in combination with changes that demand a deeper investigation of how high performance could be ensured despite interruptions and changes. For instance, unwanted incidents like the Gullfaks C incident (PSA, 2010) happened in part due to a complex organisational and technological change situation. In addition, the major accident of the Macondo blowout (DHSG, 2011) included aspects of organizational changes that contributed to complexity rendering it a hazardous situation according to the report. Another example where organizational change was considered relevant as an accident cause was the Longford Esso Gas Plant explosion (Hopkins, 2000). For this reason, this paper will investigate if traditional organizational change theories include processes that ensure safety. Our research question was: *Are prescriptive change management theories/models adequate for organizational changes where safety is an issue? If not, could the HRO theory be used to ensure safety in a change process?*

In the following, some organizational change management theories and resistance to change literature will be presented before the presentation of the safety theory of high reliability organizations (HRO). Thereafter the change theories will be discussed in accordance with HRO before presenting a model based on the safety theory of HRO.

Organizational change management theories

Cummings and Worley (2015) presented a model to obtain effective change management including 5 activity steps: 1) motivating change, 2) creating a vision, 3) developing political support, 4) managing the transition, and 5) sustaining momentum. The first activity step, motivating change, includes creating readiness for change and helping the change recipients address resistance to change. The second step, creating a vision, is a leadership task where the leaders are to create the 'why' and 'what' of the upcoming change. During the third step, developing political support, the leaders need to gain employees' support to implement the change and avoid individuals and groups from blocking it. As a fourth step, the management needs to create an activity plan for the change activities. In addition it is the management's task to plan how to keep the employees committed and to build a management structure to guide the organization through the planned change. The fifth activity, sustaining momentum, includes providing resources for change, building a support system for change agents, developing new competencies and skills, reinforcing new behaviours, and staying the course to complete the change process.

Armenakis and Harris (2009) presented a model for managing organizational readiness for change. This model consists of five key components and seven strategies designed to create readiness for change. The five components are: 1) discrepancy, 2) efficacy, 3) appropriateness, 4) principal support, and 5) personal valence. The first component, *discrepancy,* involves a perception of discrepancy between the current situation and a desired future situation amongst the employees. *Efficacy* refers to the trust in one's capabilities to accomplish the change process. The third component is *appropriateness* which relates to the perception that the planned change is the best solution for obtaining a future desired situation. The fourth key component, *principal support,* refers to the support provided by the employees during the change process. The fifth is *personal valence*. In this component Armenakis and Harris (2009) stated that the question 'What's in it for me?' must have, at least in part, a positive answer for the change recipients to be willing to commit to the change process. In addition, there are seven strategies for transmitting and reinforcing the above five core message components in a process of creating readiness for change. These strategies are management of information, persuasive communication, formalisation activities, diffusion practices, human resource practices, rites and ceremonies, and active participation (Armenakis & Harris, 2009).

Kotter (1996) presented eight steps to produce a successful change of any magnitude in organizations: 1) establishing a sense of urgency, 2) creating a guiding coalition, 3) developing a vision and strategy, 4) communicating the change vision, 5) empowering broad-based action, 6) generating short-term wins, 7) consolidating gains and producing more change, and 8) anchoring new approaches in the culture. The first 4 steps are meant to unfreeze the organization. Steps 5 through 7 comprise the real change and the move, and step 8 freezes the organization again to make sure the change stays in the organization.

The HSE in the UK provided an information sheet regarding organizational change and major accident hazards (HSE, 2003). This information sheet was mainly based on changes including those in roles and responsibilities, organizational structure, staffing levels, staff disposition or any other change that directly or indirectly affected the control of hazards. The main focus

was on an operational level and was mainly meant to cover offshore and onshore oil and gas, and chemical installations. The hand-out provided a three-step framework: 1) get organized for change, 2) assess risks, and 3) implement and monitor the change.

