Towards vision zero

The possibilities and challenges for accident prevention in the Danish oil and gas industry

PhD thesis

Hanna Barbara Rasmussen
Centre of Maritime Health and Society

Faculty of Health Sciences
University of Southern Denmark

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SUPERVISED BY:

Main supervisor:

Pernille Tanggaard Andersen, PhD, Associate Professor, Unit for Health Promotion Research, Institute of Public Health, University of Southern Denmark, Esbjerg, Denmark.

Co-supervisor:

Jorunn Elise Tharalsen, PhD, Principal Engineer, PhD, Petroleum Safety Authority, Stavanger, Norway.

Fabienne Knudsen, PhD, retired, former main supervisor, Centre for Maritime Health and Society, Institute of Public Health, University of Southern Denmark, Esbjerg, Denmark.

REVIEWED BY:

Associate Professor Kirsten Jørgensen, DTU Management Engineering, Technical University of Denmark.

Professor Emeritus Andrew Hale, Safety Science Group Delft University of Technology, Netherlands and chairman Health and Safety Technology and Management, England.

Associate professor, Jesper Bælum, Research Unit of Occupational and Environmental Medicine, Institute of Clinical Research, University of Southern Denmark (chairman).

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Hanna B. Rasmussen

Summary

This thesis describes accident prevention in the Danish oil and gas industry. It provides new knowledge about accident prevention within the Danish oil and gas industry and describes the possibilities and challenges of this task. The overall research question is

What are the possibilities and challenges in accident prevention in the Danish oil and gas industry?

This topic was examined with a focus on 1) involvement of employees (hereunder safety representatives) in safety work, 2) learning from near-misses, and 3) the attitude toward safety (safety climate) and risk perception among offshore employees. These issues were explored in four articles, which are included in second part of the thesis. This thesis uses mix methods approaches that include quantitative and qualitative methods. The first article examines the role of safety representatives and their participation in safety and the second article examines learning from near misses with qualitative methods; the third and fourth articles explore the association between risk perception and safety climate through the use of quantitative methods.

The thesis is divided into two main parts. Part I consists of seven chapters that constitute the overall framework for the thesis, while Part II includes the four articles. In Part I, chapter one introduce the aims, the main research problem, the research questions, and the conceptual model of the thesis, while the second chapter describes the industrial context. The theoretical framework is presented in chapter three, followed by methods in chapter four. The main results are briefly presented in chapter five and discussed in chapter six. The last chapter in Part I presents the conclusions.

Safety research constitutes a cross-disciplinary research field, which means that theoretical frameworks in the field are inspired by different sciences, such as sociology, psychology, anthropology, and engineering. This thesis is mainly based on sociological theory but also found inspiration in research on community-based approaches to promote health. The project has a broad approach to accident prevention because it focuses on all levels of the organisations and encompasses both structure and agency. One of the important elements in this thesis is the examination of culture/organisational culture and its influence on safety. In this thesis, the concept of culture is inspired by Alvesson (2002), who defined culture as existing not in people's heads but *between* people, and culture is central to our understanding of behaviour, social norms, institutions, and processes. Culture makes social phenomena comprehensible and meaningful.

The first article explores the role of safety representatives, their participation in safety, and their dilemmas connected to their role. The study concludes that the role of safety representatives is unclear and that

safety representatives find themselves caught between legislative demands and contradictory expectations from colleagues and management. The training of safety representatives is not very systematic apart from the mandatory environmental course. The study emphasises several dilemmas, such as the time required to perform the tasks required of a safety representative, the lack of support from management, and difficulties with influencing safety planning by safety representatives. The study concludes that the Danish safety representatives in the oil and gas industry meet the same challenges as their colleagues in Norway and the United Kingdom (UK) and that safety representative could increase the effectiveness of accident prevention.

The second article focuses on learning from incidents. All companies involved in the study have procedures in place and comply with these procedures; however, reports on near- misses as learning tools are still not used effectively. One of the barriers to the effective use of these reports is the underreporting of near - misses, particularly those related to personal behaviour. The study indicates several reasons for underreporting, including unclear definitions of near misses, employees´ fear of reporting, and an overly demanding reporting system. As currently designed, the report systems are aimed at gaining an overview and log of the reports, which limit the possibilities of learning from these incidents.

The third and fourth articles examine the association between risk perception and safety climate/organisational factors. The first article shows that the organisational and human factors have an impact on the offshore employees' risk perception. Individual factors, such as safety behaviour, work experience, or experience of injuries, influence the risk perception of occupational hazards, while the priority of safety versus production influences the risk perception of process incidents. The study also shows that offshore employees' risk perception for both categories appears to be influenced by organisational factors, such as satisfaction with safety measurements (e.g., detection systems) and working conditions.

The fourth article identifies differences in risk perception between Danish and Norwegian offshore employees. Norwegian employees have a more positive perception of safety and management's involvement in safety than Danish offshore employees. However, the risk perception for both process incidents and injuries are higher among Norwegian offshore employees than Danish offshore employees. Although the study found differences between these two populations, these differences are relatively small.

Based on the findings from the four articles, this thesis identifies possibilities and barriers in accidents prevention within the Danish oil and gas industry. The possibilities could be found in the focus on safety within the industry; the development of procedural systems, which provide safety guidelines for the

employees; reporting systems; safety organisations; and safety awareness among employees. If these factors could be strengthened, these changes would likely improve safety on oil and gas installations. However, this thesis also identifies some barriers, including a lack of focus on structural/organisational factors to prevent accidents, a fragmented view on accident prevention, lack of support from management in certain areas, lack of a long-term strategy to prevent accidents, and a lack of follow-up on and evaluation of actions taken. The overall conclusion is that while the Danish oil and gas industry is promoting accident prevention, there is still room for improvement. Accident prevention must be viewed as a complex process in which several factors are involved, and a more complex intervention program that simultaneously focuses on several factors and structural changes are required.

Dansk resumé

Denne afhandling handler om forebyggelse af ulykker i den danske olie- og gas industrien. Det giver ny viden om forebyggelse af ulykker i den danske olie- og gas industri og beskriver muligheder og udfordringer forbundet med dette. Det overordnede forskningsspørgsmål er:

Hvad er mulighederne og udfordringerne i forebyggelse af ulykker i den danske olie-og gasindustri?

Dette forskningsspørgsmål blev undersøgt med fokus på: 1) medarbejderens (her under sikkerhedsrepræsentantens) deltagelse i sikkerhedsarbejde, 2) at læring af tæt-på hændelser, og 3) holdning til sikkerhed (sikkerhed klima) og risikoopfattelse blandt offshore medarbejdere. Disse emner blev undersøgt i fire artikler, der indgår i anden del af afhandlingen. Afhandlingen anvender mix-metode model, der omfatter både kvantitative og kvalitative metoder. Den første artikel undersøger sikkerhedsrepræsentantsrolle og deltagelse i sikkerhed og den anden artikel analyserer læring fra tæt-på hændelser ved hjælp af de kvalitative metoder, mens den tredje og den fjerde artikler udforsker sammenhængen mellem risikoopfattelse og sikkerhedsklima ved hjælp af kvantitative metoder.
Afhandlingen består af to dele. Del I består af syv kapitler, der udgør den overordnede ramme for afhandlingen, mens del II omfatter de fire artikler. I del I, det første kapitel præsenter forskningsproblemet, forskningsspørgsmål, og afhandlingens konceptuelle model, mens det andet kapitel beskriver den industrielle kontekst. Den teoretiske ramme er præsenteret i kapitel tre, efterfulgt af metodebeskrivelse i kapitel fire. De vigtigste resultater er kort præsenteret i kapitel fem og diskuteres i kapitel seks. Det sidste kapitel i del I er konklusionen.
Sikkerhedsforskning udgør et tværfagligt forskningsfelt, hvilket betyder, at teoretiske rammer på området er inspireret af forskellige videnskaber, såsom sociologi, psykologi, antropologi og teknik. Denne afhandling er hovedsagelig baseret på sociologisk teori, men også har fundet inspiration i forskning i lokalsamfundsbaserede tilgange fra sundhedsfremme. Projektet har en bred tilgang til ulykkesforebyggelse, fordi det fokuserer på alle niveauer i organisationen og omfatter både struktur og agenter. Et af de vigtige elementer i denne afhandling er en undersøgelse af kultur / organisatorisk kultur og dens indflydelse på sikkerheden. I denne afhandling, er begrebet kultur inspireret af Alvesson (2002), der definer kultur som ikke eksisterende i "menneskets hoveder", men mellem mennesker, og kultur er centralt for vores forståelse af adfærd, sociale normer, institutioner og processer. Kultur gør sociale fænomener forståelige og meningsfulde.
Den første artikel undersøger sikkerhedsrepræsentantsrollen, deltagelse i sikkerhed, og dilemmaer forbundet med rollen. Undersøgelsen konkluderer, at sikkerhedsrepræsentantsrollen er uklar, og at

sikkerhedsrepræsentanter føler sig fanget mellem lovgivningsmæssige krav og modstridende forventninger fra kolleger og ledelse. Uddannelsen af sikkerhedsrepræsentanter er ikke meget systematisk bortset fra et obligatorisk arbejdsmiljøkursus. Undersøgelsen understreger flere dilemmaer, såsom tid, der kræves for at udføre de opgaver, der kræves af en sikkerhedsrepræsentant, den manglende opbakning fra ledelsen, og problemer med at påvirke planlægning af sikkerhed af sikkerhedsrepræsentanter. Undersøgelsen konkluderer, at de danske sikkerhedsrepræsentanter i olie- og gasindustrien møder de samme udfordringer som deres kolleger i Norge og England, og at sikkerhedsrepræsentanter kunne øge effektiviteten af ulykkesforebyggelse.

Den anden artikel fokuserer på at læring fra tæt-på hændelser. Alle selskaber, der deltager i undersøgelsen har procedurer og overholder disse procedurer, men tæt-på rapporter anvendes stadig ikke effektivt som læringsværktøjer. En af hindringerne for en effektiv udnyttelse af disse rapporter er underrapportering af tæt-på hændelser, især dem der er relateret til personlig adfærd. Undersøgelsen viser flere grunde til underrapportering, herunder uklare definitioner af tæt-på hændelser, medarbejdernes angst for indberetning og et alt for krævende rapporteringssystem. Som i øjeblikket designet, er rapporteringssystemer designet med henblik på at få et overblik og rapportering af rapporterne, men ikke så meget til læring fra disse hændelser.

Tredje og fjerde artikler undersøger sammenhængen mellem risikoopfattelse og sikkerhedsklima. Den første artikel viser, at de organisatoriske og menneskelige faktorer har indflydelse på offshore medarbejdernes risikoopfattelse. Individuelle faktorer, såsom sikkerhedsadfærd, erhvervserfaring, eller oplevelse af ulykker, påvirker risikoopfattelse af erhvervsbetingede risici, mens prioritering af sikkerhed kontra produktion påvirker risikoopfattelsen af processes ulykker. Undersøgelsen viser også, at offshore medarbejdernes risikoopfattelse for begge kategorier synes at blive påvirket af organisatoriske faktorer, såsom tilfredshed med sikkerhedssystemer f.eks. detektionssystemer og arbejdsvilkår.

Den fjerde artikel identificerer forskelle i risikoopfattelse mellem danske og norske offshore medarbejdere. Norske medarbejdere har en mere positiv opfattelse af sikkerhed og ledelsens engagement i sikkerhed end de danske offshore medarbejdere. Men risikoopfattelsen for både procesulykker og personlige skader er højere blandt norske offshore medarbejdere end danske offshore medarbejdere. Selv om undersøgelsen fandt forskelle mellem disse to populationer, er disse forskelle relativt små.

Baseret på resultaterne fra de fire artikler, identificerer afhandlingen muligheder og barrierer i ulykkersforebyggelse inden for den danske olie- og gasindustrien. Mulighederne kunne findes i fokus på sikkerhed inden for industrien, udvikling af systemer af procedurer, som giver retningslinjer for sikkerhed for de ansatte, rapporteringssystemer, sikkerhedsorganisationer og høj bevidsthed om sikkerhed blandt medarbejderne. Hvis disse faktorer styrkes, vil det sandsynligvis forbedre sikkerheden endnu mere på olie- og gasinstallationer. Afhandlingen identificerer også nogle barrierer, herunder manglende fokus på

strukturelle / organisatoriske faktorer for ulykkesforebyggelse, et fragmenteret syn på ulykkesforebyggelse, manglende støtte fra ledelsen på visse områder, mangel på en langsigtet strategi for ulykkesforebyggelse, og manglende opfølgning på og evaluering af initiativer. Den overordnede konklusion er, at selv om den danske olie- og gasindustrien har nået lang med ulykkesforebyggelse er der stadig plads til forbedringer. Forebyggelse af ulykker skal betragtes som en kompleks proces, hvori adskillige faktorer er involveret, og et mere kompleks interventionsprogram der samtidig fokuserer på flere faktorer og strukturelle ændringer er nødvendig.

Introduction

"If you have a flower bed at home, which you like very much, then you make sure to take weeds away, we do the same here: it is like a little garden, where you remove weeds away and rake, then weeds are kept down, so here the weeds are the dangerous situations, we are trying to keep them away, so in this way you can compare it "(offshore employee)

This phrase illustrates both the risk of oil and gas industry interests of the industry in the prevention of this risk. The oil and gas industry is exposed to high-risk scenarios and accidents, which could have serious consequences for employees and the environment. This exposure is not only the reason to focus on safety and the reduction of risk and accidents, which are crucial to this sector, but also the reason for two of the largest disasters in the industry: Alexander Kjellander in Norway in 1980, where 123 persons died, and Piper Alpha on the Scotland coast in 1988, where 167 persons died. These disasters were a turning point concerning safety awareness in the oil and gas industry. Since that time, the focus on safety, risk reduction and prevention of accidents has intensified in the industry and in related research; however, the focus is still inadequate when considering the Deepwater Horizon disaster in the Gulf of Mexico in 2010, which caused 11 fatalities and resulted in significant environmental consequences.

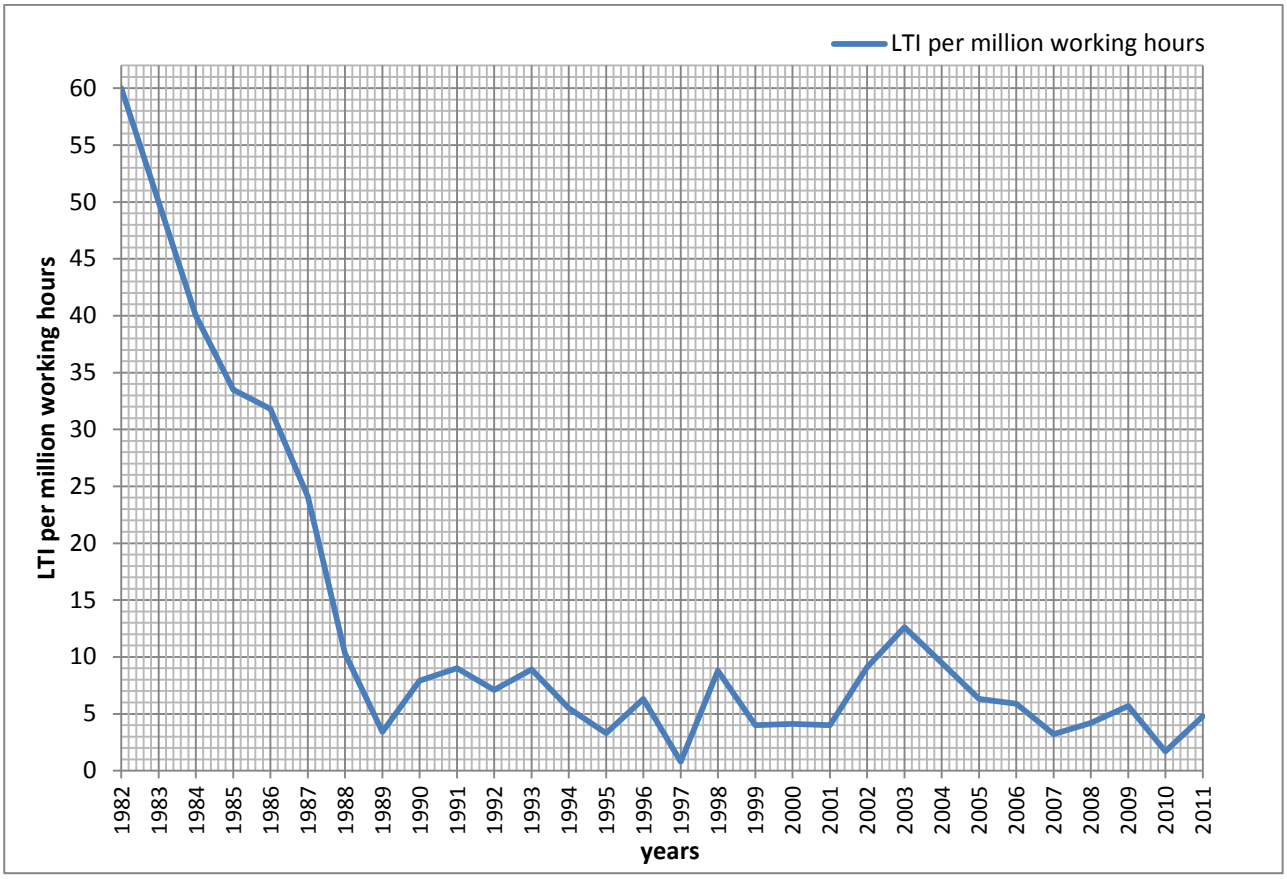
In the Danish sector, operating companies have managed to decrease the accident rate from 60 accidents per million hours in 1982 to 4.8 accidents per million hours in 2011 on fixed installations (Energistyrelsen, 2012). Although the number of accidents has decreased and the oil and gas industry has experienced lower accident rates compared to onshore industries, employees continue to become injured at work, and the frequency of injuries has stabilised over the last 20 years (see Figure 1).

Knowledge of accident prevention in the Danish oil and gas industry is considerably limited due to a lack of research. Most research regarding safety and accident prevention within the oil and gas industry originates in the United Kingdom (UK) and Norway.

Research on safety within the oil and gas industry

The highest intensity of the studies concerning the oil and gas industries can be found during the 1990s after the Piper Alpha and Kjellander accidents. Research on the oil and gas industry in that time focused mainly on risk perception and factors that influenced the perception of risk (Flin, Mearns, Gordon & Fleming, 1996; Flin, Mearns, O'Connor & Bryden, 2000; Mearns & Flin, 1995; Mearns, Flin, Gordon & Fleming, 1998; Mearns, Flin, Gordon & Fleming, 2001a; Rundmo, 1992a; Rundmo, 1996b; Rundmo, 2000; Rundmo, Hestad & Ulleberg, 1998; Rundmo & Sjoberg, 1996; Tharaldsen, Olsen & Rundmo, 2008). The results of these studies indicated that such factors as control over job, work conditions, accident

Figure 1 Lost-time incidents per million working hours on production installations in Denmark



Source: Danish Energy Agency and data from one of the companies.

experience, work experience, and management commitment to safety had considerable influence on risk perception (Fleming, Flin, Mearns & Gordon, 1998; Flin et al., 1996; Mearns & Flin, 1995; Mearns et al., 1998; Mearns, Rundmo, Gordon & Fleming, 2004; Mearns, Whitaker & Flin, 2003). Most studies on risk perception are questionnaire survey studies in which factor analyses are conducted and the association between risk perception and dimensions of safety climates is investigated. However, the focus in Norway is still intense, and several studies have been published more recently (Antonsen, 2009a; Antonsen, 2009b; Høivik, Moen, Mearns & Haukelid, 2009; Høivik, Tharaldsen, Baste & Moen, 2009; Tharaldsen et al., 2008). The Norwegian authorities—the Petroleum Safety Authority—have an on-going project, "Trends in risk level–Norwegian Shelf", which measures safety climate and risk perception on the Norwegian shelf.

Besides risk perception, research on the oil and gas industry focuses on other issues. One of the issues involves the role of safety representatives with regard to safety. The few studies conducted on this issue originated in the UK and Norway. Hart (2002), who has studied the involvement of safety representatives in safety within Norway, focused on the regulatory framework (macro level) and the perspective of the participants (micro level). The results of that study indicated that safety representatives in the oil and gas

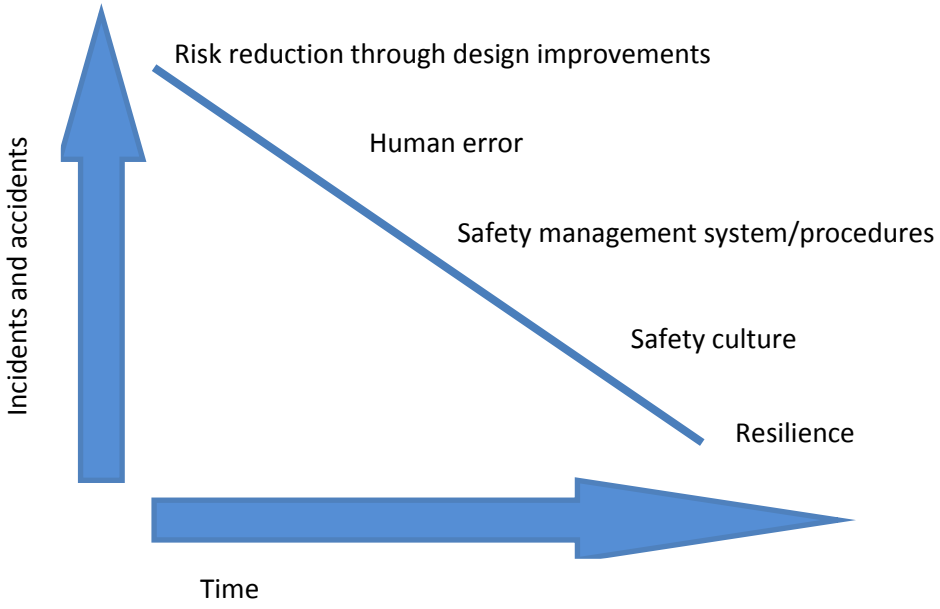
industry in Norway have difficulty in influencing safety. Similar conclusions can be found in the research from the UK (Hart, 2002; Spaven & Wright, 1998; Walters, 1996; Wright & Spaven, 1996).

More recent studies have shifted the focus from an examination of the relation between risk perception and safety climate to an examination involving a broader cultural understanding of safety with a focus on safety leadership (Mearns et al., 2003), including such issues as power and trust (Antonsen, 2009a; Tharaldsen, 2011), or on structural issues. In newer studies, qualitative methods are used to support and provide a deeper understanding of quantitative methods.

Contemporary safety approach—a historical review

Research on safety and accident prevention is not only conducted within oil and gas industry but has a long tradition that has developed over the years. Figure 2 illustrates the development of trends in safety research.

Figure 2 Developments in safety research



(Based on Hale and Hovden 1998)

The roots of safety research derive from the 19th century. At first, the main focus of safety research was on technical improvement of equipment, stopping explosions, or preventing structures from collapsing. In 1931, the first accident model, termed the domino model, was developed by Heinrich (1931). In this model, an accident is described as a chain of conditions and events that culminate in an accident. The model focuses on an unsafe act or unsafe condition in the workplace, considers them an important link in the chain, and suggests reduction of the unsafe act or condition. The domino model has significantly influenced the development of other accidents models, such as the Swiss cheese model and TRIPOD model (Glendon

& Stanton, 2000; Hale & Hovden, 1998; Heinrich, 1959; Kjellén, 2000a). The theoretical framework for this period was based on theories of accident proneness.

In the period between the two world wars and until the 1960s and 1970s, safety research was divided into two areas: the first area focused on technical issues and improvements in machinery, and the second area focused on accident proneness.

During the 1960s and 1970s, the development in probabilistic risk analysis and the increasing influence of ergonomics were the primary reasons for merging those two areas into a more integrated research field on human errors and human factors. During this time, other accident models were developed, such as the Swiss cheese model, which focuses on the chain of layers protecting the occurrence of incidents; sometimes the layers contained weaknesses, which created a hole in the layers. Too many holes could cause an accident (Reason, 1997).

Major disasters, such as Chernobyl in 1986, Piper Alpha in 1988, and Challenger in 1986, were reasons to change the focus of safety research to interest management systems, procedures, and organisational factors (Hale & Hovden, 1998). A focus on organisation was connected to a visible safety priority by the management and culture of organisations. Researchers became increasingly interested in safety managements systems and new concepts, such as safety culture and safety climate (Hale & Hovden, 1998).

Research on Safety Management System (SMS) focused on several issues like definitions and elements of SMS, creating SMS in organisations or effectiveness of it (Grote, 2012; Hale, 2003; Hale, Heming, Carthey & Kirwan, 1997; Hale & Hovden, 1998; Robson, Clarke, Cullen, Bielecky, Severin, Bigelow et al. 2007). There is no one clear definition of SMS. Some of the definitions are quite broad and some are more specific. SMS was adopted in the high risk organisations and organisations found their own models and definitions, however similarities between definition and the common major elements could be found. One of the examples of definitions comes from Civil Aviation Authority, which defines SMS as following:

> *"SMS is an organised approach to managing safety, including the necessary organisational structures, accountabilities, policies and procedures. It is more than a manual and a set of procedures and requires safety management to be integrated into the day to day activities of the organisation. It requires the development of an organisational culture that reflects the safety policy and objectives"(Civil Aviation Authority, 2008) .*

This definition focuses on the structure, policies and procedures, but also takes the culture and daily praxis into account. The most common components of SMS mentioned in research are:

- *Management commitment and resources*

- *Safety policy /Standards and procedures/ Goals and objectives*
- *Employee participation*
- *Safety resources and responsibilities*
- *Risk identification and hazard control system*
- *Safety performance measurements and monitoring /Auditing and evaluating system*
- *Incident reporting and investigation*
- *Safety training*
- *Continuous improvement*
- *Management of change (Grote, 2012; Robson et al., 2007)*

Lack of the single definition of SMS has an influence on the model of SMS, which means that there are several models, which are created by researchers or organizations and which suit best to their goals. In figure 3 four different SMS models are presented.

The first presented model in figure 3 focuses on four different components such as: safety policy, safety assurance, safety risk management and safety promotion. This model is quite simple, however it includes several components. The second model (next to the first one) includes 10 different components. Somehow this model is not very different from the first one, but goes more to the details. The third model is inspired by Rasmussen (Rasmussen, 1997) and focuses not only on the different components but also shows the flow and interactions between the elements of the components included in the model. The fourth model comes from the Health and Safety Executive (HSE) for the oil and gas industry in UK. This model focuses more on factors like organisation, risk control and human factors (HSE, 2007).

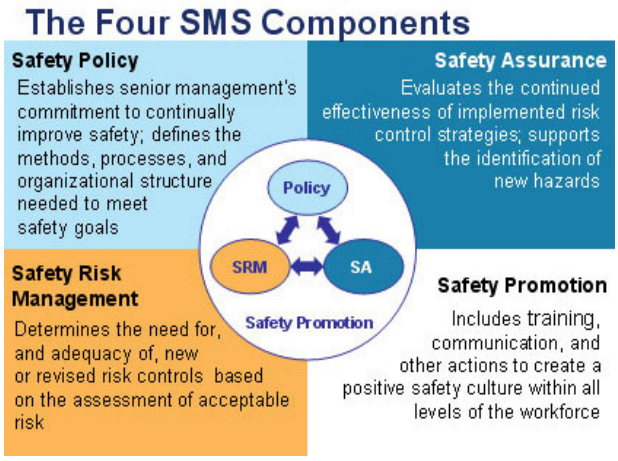
Another concept mentioned before, which had an interest in safety research and is connected with SMS, is safety culture. One of the most prominent safety culture definitions derives from the reports written after the Chernobyl disaster. The International Atomic Energy Agency (IAEA) defined the safety culture of an organisation as:

"*the product of individual and group values, attitudes, perceptions, competencies and patterns of behaviour that determinate the commitment to and the style and proficiency of an organisation's health and safety management. Organisations with a positive safety are characterised by communications founded on mutual trust, by shared perceptions of the importance of safety and by confidence in the efficacy of preventive measures" (Advisory Committee on the Safety of Nuclear Installations (ACSNI), 1993)).*

In the safety research field, there are different opinions regarding whether safety climate and safety culture are the same. Safety culture is typically seen as a broader concept than safety climate. Guldenmund (2000) suggested that safety climate refers to attitudes towards safety in the organisation, whereas safety culture

concerns the actual value of specific social groups in the organisation (Guldenmund, 2000). According to Cox and Flin (1998), safety climate is often regarded as an indicator of the perception by an employee of the safety culture in an organisation at a given time (Cox & Flin, 1998; Mearns & Flin, 1995).