The first step, getting organized, comprised 5 factors. 1) Have a strong policy for managing organizational change. Principles, commitments and accountabilities regarding health, safety and the environment must be clear from the beginning of all changes, large and small. 2) Make senior-level managers accountable and demonstrate a clear commitment to safety by their actions. 3) Have a clear change-management procedure because all changes should be planned in a thorough, systematic, and realistic way. The following should be clear: Identify the processes and activities that are to be carried out, set out the protocols to be followed, who is accountable and who is responsible for these activities, who else is involved and how, what potential risks factors are to be considered, who reviews the change process, both when and how. In addition, all stages should be recorded adequately to assure transparency and traceable decision processes. 4) Communicate and include everyone because all staff will have unique knowledge about what their work is really like and how to perform it. This knowledge can be crucial. Because of this, organizational change should involve all those concerned from an early stage. This involvement of staff includes active participation in decisions. 5) Review and challenge the process both by internal and external experts.

The second step, risk assessment, involved five factors: 1) identify the people involved including those in the existing and proposed organizations that will be affected. It is important that this information is accurate and that all the roles are registered; 2) identify all changes because complexity could be a hazard and in larger organizations simultaneous changes could hinder smooth processes; 3) assess the risks within the change process; 4) consider human factors, competence and workload for instance by checking if tasks or responsibilities have been overlooked, what training is required and if accumulated workload for individuals are within reasonable levels; and 5) test scenarios that are realistic and structured to prepare for incidents and emergencies.

The third and last step, implementing, monitoring and considering safety during the transition itself, consisted of five factors: 1) provide adequate resources to make the change safely, for instance not underestimating the need for training and not reducing staff until the required actions are completed. This is in addition to ensuring enough staff can plan and monitor the change, and provide experienced support during the transition; 2) monitor risks during change; 3) keep the plan under review and track actions; 4) monitor performance after change and be ready to change or reverse decisions if significant risks are discovered; and 5) review the change policy to amend the organization's change procedures.

The theories presented above have revealed different aspects of organizational change theories. Next, a model of resistance to change and the theory of high reliability organisations will be presented.

Resistance to change

Oreg (2006) stated that resistance to change consists of two main factors: personality and context. Personality relates to the person's dispositional resistance to change and people's internal inclinations that affect whether one adopts or resists the change. Oreg (2003) found dispositional resistance to change was a stable personality trait. The second factor, context, consisted of six variables: 1) power and prestige, 2) job security, 3) intrinsic rewards, 4) trust in management, 5) information, and 6) social influence. These contextual variables were related to employees' resistance to change and concerned both the outcome of the change and the way the change was implemented. The first three, power and prestige, job security, and

intrinsic reward were related to the individual outcome of the change and were predicted to affect how the person relates to the change. The last three, trust in management, information, and social influence concerned how the change is implemented and will influence how employees perceive the change process.

Theory of safety – High reliability organizations (HRO)

Weick and Sutcliffe's (2007) theory of high reliability organizations (HRO) is based on organizations that are more capable than others for maintaining function and structure when facing changes and challenges. These organizations are typically ones that perform well in settings where the potential for error and subsequent disaster is large, like nuclear aircraft carriers, air traffic control systems, nuclear power generation plants, and so forth. As a safety aspect, the perception and cognition of the personnel are seen as key factors to obtain high reliability. The cognitive techniques used ensure faster learning, more alert sensing, and better relationships with customers. However, these organizations are not stable safe entities, but they have a focus on avoiding complacency and hubris on a continuous basis. In other words, they work with this every day. They organize for high reliability.

According to Weick and Sutcliffe (2007), the five collective cognitive techniques comprising the key elements included: 1) tracking small failures, 2) resisting oversimplifications, 3) remaining sensitive to operations, 4) maintaining capabilities for resilience, and 5) taking advantage of shifting locations of expertise. Using these five processes is called having a mindful infrastructure in the organization.

By *tracking small failures*, personnel in HRO's treat any small error or unwanted incident as a symptom that something is incorrect with the system. The personnel then face it, analyse it, and respond to it. This is because if separate small errors happen to coincide it can lead to major accidents, and acting on small errors helps prevent this from happening. One common way to do this is to report on unwanted incidents to get an overview of the situation in the organization and to be able to track what happens. Further, they continue to articulate errors that are not wanted and assess strategies to avoid them.

Another principle important for achieving high reliability is to *resist oversimplifications* of interpretations. This includes creating images that better correspond to the complex context in which the personnel operate. The personnel tend to have more alternatives and spot unexpected events earlier because of their active work in creating a more nuanced picture. To achieve this, HRO's welcome diverse experience, scepticism, and negotiating tactics that reconcile differences of opinion. Recognising an event as something previously experienced is a source of concern rather than comfort. People interpret new data and assimilate it into already created schemas. However, to be able to spot signs that this episode might not be the same and finding errors corresponding with it, diversity and sceptical thinking are necessary. For this reason, even in the middle of an operation there must be room to step back and assess the situation.