Figure 3 Different Safety Management Systems' models



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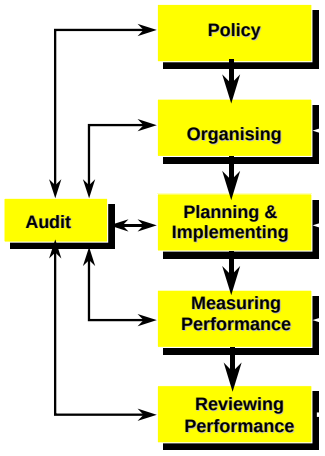
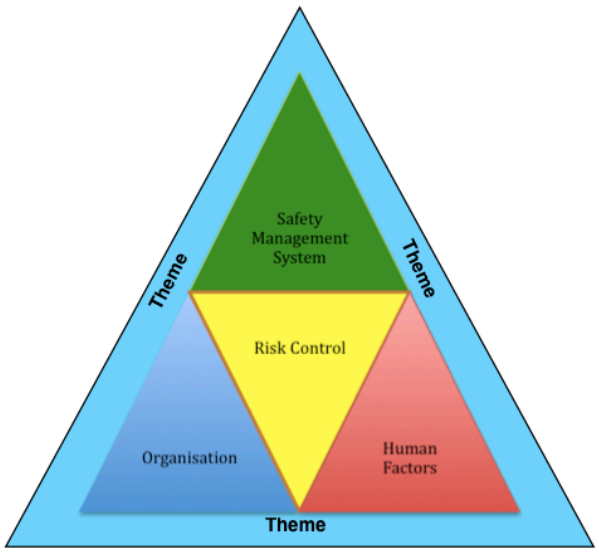


Based on Rasmussen (1997)



HSE (2007)

The discussions about impact of safety culture on accident prevention are still relevant and on-going, but the complexity of the systems makes the prevention even more complex and safety culture concept is not able to explain all the mechanisms in the organisation. Therefore the theoretical framework was developed further. The newest theoretical trend in safety research, which should cope with complexity of systems and

accident prevention, is resilience. Resilience engineering is a paradigm for safety management. Resilience is defined as follows: *"the ability of a system or an organisation to react to and recover from disturbances at an early stage, with minimal effect on the dynamic stability. The challenges to system safety come from instability, and resilience engineering is an expression of the methods and principles that prevent this taking place"* (Hollnagel, Woods & Levson, 2006). The resilience theoretical framework also developed accident models, which include dynamic models, such as Rasmussen's model (1997), and the safe envelope concept (Hale & Borys, 2013).

Aim of the thesis

The historical review showed that different theories have existed over the years. Furthermore models and points of view have had an influence on safety and accident prevention. However, the knowledge about accident prevention in Danish oil and gas industry is quite limited and number of injuries has been stable for the last 20 years. This thesis is the first study conducted on safety in the Danish oil and gas industry. It is a descriptive study that will explore state-of-the-art methods for safety and accident prevention on production installations in the Danish Sector of the North Sea. The overall objectives of the study are as follows:

- To identify the possibilities and challenges for preventing accidents within the Danish oil and gas industry
- To contribute new knowledge on accident prevention to a high-risk industry that could be useful for other sectors

Research problem

The overall research problem is defined as follows:

What are the possibilities and challenges for accident prevention in the Danish oil and gas industry?

The complexity of the accident prevention presented in the historical overview makes it impossible for this thesis to cover all the aspects of accident prevention. The main research problem is very broad and there is need for more specific questions. In the following, the chosen aspects of accident prevention will be described. This will lead to a conceptual model of the thesis and the more specific research questions.

As mentioned before in description of SMS there are several aspects of prevention of accident and control of safety. The choice of the aspects is based on the literature review in the safety research with most focus on issues explored in the research within the oil and gas industry (Fleming et al., 1998; Flin et al., 1996; Flin et al., 2000; Hart, 2002; Health and Safety Ececutive, 2009; Hovden, Lie, Karlsen & Alteren, 2008; Leveson, 2011; Mearns, Flin, Gordon & Fleming, 2001b; Pidgeon & O'Leary, 2000; Rundmo, 1995; Rundmo, 1996a; Rundmo, 2000; Rundmo et al., 1998; Rundmo & Sjoberg, 1996; Spaven & Wright, 1998; Tharaldsen et al.,

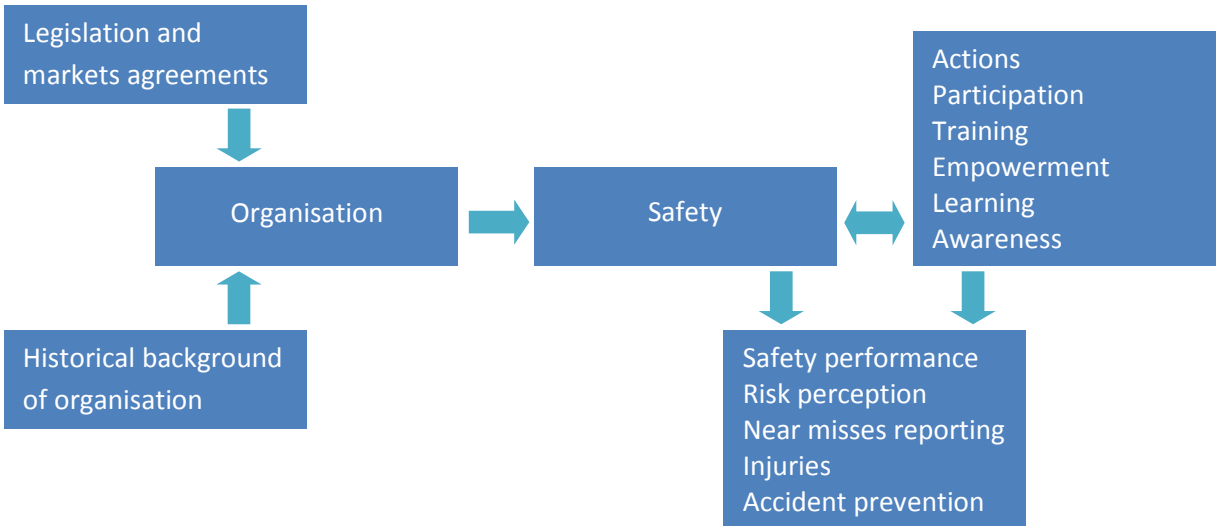
2008; Walters, 1996). Figure 4 shows the starting point of this thesis and the issues chosen. The thesis focuses on the several levels:

- macro level – legislation
- mezzo level – organisation
- micro level – the employees

The conceptual model presents the relation between the different aspects of accident prevention. On macro level is the legislation which have impact on the organisation dictating the general frame of safety work, risk control and how they should be executed within organisation. On the mezzo level is organisations way of the controlling risk and promoting safety through learning, training and involvement of employees. All those efforts give the results in the safety performance indicators and are connected to the micro levels, employees' resources and possibilities in improving safety.

Compared to the SMS models, the conceptual model (figure 4) in this thesis is very simple and is an attempt to simplify accident prevention and the visual presentation of issues explored in the thesis. The issues chosen in the model are based on different theoretical frameworks, which will be presented in the theoretical chapter. The overall theoretical approach comprises structural theory with an assumed duality of structure, in which the structure influences the agents but the agents also have an impact on the structure (Giddens, 1984).

Figure 4 Conceptual model of the thesis



The left side of the conceptual model includes a structure in the form of national legislation and labour market agreements, which influence the organisation and its structure. The structure of an organisation has an impact on safety, which determines the daily praxis and initiatives performed within an organisation (the box on the right side of the model).

The safety of the organisation is reflected in its safety performance and practice. In the box on the right side of the conceptual models, there are several chosen factors, such as participation, training, empowerment, learning, and awareness, regarded as outputs of the safety of an organisation. The selection of those factors is determined by certain sociological theories, such as social leaning theory, the theory of the role, and empowerment theory and the results of the research conducted within the oil and gas industry (Fleming et al., 1998; Flin et al., 1996; Flin et al., 2000; Hart, 2002; Health and Safety Ececutive, 2009; Høivik et al., 2009; Hovden et al., 2008; Mearns & Flin, 1995; Mearns et al., 1998; Mearns et al., 2001b; Mearns et al., 2004; Mearns et al., 2003; Rundmo, 1992a; Rundmo, 1992b; Rundmo, 1995; Rundmo, 1996a; Rundmo, 2000; Rundmo et al., 1998; Rundmo & Sjoberg, 1996; Spaven & Wright, 1998; Tharaldsen et al., 2008).These factors, combined with the safety of an organisation, have an impact on safety performance. The selected safety performances include the following: risk perception, near-miss reporting, and injury and accident prevention. However, this thesis describes risk perception and near-miss reporting in more detail.

Based on current research within safety and accidents prevention both onshore and offshore and the components used in SMS, this thesis will focus on three different issues within accident prevention in the Danish oil and gas industry :

- Involvement of employees (here safety representative) in safety work
- Organisations learning with focus on near-misses
- Employees risk perception and their attitude to safety

With focus on those three issues the thesis explores the possibilities and challenges in accident prevention within the Danish oil and gas industry. To address this main research objective, the following four questions will be answered:

1. ***How do organisations within the Danish oil and gas industry involve safety representatives in safety work?***
2. ***How do organisations within the Danish oil and gas industry learn from their near-misses?***
3. ***Which organisational and human factors influence risk perception among Danish offshore employees?***
4. ***How are risk perception and attitudes regarding safety distributed among Danish and Norwegian offshore employees?***

The first question primarily explores the first part of the conceptual model, with a focus on safety representatives and their role in safety within an organisation compared to legislation. The second question explores the box on the right side of the conceptual model, which examines the concept of learning from near-misses. The third question and fourth explore safety performance, which is based on risk perception.

In the third question the focus is on which organisational and human factors have an influence on risk perception among Danish offshore employees while the fourth question examines how are risk perception and attitudes regarding safety distributed among Danish and Norwegian offshore employees.

The thesis uses the mix methods model design, which provides the possibilities of asking different questions and triangulation of the data. The quantitative methods - survey data are used to measure the relationship between risk perception and safety climate dimensions by testing hypotheses that safety climate dimensions will influence risk perception. Furthermore, involvement of the safety representatives in safety and learning from near-misses is explored using interviews with offshore employees, document analyses, and observations on production installations in the Danish portion of the North Sea.

Structure of the thesis

The thesis is divided into two main parts. Part I consists of six chapters, which constitute the overall framework for the thesis, whereas Part II includes four articles. In Part I, chapter one introduces the aims, main research problem, research questions, and conceptual model of the thesis, and chapter two describes the industrial context. The theoretical framework is presented in chapter three, followed by a presentation of methods in chapter four. The main results are briefly presented in chapter five and discussed in more detail in chapter six. The last chapter in Part I present the conclusions of this thesis.

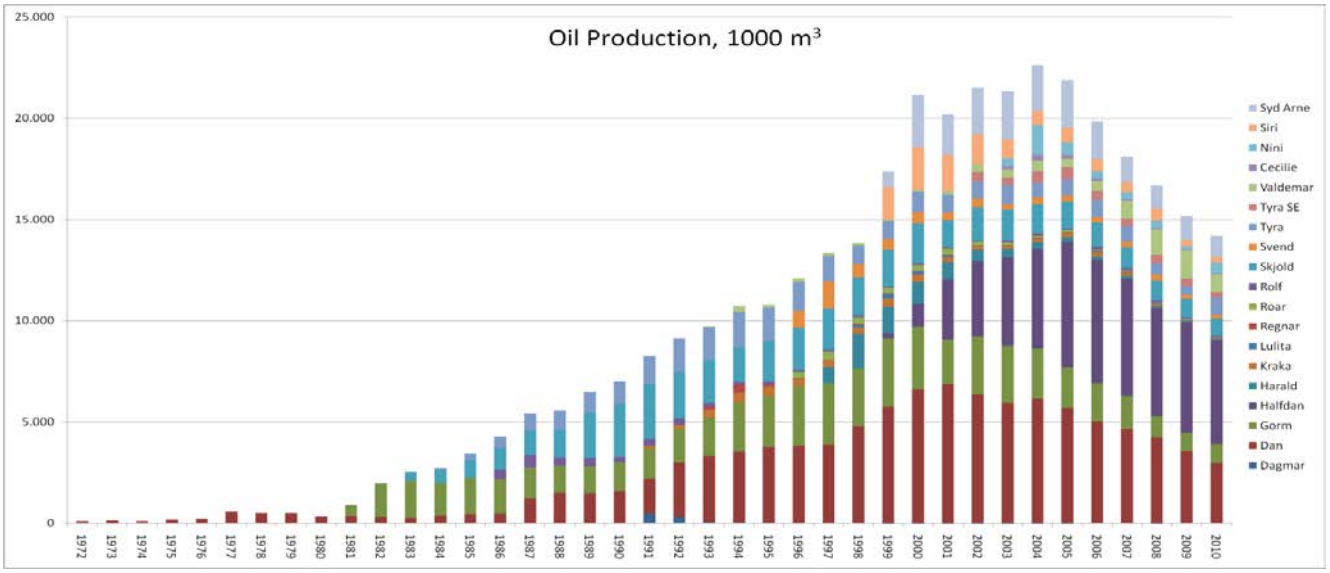
Overview of the articles:

1) The safety representatives' roles and dilemmas in the Danish oil and gas industry. Rasmussen, Hanna Barbara, Hasle Peter, and Andersen Tanggaard Pernille, *Policy and practice in health and safety (submitted)*
2) Can we use near-miss reports for accidents prevention? A study in the Oil and Gas industry in Denmark. Rasmussen Hanna Barbara, Drupsteen Linda, Dyreborg Johnny, *Safety Science Monitor (submitted)*
3) The impact of human and organisational factors on risk perception on Danish production platforms. Rasmussen, Hanna Barbara: Advances in Safety, Reliability and Risk Management. red. / Christophe Bérenguer; Antoine Grall; Calros Guedes Soares., Taylor & Francis, 2012. s. 1240-1245
4) The impact of safety climate on risk perception on Norwegian and Danish production platforms. /Rasmussen, Hanna Barbara; Tharalsen, Jorunn Elise. I: Advances in Safety, Reliability and Risk Management. red. / Christophe Bérenguer; Antoine Grall; Calros Guedes Soares, Taylor & Francis, 2011. s. 1833-1939.