The third principle is *sensitivity to operations*. This is linked to 'latent failures' (Reason, 1990) which means that imperfections in features, such as supervision, reporting, and safety training lead to loopholes in the defence barriers of the system. For this reason, Weick and Sutcliffe (2007) emphasised that by integrating the front-line workers in the mindful culture and developing situational awareness in the working environment, errors might be prevented from evolving to the level of accidents. Attentiveness to the front-line workers, where the real work is done, helps prevent unwanted incidents. Focus lies more on the situational features and less on the strategic features. This means that situational awareness helps adjustments to prevent errors from accumulating (Endsley, Hansman, & Farley, 1999). For this reason

HRO's are aware of the fact that sensitivity to operations is closely linked to sensitivity in relationships. Personnel must trust that their scepticism is valued so they do not refuse to speak up for fear of reprisals. Reprisals in contrast to rewarding such behaviour could undermine the system because important information might be left out to effectively handle situations. A big picture of operations cannot be produced if information regarding the symptoms is withheld. A trustful, open, and good work environment are therefore key to safe operations.

The fourth principle is *maintaining capabilities for resilience*. The key here is that personnel do not view the organization as error-free but manage errors by learning from failures. In addition they provide their perceptions of the context so that errors are prevented from disabling the organization. In other words, they commit to resilience. Resilience is defined as 'the intrinsic ability of an organization (system) to maintain or regain a dynamically stable state, which allows it to continue operations after a major mishap and/or in the presence of a continuous stress' (Hollnagel, 2006, p 16). To do this, resilience demands a deep knowledge of the system, the technology, the people one works with, and oneself. Further, having a rich imagination of possible scenarios, including the worst case, is important for training and gaining cognitive skills (Weick, 2005). Training, in combination with personnel with deep and varied experiences and skills, are therefore viewed as a strength (Weick & Sutcliffe, 2007).

The fifth principle is *taking advantage of shifting locations of expertise*. To make use of the expertise in the organization they tend to empower those closest to the occurrence. To avoid the vulnerability that a tight hierarchy can lead to, they instead push decision making down and around. Decision making is placed on the front line and the focus is on listening to those with the best expertise, regardless of their rank. However, it is important to notice that experience is not equivalent with expertise. It is not necessarily the person with the longest experience that has the best expertise. Because businesses today deal with greater complexity, HRO's use diversity in expertise and skills as a strategy. This is not just because it helps them to notice more in an increasingly complex environment, but also because it is beneficial for the greater complexity at hand. Another aspect is to use the changing location of expertise to avoid deference (Sætren & Laumann, 2015). If one person's expertise leads to others un-nuanced trust, it could lead to hazardous accidents. For instance if the personnel trust the leader's ability to spot everything, the leader's expertise could hinder someone else from being alert and noticing something the leader missed. If then in addition the personnel are not being used and their opinions not appreciated, they probably will not be trained to look for errors either, and will therefore probably not spot them (Weick & Sutcliffe, 2007).

Summary

The organizational change literature has to a large degree adopted a leader-centric focus on change processes (see for instance Armenakis & Harris, 2009; Cummings & Worley, 2015; Kotter, 1996; Oreg, 2003). The focus is mainly on transformational leadership and inspiring visions in addition to an employee-centric focus representing how employees makes their considerations regarding embracing or rejecting the change. It could, however, be questioned whether this is sufficient in high-risk industries where safety should be the main focus. In a high-risk industry, recent research showed that it could potentially be a safety hazard persuading the employees in believing it is a safe change instead of inviting them into the change process with their expertise (Sætren & Laumann, 2015). In the following, a discussion will be presented to show how safety could be ensured in organizational change by using the principles of HRO. Finally, a model will be presented for changes in organizations where safety is a focus.