Industrial context

Oil and gas are important sources of energy in Denmark. In the years prior to the discovery of oil and gas, Denmark was dependent on imported energy and oil from other countries. After the oil crises in 1970, the Danish government decided to reduce Denmark's energy dependency on other countries. Oil and gas in Denmark was first discovered in 1966; oil production began in 1972 from Dan field, and the production of gas commenced in 1984. The production of oil and gas has increased since that time; since 1997, oil and gas demand has been met. However, production has decreased over the last few years. In 2011, there were 19 oil and gas production fields in the Danish sector of the North Sea, with 55 offshore production installations, of which 10 are manned. The remainder are controlled automatically from the manned platforms.

Figure 4 Oil production in Denmark

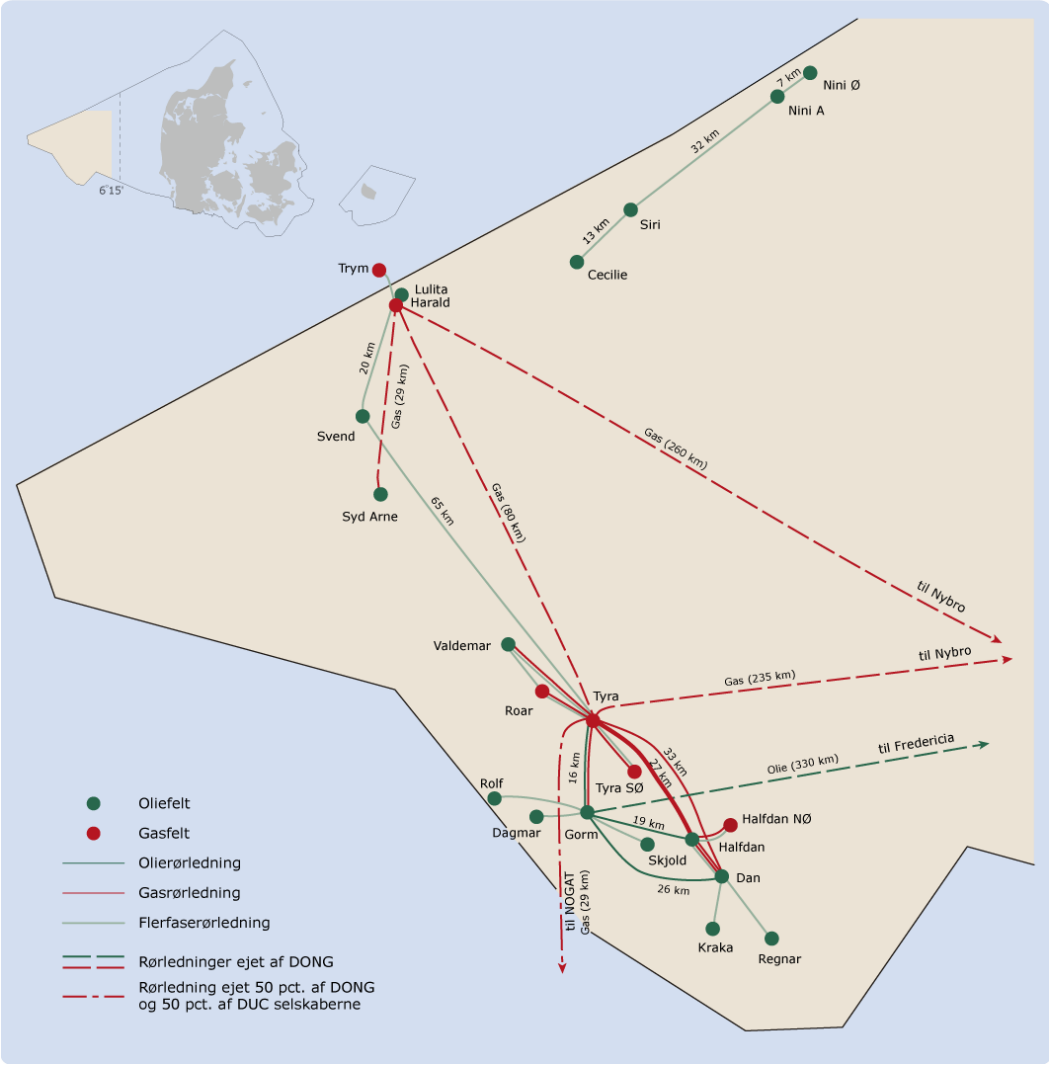


Source: Danish Energy Agency

A total of 10 companies contribute to the Danish production, but only three of the companies serve as operators. The largest company accounted for 86% of the oil production and 97% of the gas production in 2011. During 2011, the production in the North Sea occurred in 278 active production wells, of which 199 were oil wells and 79 were gas wells. In addition, 109 active water-injection wells and six gas-injection wells contributed to an overall production (Energistyrelsen, 2012). Total oil production in 2011 was 12.8 million m^3, constituting a 9.8% decline compared to 2010. This recent decline reflects the trend of oil production since 2005, which has continued downwards at the rate of 3-9% annually. Total gas production in 2001 was 6.5 million Nm^3, which is 21% higher than total gas production in 2010. This decreasing trend is partly due

to the ageing nature of oilfields in Denmark (Energistyrelsen, 2012). Figure 5 shows the production fields in the Danish sector.

Figure 5 Overview of the production fields in the Danish sector



Source: Danish Energy Agency

The production of oil and gas has made an impact on Denmark's economy; the income from the production to the Danish state in the form of taxes and other duties is approximately 30 billion Danish Kroner. In addition to the income to the state, the oil and gas industry employs a significant number of people both onshore and offshore, which also contributes to the national economy (DEA, 2012).

Danish legislation

Legislation is an important factor influencing work safety within the oil and gas industry. Legislation regarding the oil and gas industry exists on an international level in the form of directives from the EU and on the national level in the form of legislation and executive orders. There are several regulations governing the Danish oil and gas industry; however, only the Offshore Safety Act (OSA) and executive order 1504 of 15 December 2010 are briefly presented in this thesis.

Although oil production began in 1972, the first legislation concerning occupational health and safety that was applicable to the offshore sector was not adopted until 1981 as the Offshore Installations Act (havanlægsloven). This piece of legislation was replaced by the OSA on 15 December 2005, which became effective on 1 July 2006. The new legislation was expected to promote high standards of offshore safety and health, which would be consistent with the technical and social progress in society and follow the changes that were implemented onshore in relation to effective environmental legislation. The legislation was largely inspired by an effective environmental legislation, although it has been modified for offshore conditions (, 2012b).

The Offshore Safety Act

The OSA consists of 10 parts. The first part entails the objectives, scope, and definition. The second part describes the distribution of responsibility for safety between the different parties, including operators and employees.

Part two of the OSA focuses on the obligation to operators. Some of the obligations include the following: ensuring that necessary safety and health instructions are provided to contractors who work on the installation; appointing an offshore installation manger (OIM) and ensuring that safety and health risks on the offshore installation have been identified, assessed, and reduced to the extent practically feasible. In addition to the obligations of the operators, part two emphasises the participation of employees in safety and health and their obligation to inform their supervisors or management on the installation of dangerous conditions. The employees also have the right to leave the workplace in the event of serious danger that cannot be avoided without consequences for their employment.

Part three focuses on management systems for ensuring safety and health. The operating company shall establish and maintain a management system for safety and health that ensures and documents that conditions, operations, and maintenance conform to the safety requirements provided in the OSA.

Part four addresses several issues, including construction, arrangement, and equipment; safety and health work; training and qualifications; working hours; registration and reporting; and work performance. The operating company shall ensure that the safety and health work is organised in collaboration with the employees. The employees or their representatives shall be involved in the planning of work performance and changes to offshore installations with regard to safety and health matters. The employer shall ensure that employees have adequate education and are instructed on their jobs. The operating company shall report accidents and other conditions that are important from a safety and health perspective to the supervising authority.

The other parts of the OSA contain descriptions of offshore safety councils, supervision, the complaints procedure, civil law, penalties, and information concerning the effective period of the legislation. In

addition to the OSA, there are executive orders that explain OSA issues in further detail. The executive order about safety work and offshore organisation will be briefly presented here.

According to executive order number 1504 of 15 December 2010, every installation that has more than five employees is required to have a safety organisation consisting of employee and management representatives. The employee representatives are elected for a two-year period. The operator of the installation is required to appoint a supervisor (foreman) in each workgroup on the installation who, together with the employee representatives, comprises the safety group at the installation. Safety groups are selected from each workgroup and, together with the representative from the operating company, comprise a safety committee. The executive order for health and safety work on fixed platforms defines the tasks, duties, and rights of the safety group in these terms:

1. ensuring that working conditions are completely satisfactory
2. influencing the individual in a behaviour that promotes the safety and health of others and themselves
3. participating in the planning of safety and health activities at work and risk assessments
4. participating in the investigation of accidents
5. acting as a liaison between employees and the safety committee

Safety groups may order to stop working if conditions become too dangerous (, 2012a).

Organisational structure and working patterns

The oil and gas industry has a special organisational structure compared to onshore organisations. As mentioned previously, a total of 10 companies contribute to the oil and gas production. Each of these companies has permission to explore and produce hydrocarbons and hold licenses, but only three of the companies are currently operational. An operating company is one that on behave on licensee carries out exploration and recovery of hydrocarbons. The operating companies are responsible for day-to day operations of an offshore installation. However, these companies do not perform all activities on the installation. The operating companies provide the core crew, which includes management of the installation, supervisors, and technical employees in the control room. The size of the core crew is quite stable and is approximately one third of the crew on the installation. The remaining employees originate in contracting companies. The contractor is the company that performs the work for the operating company. The number of employees from contracting companies varies and is dependent on the activity on the installation.

The operating companies in the Danish sector of the North Sea differ in their background, which impacts their approach to the organisation of safety and accident prevention. Table 1 shows the main features of the companies included in the study.

Table 1 Features of case studies in the Danish North Sea

Company A	**Company B**	**Company C**
o Public limited company with the state as its major shareholder o Oil and gas production are not the main production; the company takes over production from other company o Leadership is quite insipid, but the company has features of publicly owned companies o Large and constantly growing with several offices	o Privately owned o Background in the maritime industry; oil and gas is not the main production but only part of the enterprise o Leadership is more hierarchical in the maritime industry o Large company with one main office and some smaller offices	o Private foreign company o Background in the oil and gas industry o Leadership is quite insipid o Large company with a main office abroad; however, the office in Denmark is not as large

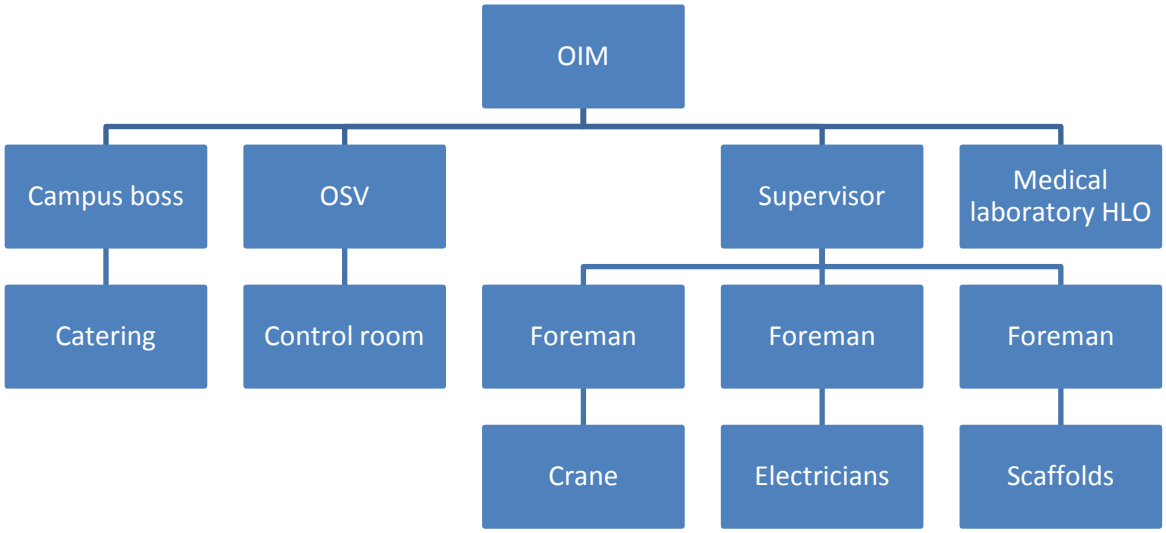
The Danish oil and gas industry is characterised by offshore production, whereas the management, planning, and support of the production are established onshore. Onshore is divided into different units, such as support for offshore, exploration, production, and the Health, Safety, and Environmental Department. The Health, Safety, and Environmental Department is a consulting unit for offshore activities and assists with safety improvements, organising safety campaigns and conducting internal safety audits on the installations.