Discussion

When implementing organizational change, there are mainly two types of perspectives concerning how to make the change recipients change. As a change recipient, one is often either resistant to the change (Oreg, 2003, 2006; Thomas & Hardy, 2011) or willing to change (Herscovitch & Meyer, 2002; Wanberg & Banas, 2000). This terminology is relatively loaded where being resistant to change is related to a negative outcome while willingness is the key to success (Miller, Johnson, & Grau, 1994). Resistance to change is often mentioned as the reason why planned change processes do not go according to plan (Dent & Goldberg, 1999; Ford & Ford, 2009) and something the organizations must conquer (Furst & Cable, 2008; Harvard Business School, 2005). Strategies such as persuading change recipients and creating discrepancy in the work situation for employees are recommended in these theories.

HSE's (2003) guidelines for changes in organizations represent another view where safety is the focus and empowerment of the employees is central. This theory presents definite step by step actions that need to be taken to ensure safety during change. However, this guide lacks a theoretical presentation of why these elements should be conducted. The guidance says what to do, but is insufficient in explaining why. As a safety theory, HRO might provide an insight into why such actions are necessary. In this regard our research question is: Are prescriptive change theories/models adequate for organizational changes where safety is an issue? If not, could the HRO theory be used to ensure safety in change processes? In the following we will present why the theory of HRO could function as a reliable foundation for future changes in organizations.

Principle 1: Tracking small failures.

Traditional change theories promote making change recipients ready for change, for instance, by persuading them (Armenakis & Harris, 2009) and helping the change recipients address resistance to change (Cummings & Worley, 2015). This stands in contrast to, for instance, tracking small failures. By having a mindful structure of tracking small failures, management and employees question the processes that arise instead of being confident that they are right. HRO have not experienced all of the ways that their system can fail, however they work knowing that overconfidence might hinder good structures (Weick & Sutcliffe, 2007). They organize to encourage and reward behaviour such as reporting of errors (Rochlin, 1993). For instance, instead of preventing resistance to change by persuading the change recipients, the theory of HRO promotes questioning the process. Questioning would be appreciated and welcomed to broaden the information pool when decisions are being made. By enacting alertness, broadening attention, and forestalling simplifications, HRO do more or less the opposite of organizational change theories in many ways (Weick & Sutcliffe, 2007). Discrepancy is an example of such a factor that foster the opposite. Discrepancy is a factor mentioned by change theories to accomplish readiness for change (Armenakis & Harris, 2009; Cummings & Worley, 2015). If discrepancy does not already exist in the change recipients it is recommended by making the present situation uncomfortable as a strategy for reducing resistance to change and making the employees want to go with the change suggested by the management (Cummings & Worley, 2015). However, by creating uncomfortable situations to make employees willing to change could result in well-functioning structures being thrown overboard. Resilient actions enable recovery from setbacks and a strategy like this seems unlikely to accomplish this. According to HRO, organizations will benefit from instituting practices that encourage employees to report detected errors (Weick, Sutcliffe, & Obstfeld, 1999) because it will lead to more effective organizational learning (Rochlin, 1993). If the management is manipulating the context to make employees experience discrepancy to hinder resistance to change, it could be questioned if trust exists for employees to report errors that could prevent change processes from going wrong.

Principle 2: Resist oversimplifications.
Kotter (1996) stated that trying to change the organization without establishing a high enough sense of urgency in fellow managers and employees might hinder a good change process. Organizations typically overestimate how much they can force big changes and underestimate how hard it is to drive people out of their comfort zone. He further stated that driving people out of their comfort zone often produces even more resistance to change. However, by viewing resistance as a unilateral factor, important scepticism could get lost (Ford & Ford, 2009). To oversimplify the employee's critical regards in the process of change, their expertise in the everyday work situation might get overlooked (Weick & Sutcliffe, 2007). Traditionally organizations do not have a focus on what they ignore and simplify whereas HRO's tend to be restricted in this regard (Roth, 1997). Persuading employees and conquering resistance to change embraces simplifications that might not be beneficial. However, it is important to know that people do simplify in order to handle complex tasks, yet in order to resist important simplifications one can be more deliberate in the choice of what to simplify. Simplifications from the management in such complex situations such as a change process, are potentially hazardous because simplifications limit the number of consequences they should be envisioning (Weick et al., 1999). Where many organizations make assumptions and socialise the members to ignore the same thing, HRO's organize to socialise the members to notice more (Xiao, Milgram, & Doyle, 1997) promoting organizational learning. Because HRO's promote a broad range of expertise, rather than conformity, a broad range of opinions might also be a part of the culture. With this heterogeneity, it is important to have high standards regarding interpersonal skills to promote a healthy climate for bringing out one's scepticism and reporting errors. This includes guidelines on how to behave respectfully like critiquing with the case and not the person in addition to not tolerating, for instance, bullheadedness, hubris and self-importance (Schulman, 1993).