Figure 6 shows an example of the structure of an installation. The main responsibility on the installation belongs to the Offshore Installation Manager (OIM), which is also an administrative function; the OIM refers to the onshore management. The OIM is responsible for the overall safety and health conditions on the offshore installation and for ensuring that the installation is operated in accordance with existing legislation (, 2012b). The Operational Supervisor (OSV) is responsible for the production and refers to the OIM. The crew contains different groups, all of which have supervisors/foreman. The division of groups depends on the size of the installation; on some installations the construction group includes maintenance, whereas maintenance will comprise a separate group on larger installations. Catering, the medic, and laboratory technicians constitute separate groups, each of which refers to the OIM.

Figure 6 is an example of the hierarchy of an offshore installation, in which the groups could be different. Operators' employees are always at the top of the hierarchy, and at the bottom of the hierarchy are predominantly contractors. The education of offshore employees varies from uneducated employees to highly specialised technicians. Most offshore employees work shifts consisting of two weeks offshore and three weeks at home. Some groups, such as catering or the medic, are given two weeks on and four weeks

off. The rotations on the installation require that employees during their two weeks will have two different OIMs or two different foremen during their two-week shifts.

Figure 6 Example of the installation structure



Theoretical framework

Safety research constitutes a cross–disciplinary research field, which means that theoretical frameworks in the field are inspired by different fields of science, such as sociology, psychology, anthropology, and engineering. This thesis mainly uses a sociological point of view but also incorporates some elements of health promotion. The project focuses on accident prevention, which is considered a broad and multilevel approach. The theoretical framework used in the thesis is presented in this chapter. The chapter presents chosen theories and concepts. The first concept is culture and organisational culture, which are followed by learning and risk perception.

The main theoretical frame for the thesis is structural theory, and the main aspect is the duality of structure. Social structure, according to Giddens, can be defined as products of interaction that provide objectified rules and resources for this interaction (Giddens, 1984). He stated that *"the constitution of agents and structures are not two independently given set of phenomena, a dualism, but represent a duality*" (Giddens 1984, p.25). Structure is not "external" to individuals but more "internal", as emphasised by Bourdieu, such that we are so much a part of the structure that we do not notice its existence (Bourdieu, 2004). In relation to the conceptual model, the duality of the structures could be explained as an influence of legislation on the organisation but also as a potential for the organisation to influence the structure. On the mezzo level, such duality means that an organisation has an existing structure with certain patterns, which creates the framework for employee interaction. When employees enter an organisation, they are introduced to the existing structure, which has an influence on interaction patterns; conversely, employees influence, create, and reproduce the structure though interactions (Giddens, 1984). The organisation creates the framework for accident prevention and "forces" this framework on employees. Through socialisation processes, employees adopt the existing structure and culture, but as active agents, they interact and attempt to change the structure.

Organisational culture

As mentioned previously, every organisation has a structure that provides the framework for interactions. This structure, which is created by the organisation, has an impact on the attitude of the organisation to safety. Another element of the organisation that influences safety is the culture of the organisation. However, what does culture mean? How can it be defined? Defining culture is not an easy task because the concept is very broad. Most definitions of culture relate to a common way of thinking, feelings, rules, and norms, which indicate construction or common practices (Alvesson, 2002). Alvesson defined culture as follows:

"Culture is not primarily 'inside' people's head, but somewhere 'between' the heads of a group of people where symbols and meanings are publicly expressed, e.g., in work group interactions, in broad meetings but also in material objects. Culture then is central in governing the understanding of behaviour, social events, institutions and processes. Culture is settings in which these phenomena become comprehensible and meaningful" (Alvesson 2002: 4).

Organisational research can be characterised by several perspectives in defining culture. One perspective is the distinction between the functionalist and interpretative approaches (Glendon & Stanton, 2000). Functionalist approaches assume that an organisational culture exists as an ideal that organisations should try to achieve. This approach is top down, which assumes that the primary function of organisational culture is to support management strategies, systems, and goals. The interpretative approach assumes that organisational culture is a complex phenomenon of social grouping, which aims to assist members of the organisation in interpreting their collective identities, beliefs, and behaviours. Organisational culture is not the property of any one group or individual but is created by all members of an organisation. An interpretative approach is more likely to be considered a "bottom up" approach and allows for existents of subcultures within organisations (Glendon & Stanton, 2000).

Another distinction divides organisational culture into the following three perspectives: integration, differentiation, and fragmentation. From the integration perspective, culture is often viewed as the 'glue' of an organisation or as a 'compass' that provides direction to members of the organisation (Alvesson, 2002). Culture is a shared understanding in the organisation and could be characterised by a high consensus between the members of the organisation, consistency among different cultural aspects, and clarity of cultural traits (Antonsen, 2009b; Richter & Koch, 2004).

The differentiation perspective focuses on the coexistence of different groups and cultures in the organisation. In the larger organisations, the existence of a complex division of labour signifies that some of the communication and interaction will occur in subgroups. Those subgroups will create the local culture with a common understanding of their practice. The differentiation perspective focuses on consensus within subgroups and attempts to uncover conflicts and power relationships within organisations. While the integration perspective focuses on consistency, the differentiation perspective focuses on inconsistency between different aspects of the culture of an organisation, e.g., differences between words, action, official values, and real-life practices. This inconsistency could be compared with Goffman's concepts of the front stage and backstage of social life (Antonsen, 2009b; Goffman, 1959).

Finally, the fragmentation perspective views an organisational culture as a *"web of individuals, sporadically and loosely connected by their changing position on a variety issues"* (Martin 1992:153). In this perspective, members of an organisation construct their own definition of reality and there is no predefined cultural script that provides guidance for behaviour (Antonsen, 2009b).

Based on the different definitions and perspectives, it is necessary to determine the standpoint of this thesis. My standpoint is a forward interpretative definition of culture, where culture is created in day-to-day interactions; however, based on Giddens, Berger, and Luckmann (1966), those interactions create lasting patterns for behaviour. According to Berger and Luckmann, the social reality is both objective and subjective. It is subjective because this reality is created by interactions between individuals in a community, but it is also objective because these interactions existed in a given form and are perceived by members of a community (organisation) as if they were not human products (Antonsen, 2009b; Berger & Luckmann, 1999).

The structural theory and organisational culture is the overall theoretical framework but cannot stand alone in the exploration of accident prevention. The structural theory explains the relation between agent and structure but does not provide an explanation that enables an agent to act and influence the structure. Other theories, such as learning theory, the theory of the role, and empowerment theory, can provide a more detailed picture of the ability of an agent to influence the structure and organisational culture. In the following section, social learning theory will be presented.

Learning

Learning is critical for accident prevention. This thesis focuses on two different types of learning: individual learning and organisational learning. To understand individual learning, social learning theory, the theory of the role, and empowerment theory are used and in relation to organisational learning. The Kjéllan model of learning from experience is also utilised. In the following section, the theories utilised are briefly described and presented.

Learning on an individual level

In the thesis, learning on an individual level consists of three theories: social learning theory, the theory of the role, and empowerment theory. Social learning theory focuses on how environmental and cognitive factors interact to influence human learning and behaviour. The main message of social learning theory is that learning occurs within a social context. It considers that people learn from one another, including such concepts as observational learning, imitation, and modelling. The primary focus of social learning theory is on learning by social participation, which refers to the process of being active participants in the practices of social communities and constructing identities in relation to different contextual communities (Wenger E., 1999). The learning process contains different elements, such as learning through practice and within the community. What we learn should be meaningful because we create our identities through the learning process. According to social learning theory, relationships are created around activities and activities form through social relationships and experiences of those who perform them. In this manner, knowledge and

skills become a part of individual identities. Knowledge about safety is culturally mediated through social participation and is historically rooted in the cultural heritage of an organisation through procedures. New members learn safety culture and practices through participation in the community on an equal basis with their education and training (Gherardi & Nicolini, 2000). Gherardi and Nicolini applied this theory in their safety research. According to these authors, safety is taught in communities of practice and knowledge about safety is communicated through social participation and historically anchored in the cultural heritage of the organisation through procedures (Gherardi & Nicolini, 2000). Safety is a competence that is practiced, socially constructed, and transferred to new members. Learning safety means knowing how to behave as a competent member of the culture of safety practices. This approach fits well with structural theory and the duality of the structure because it focuses on membership within an organisation and interaction between members of an organisation and community of practice. Social learning theory is used in this thesis to explore the participation of safety representatives.

In the process of learning in the community of practice, empowerment and roles are elements that can support learning. Role is an important sociological concept that provides the pattern according to which the individual acts in a particular situation. According to Berger, role can be defined as a typified response to a typified typology (Berger, 1967). There are two main approaches to the theory of social role. The first approach derives from symbolic interactionism. According to this approach, role is an outcome of the process of interaction. For symbolic interactionism, every role involves interacting with other roles, people in roles always test their conception of other roles, and responses of people in other roles reinforces or questions such conceptions (Mead, 1962). This process leads people to maintain or change their behaviour depending on the responses of others.

Another approach to role derives from functionalism. Linton viewed roles as essentially prescribed and static expectations inherent in particular positions. The prescriptions come from culture in society and are expressed in social norms that guide their behaviour in roles (Abercrombie, Hill & Turner, 1984). These two approaches are somehow contradictory in their interpretation of role and potential to create a role, but they are very useful in the exploration of role. Rather than select one of the approaches in this thesis, I explore the role of safety representatives with regard to both approaches and examine which approach more closely mimics reality in the companies within the Danish oil and gas industry.

The last concept is empowerment, which is connected to learning on an individual level and allows the agents to influence the structure. Empowerment is a concept for which there are many definitions but little consensus about their meaning. Empowerment may be viewed on different and interlinked levels, as well as on individual, psychological, and organisational/community levels. Empowerment is strongly associated with power relations, the capacity of participation, and the distribution of power in an organisation or

society (Andersen, Jorgensen & Larsen, 2010). The potential for empowerment depends on two factors—empowerment requires that power can change and expand (Czuba, 1999). Based on these findings, empowerment is assumed to be a process that fosters power. There are several definitions for empowerment, but Wallerstein's definition is used in this thesis. According to Wallerstein, empowerment can be defined as "a social-action process that promotes participation of people, organisations, and communities towards the goals of increased individual and community control, political efficiency, improved quality of community life and social justice" (Wallerstein, 1992). The definition emphasises the importance of empowerment as a multilevel construct. Empowerment is mostly used in connection with health promotion research and practice but also provides a theoretical framework for analysing participation and power relations in safety research as a social-action process towards a goal of increased safety.

All of these theoretical frameworks contribute to an understanding of learning on an individual level and contribute to exploring the first research question (see p. 17).

Learning on an organisational level

On an organisational level, the learning approach is inspired by two models. One model derives from Drupsteen et al. (Drupsteen, Groeneweg & Zwetsloot, 2012) and describes seven necessary steps for learning from incidents. Drupsteen et al. described learning from events as an organisational process, in which events, such as incidents, are analysed and used to improve the organisation and prevent future occurrences (Drupsteen et al., 2012). The "'learning from events process" consists of sequential stages: reporting a situation, analysing the situation, making plans for improvement, performing those plans, and evaluating their effect and the learning process itself. This process could be applied to near misses as a specific type of event from which to learn. Drupsteen et al. used the learning process model to identify where in the process the main limitations occur and to determine the differences between the formal learning processes (i.e., how the steps are to be performed according to formal rules and procedures) and actual learning process (i.e., how the steps are performed in daily practice)(Drupsteen et al., 2012). The results illustrated that formally organising the steps, such as by reporting, does not necessarily lead to the successful performance of those steps in daily practice. The second article focuses on the first steps of learning—reporting and analysing information—to identify the lessons that require learning.

Another model used in connection with organisational leaning is the Kjellén model for learning from incidents. The model presents a comprehensive approach for accident investigation on three levels. On the first level, accidents or near misses are reported and investigated by the first-line supervisors. After the investigation, remedial actions are implemented. Frequent or severe events are investigated by a problem-solving group that suggests actions; these investigations are second-level investigations. For a third-level

investigation, an independent investigation commission investigates incidents of major severity. Based on the recommendations from the commission, such actions as changes in procedure or other improvements are implemented.

According to Kjellén, minor incidents can be divided into two categories: incidents that occur once and incidents that occur frequently. The investigation of singular incidents is primarily focused on the correction of the deviations, i.e., the direct preventive effect, whereas the investigation of frequent incidents is aimed at changing the contributing factors in the workplace, e.g., organisational strategies and procedures. The investigation of serious incidents is mainly aimed at identifying 'root causes' and typically results in recommendations. In this thesis, the Kjellén model for accident investigation is used to evaluate the process for handling near misses and exploring the feasibility of learning from them or potential barriers to this type of learning (Kjellén, 2000a).

Apart from the Kjellén model, the Van Court Hare hierarchy of feedback, which is based on the experiences of traditional industrial and military organisations, is also used in connection with organisational learning. According to Van Court Hare, there are five levels of system order, from level 0, with no feedback, to level 4, which includes a goal-changing system. Van Court Hare emphasised the importance of organisational memory to allow for learning from near misses. The first level is characterised by a very simple system with no memory storage or feedback; the second level includes feedback but without selective memory. The third level is a tactical system, which evaluates and acts on a wide range of inputs. The fourth level involves learning, which indicates that it represents a system that has the ability to not only evaluate and act but also to learn and develop new plans and decisions based on experience. The fifth level is the goal-changing system, which is characterised by developing, selecting, and implementing new and improved goals (Van Court Hare, 1967a).

The theoretical approach to learning on the organisational level is used to answer the second research question (p.17).

Risk perception

The last part of the conceptual model concerns safety performance. In this thesis, the safety performance outcomes used are risk perception and near-miss reports. The theoretical framework for learning on an organisational level was presented in the previous section. This section will focus on risk perception.

Risk can be defined in different ways depending on science. Haukelid emphasised that the concept of risk is used in the fields of insurance, medical science, risk analyses, economics, psychology, social science, and anthropology and defined differently in each discipline (Haukelid, 2000). In the following section, the

definitions of risk and risk perception that are utilised in sociology and anthropology will be presented briefly. Those definitions will be related to the research on the oil and gas industry.