Kotter (1996) further stated that too much success in the past makes it harder to change, and becomes a problem regarding getting ready, because it could foster too much complacency. The theory of HRO also accentuates the danger of too much complacency (Weick & Sutcliffe, 2007). Success produces confidence and for this reason is unfortunate for a safe change (Weick et al., 1999). However, the solution of establishing a sense of urgency might not be the optimal solution according to HRO. Instead the solution could be to establish a continuous questioning culture from which the organization draws benefits during a phase of change as well as during regular operations (Weick & Sutcliffe, 2007).

Principle 3: Remain sensitive to operations.
Traditional change theories emphasise that management needs to be involved in the change and to prevent groups and individuals from blocking it (Cummings & Worley, 2015). However, according to HRO, the organization would benefit from including all personnel and involve the front-line workers in mindful thinking. If the management has a change policy of persuading the personnel, it could indicate that they are not including front-line personnel. As an example, front-line personnel such as maintenance people are often those who come in contact with the largest number of failures at early stages of error development (Weick et al., 1999). To have access to their expertise during a change process might be important in order to be sensitive to operations. Further, by persuading change recipients to want to change (Armenakis & Harris, 2009), it could imply the management is asserting a view of the employees as not being the experts at what they do. The personnel might not perceive that their opinion of expertise is necessary to communicate and important information could get lost. In addition this might be seen in fostering trust and what behaviours are rewarded. It could seem that the traditional organizational change theories promote conformity from the workers rather than emphasising the actual operations. If conformity is the rewarded

behaviour, this is most likely what the management will get (Siegrist, 1996). The diversity and sensitivity to operations through scepticism that the theory of HRO promotes to facilitate safety might be lost using a strategy promoting conformity.

Principle 4: Maintain capabilities for resilience.
When change theories emphasise elements such as overcoming resistance to change, making employees willing to change, persuasion, and staying the course to complete the change process (Armenakis & Harris, 2009; Cummings & Worley, 2015; Kotter, 1996; Oreg, 2006), it is challenging to find how they relate to maintaining safe operations and capabilities for resilience (Hollnagel, 2006; Weick & Sutcliffe, 2007). For instance, when describing the three phases of change (Lewin, 1999), Armenakis and Harris (2002) described the ideal first phase whereby the organizational members become its supporters. In the second phase, when the change is implemented one must be aware that employees still can reject the change. In the third phase, the changes are to become internalised and the norm in the organization. According to Armenakis and Harris (2009) it is the leader's task to communicate a consistent change message in order to overcome negative responses to organizational change. However, at no place during the three phases is there a questioning of whether the change is right or if the process or the change itself should be evaluated due to scepticism from the employees.

The theory of Armenakis and Harris (2009) is a framework for making employees ready to change, and the readiness consists of motivation to accept and institutionalise the change. Resilience, on the other hand, emphasises factors such as trust, inclusion, engendering a questioning atmosphere, and if necessary reversing the decisions made. These are structures that should have been established in the organization's culture and policy prior to the process of change to ensure high standard operations even during a change phase. The definition of resilience includes being able to maintain or regain operations after a mishap or during continuous stress (Hollnagel, 2006; HSE, 2003). For this reason resilience is closely related to a change process in an organization.

Principle 5: Taking advantage of shifting locations of expertise.
The leaders as the experts who persuade the employees is an attitude that prevails in the traditional organizational change theories which stands in contrast with this fifth principle. This is due to the benefit HRO's experience from pushing decision making down and throughout the organization to help overcome the complexity within the context they work (Weick & Sutcliffe, 2007). The importance of in-depth knowledge of co-workers' competence, which was a main point in the fourth principle, is visible here too. The leader might well be aware of his/her own shortcomings but if the crew is not aware of it, deference and too much trust might turn out to be devastating (Sætren & Laumann, 2015). However, on the other hand, too little deference to expertise in lower ranked personnel might also contribute to accidents (Weick & Sutcliffe, 2007) and this seems to be a potential problem that can arise from the attitude the change theories demonstrate. In the complex context in which a change process often occurs, knowing what expertise exists and taking advantage of this, regardless of which rank it is to be found, is of importance to ensure a safe process of change in organizations.

The theory of HRO is not first and foremost a change theory, but because of the focus on preparing for the unexpected, new situations, and maintaining safe operations in hazardous and constantly changing contexts, it is applicable for changes in organizations. For this reason our change model is based on the principles of HRO to ensure safety throughout the process of changes in organizations.

Organizational change management model for high-risk industries.
The model consists of three main steps each including practical tasks: **1) getting ready** (policy, create a questioning culture), **2) mapping** (conduct human factors analyses, scenario testing, ensure resources), and **3) implementing the change** (continuously questioning and evaluating the process).

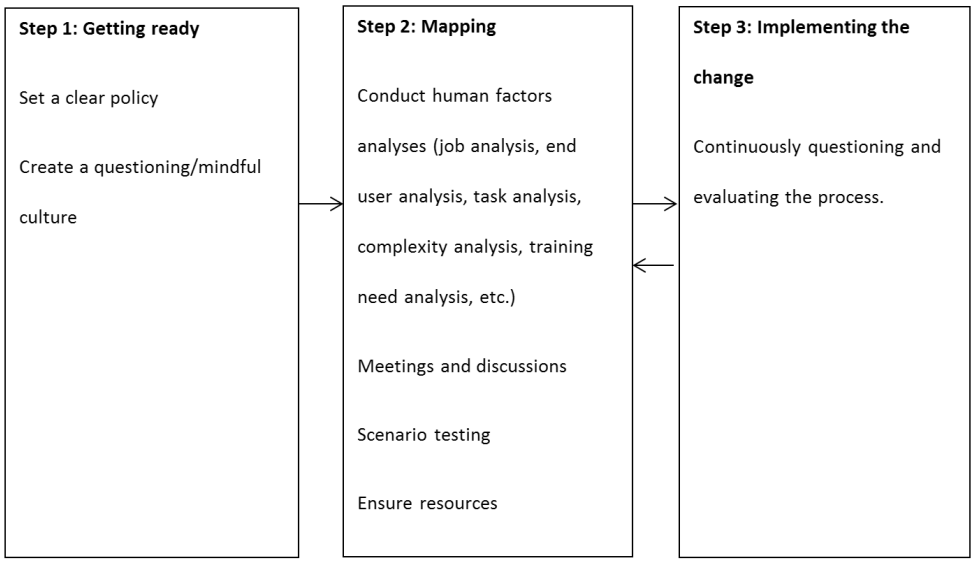

Figure 1: The steps of safe organizational changes

Step 1: Getting ready
In order to deal with critical situations the organization depends on the structures that have been developed before the chaos arrived.

1. Create a clear policy which should include principles, commitments and responsibilities regarding management of changes in the organization. When a clear policy is settled, it is easier to develop strategies and to know how to act during unforeseen actions throughout the change process. Ideally this policy should be implemented for all changes, regardless of the size, because safety hazards could be an issue even for smaller changes. The reason for this clear policy is to prevent confusion as well as promote predictability and have a guideline when unforeseen events occur. As Weick and Sutcliffe (2007) stated, to manage the unexpected, one needs to understand how expectations work, and by having a clear policy these expectations could be built within organizational roles, routines and strategies and thus be guidelines for how to react in various situations.
2. Create an atmosphere where open questioning is promoted. It is important that the culture is mindful regarding safety. For this reason the organization will benefit from rewarding behaviour that promotes mindful acts. Part of this includes being aware of the processes that go on and to question what happens for the benefit of safety in accordance with the fourth principle of the theory of HRO: commitment to resilience. The atmosphere within the work group must be trustful and open to scepticism and

discussions. To maintain an open atmosphere the management must behave this way too and reward those who act mindfully. This also involves strategies for reporting unwanted incidents to ensure that personnel question their everyday work and resist oversimplifications according to the second principle of the theory of HRO. In addition, it is important for all levels of the personnel to take part in this questioning and diversity and scepticism must be rewarded in accordance with the third principle of the theory of HRO: sensitivity to operations.

Step 2: Mapping

To conduct a change process it is important that the current situation is clear. To map the situation and predict future situations will take time and resources, yet is perhaps the most crucial part of the change process because much depends on correct analyses.