The definitions of risk perception are divided into two major types: objective risk and subjective risk. Objective risk relates to the estimations of probabilities of unwanted events and the potential consequences of these events (Bye & Lamvik, 2007; Haukelid, 2000). Subjective risk relates to individual feelings of danger or safety (Haukelid, 2000; Mearns & Flin, 1995).

Beck, a contemporary sociologist, focused on risk associated with technology in contemporary industrialised societies. He defined risk as *"a systematic way of dealing with hazards and insecurities induced and introduced by modernization itself"* (Beck, 1992 p.21).

In her article, Tierney (1999) argued that risk and risk estimates are socially constructed and focused on two general topics. The first topic involves social and cultural factors that influence the selection of "risk" and the definition of dangerous. The second trend is related to the social construction of objective (formal) risk analysis (Tierney, 1999).

Anthropology has contributed to our understanding of risk by analysing how different cultures view different risks and how existing risk perception supports the social order of society. Douglas stated that risk perception depends on social contexts. She did not neglect the existence of hazards but emphasised that which hazards we define as risks depends on our social and cultural contexts. According to Douglas, risk is a product of knowledge and agreement, which make it socially constructed (Douglas & Wildawsky, 1982).

Social science, including sociology, has been dominated by the psychological and social psychological definition of risk. Psychology and social psychology focus on how individuals perceive various risks, what factors enter into the estimation of risk, and how people make risk-related choices based on their knowledge. A central notion in psychology is that people have difficulty understanding risk information and are not able to estimate risk precisely (Tierney, 1999).

Sociologists view risk and risk estimates as socially constructed. Events through social constructionist approaches indicate that risk is socially constructed; it does not claim that hazards and harm do not exist. Instead, sociologists believe that the "sociological task is to explain how social agent create and use boundaries to demarcate that which is dangerous" (Clarke & Short, 1993 p.379).

In social science, an understanding of risk is also connected to the outcome of organisational decisions. An example of organisational decisions is the Challenger accident. In her article on the Challenger accident Vaughan concluded that "*when technical systems are assigned low, moderate, or high risk potential without considering the organizations that produce and run them, the risk is always greater than we think*" (Vaughan, 1989 p.346).

Research on the oil and gas industry has also discussed the definition of risk and risk perception. Rundmo and Mearns distinguished between objective and subjective risk (Mearns & Flin, 1995; Rundmo, 1996a). Objective risk is defined by experts as the probability of unwanted dangerous events and their consequences. Mearns defined subjective risk as a person's beliefs, attitudes, judgments, and feelings about hazards, danger, and risk taking within the wider context of social and cultural values. Rundmo also noted that the perception of risk by an employee and their subjective view of their working conditions may influence their objective risk of safety. According to Rundmo, subjective risk can be a predicate of objective risk (Rundmo, 1996a).

In this thesis, the definition of risk perception is inspired by the Mearns definition about a person's belief, attitude, judgment, and feelings about hazards, danger, and risk taking, but some of the social construction approaches are also used in the discussion of the results (Mearns & Flin, 1995).

This theoretical approach is used to answer the third and fourth research questions (p.17).

Summary

The theoretical framework presented in the above sections is the background for this thesis and helps to explore the research questions and general research problem. The theoretical framework describes the mechanisms in the conceptual model. The choice of theoretical framework could be different and focus more on the safety research and the theoretical framework within safety research, but my background as a sociologist determined the choice of theoretical framework. In this thesis, I try to use some aspects of the sociological theoretical framework combined with some concepts from safety research to explore the possibilities and challenges for accident prevention from a structural viewpoint, with some elements of interactionism. I chose to use several theories instead of one because that none of the theories presented in the chapter could explain accident prevention independently. Structural theory has been criticised for its simplicity, making it unable to address the complexity of the social world (Craib, 1992). Structural theory has been criticised for providing agents too much power to influence the structure. The ongoing discussion on structural theory emphasises that Giddens was not interested in when and how the agent can influence the structure. Although Giddens emphasised that structure is both enabling and limiting, he did not provide the answer for when the agent has the potential to change the structure and when he/she is determinate by the structure. The concept of culture is not mentioned in structural theory; the theory does not yield the possibility of understanding why people act differently and does not allow for the possibility of analysing cultural differences (Archer, 1982; Kaspersen, 2001). Despite the limitations of structural theory, it contributes to an understanding of accident prevention and is considered an interaction process between an organisation and its employees.

In this thesis, the limitations of structural theory are supplemented by other theoretical frameworks, such as theory of empowerment and social learning theory, which provide some explanation about what causes an agent to act and change the structure. However, social learning theory has a greater social construction approach compared to structural theory. Both theories can be viewed as contradictory, but in relation to accident prevention, both approaches provide some theoretical framework for an explanation of the reality within the oil and gas industry.

Methods

"Research design are plans and the procedures for research that span the decisions from broad assumption to detailed methods of data collection and analysis" (Creswell John W., 2009). The thesis consists of four papers that present different research problems and different research strategies. This chapter provides an overview of the research design and strategies used in the study.

Research design

The intent of this study is to explore accident prevention in the Danish sector of the oil and gas industry with a focus on interaction and learning. To achieve this goal, a convergent parallel fixed[1] mixed methods design was used. In this type of design, qualitative and quantitative data are collected in parallel, analysed separately, and then merged (Creswell John W., 2009). In this approach, survey data are used to measure the relationship between risk perception and safety climate dimensions by testing hypotheses that safety climate dimensions will influence risk perception. Furthermore, the prioritisation of safety and learning from accidents will be explored using interviews with offshore employees, document analyses, and observations on production installations in the Danish portion of the North Sea. Both quantitative and qualitative data are collected due to the convergence of the two forms of data, which offers greater insight into the problem than would be obtained separately by either type of datum. The mixed model design provides the possibilities of asking a different question and triangulating the data.

In this study, I follow a convergent design for the independent level of interaction; however, priority of the stands is not equal, and the qualitative stand has higher priority. The reason for choosing the qualitative stand as a higher priority is the subject of the study. Qualitative data are more suitable for exploring both the interactions between employees and leaders and the process of learning from experience. Merging the two stands occurred after separate data analyses, and an interpretation will be included in the discussion and conclusion sections (Creswell John W., 2009).

The study includes five different sources of data: survey, interviews, documents, observations, and workshops.

Table 2 shows an overview of the amount of data used in this thesis. A detailed description of the data collection procedure is provided later in the chapter.

[1] Fixed mixed methods indicate that the use of quantitative and qualitative methods was predetermined and planned at the beginning of the research process (Creswell John W., 2009)

Table 2 Overview of the amount of data collected in this study

Quantitative data	**Qualitative** data
Survey on the Danish sector N=771 Response rate=30% Survey on Norwegian sector N=4,304 Response rate=30%	81 interviews 550 reports of near-misses reports Three procedures 18 observations during onshore and offshore safety meetings Field notes from five offshore visits Eight workshops

These data are the basis for this thesis and are presented in four articles: two quantitative articles and two qualitative articles. Table 3 provides an overview of the data and methods used in the articles.

Table 3 Process of data sampling and analysis in the articles

Article I	**Article II**	**Article III**	**Article IV**
o Interviews o Workshop o Observations o Methods: coding in NVivo 9 (QSR International Pty Ltd., Doncaster, Australia).	o Reports on near misses o Procedures o Interviews o Methods: coding and text analyses	o Survey n=771 o Response rate: 30% o Methods: factor analyses o Structural equation modelling (SEM)	o Survey from Denmark n=771 o Response rate: 30% o Survey from Norway o N=4,304 o Response rate: 30% o Methods: factor analyses, t-tests o General linear model: two-way analysis of variance (ANOVA), linear regression

In the following section, the quantitative and qualitative portions of the study will be described.

Qualitative research

The qualitative portion of the study includes interviews, observations, workshops, and documentary analyses. This aspect of the research was inspired by the community approach (Bracht, 1999; Minkel, 2002) The community approach, which is used in health promotion, views the health border context of social and economic improvement and views individual and community empowerment as an important factor for

improvement in health status. Due to empowerment, community members are encouraged to assume greater responsibility for and control of their own health. The community approach emphasises direct citizen participation in community analyses (Bracht, 1999). Community, which is an important sociological term, still has no clear definition; however, the aim of this thesis does not include a discussion of the definition of community. This thesis is inspired by Hunter's definition of community, which defines community as follows:

- functional spatial units that meet basic needs for sustenance
- units of patterned social interaction and
- symbolic units of collective identity

This definition could characterise the platforms as a community because the platforms are functional spatial units in which employees both work and spend their spare time while on the installation. The social interactions are patterned, and offshore employees have a collective identity to some extent.

Inspiration for the semi-structured interviews and qualitative data analyses is based on Bracht et al.'s five-stage Community Organisation Model for Health Promotion (however, this thesis uses only the first step of the model) and Minkler's Community Organizing and Community Building for Health (Bracht, 1999; Minkel, 2002).

The first step in the Bracht model is community analysis, which includes the following:

1. Defining the community
2. Collecting data
3. Assessing community capacity
4. Assessing community barriers
5. Assessing readiness for change
6. Synthesising data and setting priorities (Bracht, 1999)

An important element of the community approach is exploration, which means that the researcher meets the community with openness and without a fixed hypothesis; this approach was used to collect qualitative data. Safety was a major issue during the collection of qualitative data. Following the community approach, the collection and analyses of data should focus on community capacity, barriers in relation to safety, and readiness for change.
In the following, I will present the different sources of qualitative data.

Interviews

The majority of the data was collected from May 2009 to June 2010. The interviews occurred both onshore and offshore and were conducted by following a semi-structured interview guide that covered the following topics: communication, attitude about safety, role of safety representatives, expectation of safety representatives, management commitment to safety, procedures and accident prevention, and system for near misses. The interviews of the safety representatives included topics about their motivation and challenges of being safety representatives. Although the data were primarily collected offshore, interviews were also conducted onshore at the airport prior to offshore flights and in onshore offices with company management. The study employed a qualitative approach to undertake an in-depth study of the processes related to the development of the role of safety representatives to explore the dilemmas connected to this role and possibilities and barriers connected to learning from near misses.

The three operating companies in Denmark were included in the study, and six installations were selected. One of the companies managed several installations, of which two new medium-sized installations and two large older installations were selected. The other two companies managed only one installation each. Interviews were conducted with all safety representatives at the installations and between one third and one half of the employees distributed on jobs and groups to ensure adequate representation. In addition, similar shares of the supervisors were interviewed.

The collection of onshore data involved interviews with persons from Health, Safety, and Environmental Departments in all involved companies, management responsible for offshore productions, and persons from the Health, Safety, and Environmental Departments in the companies selected. The 81 interviews varied from 20 min to over 1 hr and were taped and transcribed. Forty-seven interviews were conducted individually, and 34 interviews involved focus groups. The interviews were divided as follows:

- 14 interviews with safety representatives from operating and contracting companies
- 10 onshore interviews with leaders and employees from Health, Safety, and Environmental Departments
- 54 interviews with offshore management employees and regular offshore employees
- Three interviews with contact persons from each company regarding procedures, near misses, and the accident process

Interviews with safety representatives, contact persons from each company, leaders and employees from Health, Safety, and Environmental Departments, and some interviews with leaders on the installations were conducted as individual interviews. Interviews with offshore employees were focus group interviews. All interviews were recorded and then transcribed and coded with NVivo 9 (for more details about program see (Binderkrantz & Andresen, 2011; Gibbs, 2002)).

Workshops

Additional data were collected onshore during the period from February 2011 to June 2011 in form of workshops. A total of seven workshops were organised, including one workshop with safety representatives from all involved companies and six workshops with offshore employees from two involved companies; the company A did not express interest in organising workshops. The workshops lasted for 4 hours, during which offshore employees were divided into groups to discuss several issues, such as communication and procedures.

The aim of the workshop with the safety representative was to discuss their role, expectations, motivation, potential, and challenges. In the workshop with safety representatives, we asked companies to select safety representatives that were not interviewed previously. The aim of the other workshops with offshore employees was to obtain additional information, validate the data collected from interviews, and engage with employees from the other installation recently visited. The workshops with offshore employees were divided into three different groups, which represented only employees from contracting companies, only employees from operating companies, or a mix of employees. The reason for this setup was to ascertain whether answers differed depending on the group in which the employees participated; however, no differences were observed between the groups. During the workshops, employees were divided into mixed groups (employees from the same installation were not in the same group) and discussed different questions. After each session, the groups presented a summary of their discussion to the other groups. Between six and 14 persons participated in each of the workshops. Note that the data from the workshops were entered into NVivo 9.

Observations

Data collection also included observations from 18 safety meetings, training courses for employees, and safety courses; however, it was not possible to follow the employees during their work offshore for safety reasons. The offshore observations included participation in different meetings and observations of communication and interactions between employees. All observations were recorded and entered into NVivo9.

Document analyses

In addition to interviews, observations, and workshops, other sources of data included documents, such as procedures, safety politics, and reports on near misses. The selected analysis procedure was a procedure about reporting accidents and near misses. The procedures are part of a larger system that is updated regularly. The procedure used in this study originated in fall 2011.

Other documents used in the study were reports on near misses. To determine how near misses are reported, 550 near misses were studied. The database with near misses included 2,361 near misses that occurred from January 2008 to October 2011. After an initial selection, 778 near misses, which contained

duplicate reports or near misses that were unrelated to production platforms such as those related to supply vessels, were excluded. One of the companies used two systems for reporting incidents; however, the databases that contained 330 cases were not included in the analysis because they contained insufficient information for analysis. The remaining 1,583 near misses were sorted according to their given categories within the companies, including gas leaks, fire, chemical, person-related, or falling objects. Some of the near misses were connected to process safety, while others were related to personal safety. To determine whether differences existed in the characteristics of learning from process-related events versus person-related events, two categories of near misses were selected: gas leaks and personal behaviour. These two categories were selected due to the division of safety into process safety and personal safety by the companies.

These considerations led to our final selection of 550 near-miss reports, including 98 gas leaks and 452 person-related near misses.

Qualitative analysis

The qualitative analysis was conducted as described below (Creswell John W., 2009).

Preparing data for analysis

All interviews were taped with permission from respondents and transcribed. Field observations and observations from workshops, safety meetings, and other courses were recorded. Reports on near misses were chosen. All data were entered into NVivo9 in three different databases concerning safety representatives, reports on near misses, and possibilities and barriers connected to learning from near misses.

Exploring data

After entering the data from all interviews into NVivo9, the observations and procedures were reviewed. The analyses of different issues, such as the role of safety representatives or learning from accidents, were entered in different NVivo9 files and analysed separately to maintain an overview of a substantial amount of data. The qualitative codebook includes only very general codes. For the first article, which focuses on safety representatives, the codebook was inspired by some key concepts of community organisation, such as empowerment, community capacity, and participation (Minkel, 2002). For the second article, which focuses on learning from experience, the codebook includes such codes as incident severity, with a learning hierarchy based on Van Hare Court. Apart from those defined codes, the remaining codes were open and were coded during the data analyses.

Analysing the data

The data analysis procedure was different for the first and second articles. In the article about safety representatives, the interviews were coded in open coding; then, the open coding was transferred to more-

focused coding. In the focus coding, the following themes were used and analysed: role, expectations, training, support, and participation. The differences between companies were not the most important issue in this study; however, the analyses did reveal company differences. The safety representative role, or the role of the safety organisation, is described in the legislation. The analyses started with comparing the formal obligations to the safety representatives with the statements from interviews. The comparison was used to explore the dilemmas connected to the role and expectations.

The analyses in the second article include the company procedures, reports on near misses, and interviews. The procedures were analysed using the criteria from Kjellén's procedural description. Using Kjellén's criteria, the procedures were analysed to determine whether they contained all of the elements described by Kjellén (Kjellén, 2000a). The analyses were focused on the scope and aim of the procedure, definitions of the near misses, and incidents or descriptions of routines.

All of the selected reports on near misses where entered into NVivo9 and coded into open and defined categories. The defined categories were based on Van Court Hare's conceptual model (Van Court Hare, 1967a). Another defined code in our analyses was accident severity, which is defined by the organisations and based on several factors, such as frequency, consequences, and remaining barriers. Severity is defined on a five-point scale ranging from one to five. The level of severity was given in the reports on near misses. However, one of the companies had two different databases including incident severity. All of the reports on near misses contained information about severity, but there was another database that was used to group and analyse near misses, in which the severity was checked again. The severity of near misses sometimes differed between these databases; in these cases, we decided to use the qualified estimate from the database in which the near misses were grouped and not derived from the original reports on near misses.

Apart from the defined categories, the reports on near misses were coded in open categories that focused on the type of incident, the type of action taken, and whether the action taken was closed.

The analysis explored which solutions were frequently applied, and queries were conducted to develop connections between specific categories of near misses and solutions to determine whether it could be related to single- or double-loop learning. The two chosen types of near misses, gas leaks and personal behaviour, were analysed separately.

The last source of data in the second article was interviews. The interviews were coded in open categories, which were subsequently merged into fewer categories. The interviews with offshore employees were predominantly used to explore the possibilities and challenges of learning and in actual daily practice.

Interpreting data

Interpretation of the data was conducted in the articles, in which research questions were answered. The data were compared to the literature, and the results were analysed. The overall interpretation of the data is also included in the discussion section, where the results from the four articles are discussed with regard to theory and the literature.

Validation of the data and results

The data were validated using different strategies, including member-checking. In particular, a summary of the findings was presented in different project meetings and workshops; the participants were asked whether the findings provided an accurate reflection of their experiences. Another validity approach employed in this thesis was data triangulation using several resources and several persons.

Limitations of qualitative studies

There are several limitations to the qualitative portion of this thesis. In particular, a qualitative study should provide a deeper understanding of culture; however, the field study was relatively brief, with only three to four days of visiting offshore and onshore participation during several meetings. The visits and participation in meetings and training offered some insight into the organisational culture and ability for more careful exploration compared to the use of quantitative methods. However, the cultural knowledge obtained in this study is rather superficial and does not show the complete picture of the organisational culture of the companies under consideration.

Another limitation is that organisations are never static and are under constant change; thus, the data collected are only a picture of the culture at a given time. The organisations could change some of the factors described in the thesis; however, cultural change requires a considerable amount of time.

During the offshore visit, the first-line management, supervisors, or foreman chose the participants to interview. There could be a bias in their selection, as they could choose more positive respondents or more negative respondents. This procedure might also have an influence on employees who may feel obligated to participate and may not feel comfortable making negative statements about their company. However, participants were observed talking openly during the interviews.

The respondents for the workshops were chosen by human resources personnel, which could introduce bias in the selection. At the beginning of some of the workshops, the employees requested an explanation of the aim of the workshops and who would receive the workshop results, but after assuring the participants that the data belonged to the university and that the company would only receive anonymous results, the employees openly discussed various issues.

Based on the data collected about safety representatives and near misses, an estimation of the impact of the results on accident prevention is challenging. This thesis can estimate the possibilities and challenges and indirect impacts on accident prevention but not the direct impacts.

One limitation of using near misses is that learning is based on the analyses of retrospective data. A disadvantage of retrospective learning based on accidents is that systems are rarely static, which means that new incidents will occur in different contexts. However, according to Leveson (2011), reactive learning is useful in some cases, particularly in such industries as the nuclear power industry, where basic design changes slowly (Leveson, 2011). The oil and gas industry could be treated as an industry in which basic design changes slowly, and therefore, we believe that this industry could benefit from retrospective learning.

Another limitation of qualitative methods is the generalisability of the results to other sections and other countries. Regarding near misses, some types of near misses are very specific to oil and gas production and can only be used in the oil and gas industry. However, there are some categories with near misses related to personal behaviour that could be used in other areas, such as housekeeping. This thesis has also demonstrated the differences within companies and the influence of culture within organisations on reporting and learning from incidents. The influence of culture indicates that generalisability is not very high and that adequate results from one company may not necessarily result in similar success for another company.

Quantitative research

The quantitative part of this research includes a survey study. In the following section, the two surveys used in this thesis are presented, followed by a description of the statistical methods employed.

Survey of the Danish sector:

a. *Study design:* The study is a cross-sectional study that employs the survey questionnaire.
b. *Study population*: The questionnaire was sent to all production platforms on the Danish part of the North Sea (n=2,400). The aim of the study was to include all offshore employees on the production installations during a period of seven weeks. The offshore employees who were not permanent on the installation were also invited to participate in the study.
c. *Questionnaire development:* The content and structure of the questionnaire was based on a review of the literature on risk perception in the offshore industry in the UK and Norway (Mearns & Flin, 1995; Mearns et al., 1998; Mearns et al., 2001b; Rundmo, 1992b; Rundmo, 1996a; Rundmo, 2000; Rundmo et al., 1998) and existing surveys from Norway from the Petroleum Safety Authority's "Trends in risk level—Norwegian shelf" and from Denmark's "Safety Culture Survey" from the National Research Centre for Working Environmental. Prior to

sending the questionnaire to each company involved in the study, the questionnaire was presented at the safety committee meetings and discussed in relation to its relevance to and understanding of the issues under consideration. Both contractors and operators were involved in the pre-evaluation of the questionnaire.

The categories included in the questionnaire were demographics, risk perception, satisfaction with safety measures, safety attitudes, working conditions, and accident history.

d. *Procedure and time*: The survey was conducted during the period from January 2010 to March 2010. The employees were given the choice of answering the questionnaire using an online or paper version. The data collection process varied over seven weeks due to different rotations (two weeks on/three weeks off and two weeks on/four weeks off); the questionnaire was given to every offshore employee who was going to the platform. In this manner, the entire population of offshore employees on the productions platforms was covered.

   The overall response rate was 32% (n=771), although this rate varied from company to company (between 28% and 80%). The response rate is quite low, which brings into question both the representative nature and validity of the results. The low response rate of our questionnaire was due to several reasons. First, one of the boxes that was scheduled to be sent to the platforms disappeared. However, I chose to include these individuals in the entire population because some of the surveys from that installation were mailed and if the entire installation were included, I should also remove those surveys that were mailed. At the time of the survey, there were two hotel rigs in the North Sea, both of which were included in the survey. Employees of those two hotel rigs were working on different installations, and the response rates from the rigs were considerably low. Employees that were hired on the rigs were not permanent crews and were only hired temporarily. Thus, they did not have an interest in the survey. Two of the hotel rigs represented approximately 25% of the entire population in one of the companies. All companies received instructions regarding how to conduct the survey and how to report the number of surveys; however, only one company followed the instructions. The other two companies did not register the correct number of surveys given to employees and did not create lists, while some of the installations completed these tasks during a portion of the period. Thus, the response rate was calculated based on helicopter lists, leading response rates to be uncertain and potentially underestimated. Some of the safety representatives contacted me to verify that the survey was anonymous because some of the employees were concerned about anonymity and afraid of answering the questions honestly on the survey. This issue also could have influenced the response rate. The response rate was particularly low in company B.

To control the representativity of the dataset, I compared the questionnaire responses to the overview of the distribution of employees on the installations. The distribution of operators and contractors was similar in the survey, and no group was overrepresented. Despite the low response rate, the data still provide a general picture of the population, and the survey yields results that correspond well with the qualitative data. Studies in both Norway and the UK have experienced similar problems with low response rates (Fleming et al., 1998; Flin et al., 1996; Høivik et al., 2009; Mearns et al., 2001b; Tharaldsen et al., 2008).

Survey on the Norwegian sector:

a. *Study design:* The study is a cross-sectional study that is repeated every two years on the Norwegian Shelf.
b. *Study population:* All offshore employees in the current study are also employees at onshore oil and gas installations. The data received from the Petroleum Safety Authority were anonymous, which prevented the possibility of exploring the differences between installations, and covered only offshore employees. A total of 7,165 employees were surveyed in this study. For comparison with the Danish sample, only employees working on the production installation were chosen. Nine-hundred employees did not indicate whether they were working on the mobile or production installation and were thus removed from the sample. The final number of Norwegian offshore employees was 4,304.
c. *Questionnaire development:* The questionnaire contained 170 items divided among the following areas: demographics, safety climate, risk perception, recreational matters offshore, sleep and rest, working environmental and work, health, and sick leave.
d. *Procedure and time*: The data used in the study include data from the Norwegian sector collected in January 2010. The Norwegian survey is conducted as a questionnaire study every two years by covering the entire offshore population. The response rate for the total sample was estimated to be 30%.

Statistical methods

Different statistical methods were used in the quantitative data analyses and are presented in the following sections.

Factor analysis

Factor analysis seeks to explore the underlying structure of a particular phenomenon through a complex array of structure-analysing procedures. A factor is “linear combination or cluster of related observed variables that represents a specific underlying dimension of a construct, which is as distinct as possible from the other factors included in the solution” (Pett Marorie A., Lackey Nancy R. & Sullivan John J., 2003).

There are two types of factor analysis: exploratory and confirmatory. Exploratory factor analysis (EFA) is employed when the number of factors needed to explain the interrelationship among a set of characteristic items is unknown, whereas confirmatory factor analysis (CFA) is used to assess the extent to which the theory or model of factors fits the data (Pett Marorie A. et al., 2003). Using EFA, the researcher must make the following assumptions:

- within the observed variables exists a set of underlying factors that can explain the interrelationship among those variables
- all common factors are correlated or uncorrelated (depends on methods used in the EFA)
- all observed variables are directly affected by all common factors
- unique factors are uncorrelated with one another
- all observed variables are effected by unique factors (Long J.Scott, 1983)

Some of the assumptions are violated in EFA because in the "real world", most of the factors measured are actually correlated with each other. This limitation of EFA has been overcome by the development of CFA. In CFA, the researcher defines the model in which he/she determines which pairs of common factors are correlated, which observed variables are affected by common factors and unique factors, and which pairs of unique factors are correlated. The statistical test confirms whether the data fit the model (Long J. Scott, 1983).

Reliability and validity

One of the important steps in factor analysis is the reliability and validity of the factors (scales). According to Pett (2003), reliability focuses on three aspects of the instrument: internal consistency, stability, and equivalence; however, internal consistency is the instrument most commonly used to measure the reliability of the scale. Internal consistency is concerned with the homogeneity of the items comprising a scale. A scale is internally consistent to the extent that its items are highly intercorrelated (Long J.Scott, 1983). The internal consistency is measured by means of the coefficient alpha (Cronbach's alpha). Cronbach's alpha ranges from 0.0 to 1.0 (DeVellis Robert F., 1991), and it should not fall below 0.7. Validity shows the ability of a scale to predict specific phenomena. There are three types of validity: content validity, criterion-related validity, and construct validity. Content validity refers to the extent to which a chosen set of items reflects a content domain. Content validity concerns the relevance and representativeness of the items chosen for the measurement. Criterion-related validity, which is often referred to as predictive validity, is concerned with the degree to which the instrument will be a useful predictor of behaviour or events. Construct validity of the scale is concerned with the theoretical relationship of a variable to other variables. Construct validity shows the extent to which empirical

correlations match the predicted patterns and provides evidence of how well the measure "behaves" relative to what is expected (DeVellis Robert F., 1991).

Fit measures in CFA

CFA fit measures indicate the degree to which our model is consistent with our empirical data. There are several measures that can estimate model fit, including the root mean square error of approximation (RMSEA), goodness of fit index (GFI), and adjusted goodness of fit index (AGFI). The RMSEA is sensitive to the number of estimated parameters in the model; values less than 0.5 indicate a good fit, values up to 0.8 indicate reasonable errors of approximation, values between 0.8 and 1.0 indicate a mediocre fit, and values over 1.0 indicate a poor fit. The GFI is a measure of the relative amount of variance and covariance in a sample that are jointly explained by the sample. The AGFI is a GFI measure adjusted for the number of degrees of freedom in the specified model. Both the GFI and AGFI compare the hypothesised model with no model at all. The value for those measures ranges from 0.0 to 1.0, with values near 1.0 indicating a good fit (Bryne Barbara M., 1998).