3. Conduct human factors analyses: a broad user analysis and job analyses for all affected personnel is advised as a start. The paramount analyses are most important to conduct in the beginning and more detailed analyses occur later in the process. Identifying who is going to be affected by the change and how are important in accordance with the second principle of the theory of HRO: resist oversimplifications. Further it will be a strength in the change process knowing the co-workers, the technology, the organization, and oneself. By mapping the existing expertise, one acts according to the fourth principle of the theory of HRO, maintaining capabilities for resilience, by knowing who the expert is.

   A task analysis, for instance, is of great importance to discover the main risks from the old to the new in a change process. To conduct a complexity analysis, however, means to identify all complexity within the change process affecting it. This could include changes that are happening simultaneously, the situation of subcontractors, and so forth. As the HSE (2003) stated, to outsource safety-critical work demands a high focus on remaining safe. This can be done by retaining resources to closely supervise the expertise and quality of the outsourced work and employees, remaining an intelligent customer by having an in depth knowledge of the system within the organization to judge the quality, and have contingency plans in case the contractor might not be able to maintain delivery of the work. Further, simultaneous changes within the organization could lead to overly complex situations which could be regarded as safety critical (Sætren & Laumann, 2015). For this reason, it is important to have control over all the changes and take them into consideration when human factors analyses are conducted and information is compared. To compare the information received during these analyses are a safety critical task in any change within organizations. Organizations much also check whether tasks or responsibilities have been overlooked or if tasks need to be completed simultaneously. Further knowing for certain the total workload of each individual and if there are other risks accumulated from the changes are important. Another important aspect to know is what training is needed and for whom. A training needs analysis is therefore recommended to ensure optimal expertise during and after the change.
4. Meetings and discussions to be sensitive to operations. These meetings should be conducted several times during the process and consist of a range of people with different expertise depending on what information is needed in the particular phase. It is important to resist simplifications in areas where it could be a hazard even though it is known that all people simplify. To avoid hazardous simplifications, according to the second principle, one can strive to be more deliberate in which simplifications are to be prohibited by thoroughly articulating which errors are not wanted. Because people tend to search for confirmation according to the expectations one holds, it is important to come together to discuss the contexts. This helps broaden one's perspective to avoid

blind spots and prevent unexpected incidents (Weick & Sutcliffe, 2007). Having constructive meetings and discussions require sensitivity to relationships and to treat each other respectfully according to the third principle: sensitivity to operations. Being able to discuss and track small failures during the process, either regarding roles or tasks that do not overlap or regard technological safety aspects or others, will help in preventing a range of small errors coinciding and causing an accident in accordance with the first principle: tracking small failures. When selecting representatives from departments to attend meetings, the person(s) should be representative, and not necessarily the best. Representative representation is important to reveal where problems might arise.

5. Analyse future scenarios. Assessment of scenarios implies realistic, structured evaluations on how the new arrangements will act out. Anticipation is an important factor in HRO, and for this reason, the more creativity and more variation and more expertise one brings into different scenarios, the more scenarios one can think of. The more scenarios one is prepared for, the better one is prepared for unexpected things to happen in accordance with the first three principles of HRO. However, thorough planning has its shortcomings as well. For instance, proper planning could result in mindlessness rather than mindfulness because they create a false feeling of everything being taken care of. Bearing this in mind is therefore important.
6. Ensure resources. Employees need to have the necessary resources to complete the change process. Having extra resources, including staff, in the change process is important to remember. It will require, for instance, questioning the process or extra meetings for discussions regarding the change process.

Step 3: Implementing the change.

7. Constantly checking and questioning the process and in the worst case being ready to change the decision or even reverse it.

Conclusion

By following these steps we argue that organizations will have a thorough focus on safety during changes. This is because by conducting the actions recommended questions such as, is this a good change, is it necessary, will it be feasible, does it contribute to a better and safer situation for the organization, and will it be safe to conduct, will be answered. We argue that it is not necessarily resistance to change that is the main reason why change processes go awry. It could also be because organizations are not organized for change. By implementing a mindful cognitive structure it could benefit the organization by increasing productivity and maintaining safe operations during change processes. However, we do not want to limit this step by step guideline to high-risk organizations only. Conducting thorough analyses and having a mindful culture could assist other businesses in successful changes too.

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