Structural Equation Modelling

SEM is a statistical methodology that uses the confirmatory approach in multivariate analysis. SEM differs from other multivariate procedures. Specifically, this method takes the confirmatory approach to data analysis and is able to test theoretical models. SEM can incorporate both unobserved and observed variables in the model. In the SEM model, exogenous and endogenous variables must be distinguished; exogenous variables are synonymous with independent variables, whereas endogenous variables are synonymous with dependent variables. The model does not explain the changes on exogenous variables but explains the direct or indirect impacts of exogenous variable on endogenous variables (Bryne Barbara M., 1998).

Multiple linear regression

Linear regression is an approach for estimating the relationship between the dependent variables and independent variables in a linear function. The method provides an estimate of the correlations estimate, which measures the closeness of the linear association. In multiple linear regressions, the model includes several independent variables and the effect of the independent variable x1 is controlled for effects of the other variable x in the model (Kirkwood & Sterne, 2003). There are four assumptions regarding linear regression: a linear relationship, normality, none or little multicollinearity, and homoscedasticity. First, linear regression requires that the relationship between the independent and dependent variables is linear. Second, the linear regression analysis requires all variables to be multivariate normal. Third, linear regression assumes that there is little or no multicollinearity in the data. Multicollinearity occurs when the independent variables are too highly correlated with each other. Fourth, linear regression analysis requires

homoscedasticity, which is also known as homogeneity of variance. The assumptions for scales used in the regression analysis have been checked (Kirkwood & Sterne, 2003).

Two-way analysis of variance

ANOVA investigates whether the differences in the sample means are due to random variation that occurred by chance or to systematic differences between the means (Iversen & Norpoth, 1987). ANOVA requires the assumptions that the observations have been collected independently of each other, the groups follow a normal distribution, and the variances within groups are identical. Two-way ANOVA compares the means of groups, but in contrast to one-way ANOVA, the model includes several explanatory variables (Iversen & Norpoth, 1987). The advantages of using two-way ANOVA are that the effect for each of two or more factors and an interaction is measured. In the study, two-way ANOVA was used to explore the relationship between safety climate and risk perception for Danish and Norwegian offshore employees.

Limitations of quantitative studies

One of the limitations of the quantitative portion of this study is the significantly low response rate presented in the methods chapter. The low response rate provides uncertainty regarding the representativity of the results; however, a check of the division of the groups among different installations reveals that overrepresentation of certain groups did not occur. Another limitation connected to quantitative methods is the cross-sectional survey, which only measures the current attitudes on safety and does not capture a tacit culture. The survey offers a limited picture of attitude to safety. Some problems were encountered during the data collection process. Although all companies received instructions concerning how to conduct the survey and how to report the number of surveys, only company C followed the instructions. The other two companies did not register the correct number of surveys given to employees and did not produce the requested lists; however, some of the installations from Company B did fulfil this requirement during a portion of the study period. Some of the safety representatives from Company A contacted me to verify that the survey was anonymous because some of the employees were concerned about their anonymity and were hesitant to answer the questions honestly. Fear of answering honestly can influence the way in which respondents answer the survey; some respondents may answer the question more positively. However, the employees had the choice of completing the survey online or by paper; some respondents used the paper method.

The questionnaire survey was used to measure risk perception and the safety climate on Danish production installations. The scales were chosen using EFA and CFA and were based on the scales used in Norway and the UK (Fleming et al., 1998; Flin et al., 1996; Høivik et al., 2009; Mearns et al., 2001b; Tharaldsen et al., 2008). Because a questionnaire was employed, the validation process was very important. The scales were validated with EFA and CFA; however, not all scales resulted in the same strength as those obtained in the

UK or Norwegian studies. Based on the EFA and CFA results, some scales were modified, indicating that the data can be compared directly but only in terms of general trends. Because the scales cannot be transferred to the Danish context, this thesis is limited to some degree. The reason for the relatively low strength of certain scales could be the differences in the comprehension of the questions by Danish offshore employees compared to offshore employees in Norway and the UK and indicates a weakness of the questionnaire surveys.

Summary of methods

This chapter presented the overall methods used in the study. A summary of the methods used to answer the research questions is provided below.

1. *How do organisations within the Danish oil and gas industry involve safety representatives in safety work?*

   This question is answered in the first article, which uses qualitative methods, interviews, observations, and workshop as the data. The method employed is coding of the text in NVivo9.

2. *How do organisations within the Danish oil and gas industry learn from their near-misses?*

   The second article answers this question. The study uses the qualitative methods and data is based on procedures, reports of near misses and interviews. The data were coded with Nvivo9.

3. *Which organisational and human factors influence risk perception among Danish offshore employees?*

   This question is answered by third article and uses the quantitative data.

4. *How are risk perception and attitudes regarding safety distributed among Danish and Norwegian offshore employee?*

   This question is answered by fourth article, which utilises the quantitative data. The table below presents the data used in last two articles.

Table 4 Overview of the methods used in the third and fourth articles

Methods	**Article III**	**Article IV**
EFA	x	x
CFA	x	x
SEM	x	
t-test		x
Eta squared		x
Linear regression		x
Cronbach's alpha	x	x
General linear model/ANOVA		x

Results

The overall research problem of the thesis involves the possibilities and challenges for accident prevention in the Danish oil and gas industry. This chapter summarises the research questions with regard to the main findings of the research articles.

Based on the research problem, three research questions are formulated:

1. *How do organisations within the Danish oil and gas industry involve safety representatives in safety work?*
2. *How do organisations within the Danish oil and gas industry learn from their near-misses?*
3. *Which organisational and human factors influence risk perception among Danish offshore employees?*
4. *How are risk perception and attitudes regarding safety distributed among Danish and Norwegian offshore employees?*

The overall research problem is complex. The four articles presented in this chapter only explain the chosen factors, which were presented in the conceptual model in the first chapter. In this section, the main findings from the articles are summarised in relation to the research questions. The first article on safety representatives answers the first research question. The second article on near misses answers the second question, and the third article answers the third question and the fourth article answers the fourth question.

How do organisations within the Danish oil and gas industry involve safety representatives in safety work?

One of the possibilities to improve safety and prevent accident is involvement of safety representatives in safety. The first article explores the involvement of safety representatives by examining the role of safety representatives and their dilemmas in relation to the role as safety representatives. The primary focus of this article is on a micro level; however, the study integrates a macro level through legislation. The study compares Danish legislation with the role of safety representatives defined by themselves, their co-workers, and their supervisors/leaders and discusses this role according to the chosen theories and research conducted within the oil and gas industry in the UK and Norway. The study explores issues concerning: the role of safety representatives, including support from companies, resources, knowledge, the power of safety representatives, participation in safety, and the effectiveness of this participation.
The results show that the role of safety representatives is marked by dilemmas between legislative demands and expectations from colleagues and management (which are not compatible with each other). The same tendency occurs in research in the UK and Norway (Hart, 2002; Hovden et al., 2008; Spaven & Wright, 1998).

Danish legislation focuses on the collaborative side of the role of safety representatives, which impacts the way in which the role of safety representatives is viewed. The role of safety representatives is mostly connected to small issues as solving daily problems on the installation rather than protecting the interest of their colleagues. This focus on small issues is not initiated by Danish legislation but by the policy of the individual company because one of the companies included their safety representative in safety work to a much larger extent than the other two companies.

Focus on small issues could be seen as a barrier to more involvement in safety work; however, the study has demonstrated the existence of differences between the companies. Safety representatives had more involvement in one company than in the other two companies. The following phrase illustrates quite well the involvement of safety representatives.

"I think that especially here they are quite open if you have some suggestions; they don't sweep it under the carpet and say they can't use it" (safety representatives, company C)

In two of the companies, the safety representatives did not always receive support from management, which caused some of the safety representatives to resign from their job as safety representatives. The following phrases describe the situation of safety representatives:

"Sometimes I think we are invited in the planning of the job, not because they want to hear us or want us to be involved, but because the legislation says so." (safety representative, company A)

"No, it is not so easy, it depends on what it is. If we say it is very dangerous, then it will be done right away, (…) but some things are difficult to get through. It is the same as in all other places, and then it is also a matter of how much does it cost and what can we get out of it" (safety representatives, company B)

Although safety representatives have a legitimate role through legislation, acceptance of this legitimacy by their companies is sometimes lacking. Lack of the support from management had an influence on how much the safety representatives were involved in safety work and the effectiveness of their work. In the company where the safety representatives were involved they had a power to make some changes and suggest solutions. In this company safety representatives were responsible for the safety campaigns and reporting system of near-misses. The situation in the two other companies was someway different, and the safety representatives did not have the same possibilities to be involved in safety work, and their effectiveness was not so high.

Another important issue of being able to participate in safety and make the changes is the knowledge and resources. Safety representatives emphasised that they felt they did not possess all of the necessary qualifications for performing their job as a safety representative. The mandatory course for this role only covers legislation issues and does not address issues like communications skills or conflict management. The safety representatives lacked the tools to effectively communicate with both management and their

colleagues. Only one company offered supplementary courses in communication and conflict management for their safety representatives.

The resources could be defined as a time given to safety representatives to fulfil their role, but the results showed that the main dilemma of safety representatives includes the balance between their job as employee and serving as safety representative. However, the results revealed differences between the participating companies. The balance between time to perform their job as employees and time for safety work as safety representatives could prove challenging for safety representatives. Although management indicates that safety representatives should allocate the time they need for safety work, some safety representatives experience difficulties with their foreman. Safety representatives felt divided between the two roles and sometimes felt guilty for not fulfilling both roles completely. One of the leaders summaries the balance as following:

"If you look from the legislation side, from authorities' perspective, it is a fulltime job, not representative. So, finding balance could be hard sometimes" (leader onshore, company B)

In general the study showed that participation of the safety representatives varies from company to company, and safety representatives as the possible resources for improving safety and accident prevention are not "properly used" . There is still place for improvement.

How do organisations within the Danish oil and gas industry learn from near-misses?

The second article investigates the reporting procedures for near misses on Danish offshore installations and what the industry learns from this reporting and the potential challenges and barriers with such systems for the further prevention of accidents. The study focuses on how organisations have formalised the reporting of near misses and explores how reporting works in daily practice. By using some examples of near misses and exploring the process for analysing near misses, the study identifies the potential challenges and possibilities within the system.

The results showed that all companies have a procedure for how to register accidents and near misses. Compared to Kjéllan's model for such procedures, all procedures contained the main suggested elements; however, the descriptions for some of the routines were limited (Kjellén, 2000a). One of the barriers to the procedures was the similarity between definitions of near misses and observations. Recognising distinctions between near misses and observation can be challenging.

Although the companies had procedures in place, the daily reporting practice experienced some challenges. Underreporting of incidents related to behaviour was observed compared to incidents related to defective equipment, gas leaks, or other incidents that are not personally related. The reason for underreporting was due to anxiety in reporting, particularly for employees from contracting companies. Differences between

the companies in the reporting of near misses were observed; in one company, the employees were not afraid of reporting incidents.

Another issue connected to reporting is whether the reporting system is user friendly. In two of the companies, some employees complained that reporting near misses was too demanding. There were numerous issues for which information should have been provided, and the Internet connection was slow, which made the process even more time consuming. The reporting system used in most companies is primarily created to register data instead of for analyses. Near misses are categorised in different groups. Several respondents mentioned the difficulty in locating similar near misses for comparison; only the same groups of near misses were found.

To examine the degree to which companies learn from incidents, two groups of near misses were chosen: gas leaks and personal behaviour. Most cases exhibited low severity and were primary solved at the installation. Based on the analyses, the study concludes that while learning from incidents occurs, it is mainly ad hoc learning instead of systematic learning. The deviations were corrected, but the principal challenge is to prevent the recurrence of frequent incidents.

Another issue presented in this article was the analysis procedure for near misses, which was very similar in all companies. How detailed the analyses were depended on the severity of the near misses. The barrier to the analyses of the near misses could be the quality of the near-miss report and subjectivity in the determination of the severity of near misses. One of the weaknesses of the analysis process for reports was the lack of follow-up. Two companies emphasised the lack of resources for follow-up.

Which organisational and human factors influence risk perception among Danish offshore employees?

The third article focuses on human and organisational factors influencing risk perception. The human factors were defined as work experience, safety behaviour, and experience of accidents, whereas the organisational factors included the working condition, safety measurements, procedures, and priority of safety versus production. The impact of those factors was tested on two types of risk perception: occupational hazards (likelihood of injuries) and process incidents (likelihood of gas leaks and explosions).

The results showed that five factors, work experience, safety behaviour, working conditions, safety measurement (detections systems), and injuries in the past 12 months, contribute significantly to the risk perception of occupational hazards by a respondent. The five factors explained 27% of the variance in risk perception. Safer behaviour and more experience decreased the risk perception of occupational hazards, whereas harder working conditions and experience of injuries during the past 12 months increased risk perception.

Three factors were found to influence risk perception of process incidents: working conditions, safety measurement (detections systems), and priority of safety versus production. These factors explained 22% of the variance. A high priority for safety versus production and more satisfaction with safety measurements decreased risk perception, whereas harder working conditions resulted in a higher risk perception of process incidents.

The results reveal differences between factors influencing the risk of occupational hazards and process incidents. The factors influencing risk perception of occupational hazards were found to be more individually oriented, such as safety behaviour, experience in work, and experience of injuries, whereas factors influencing the risk perception of process incidents were more systematic, such as priority of safety versus production. However, factors influencing risk perception of occupational hazards were individually oriented, which can also be an indication of the organisational factors. Lack of knowledge and unsafe behaviour can also be the state of the existing culture in organisations instead of the attitude and values of the employees.

How are risk perception and attitude regarding safety distributed among Danish and Norwegian offshore employees?

The fourth article compares risk perception and attitude about safety between Norwegian and Danish offshore employees and explores the impact of safety climate on risk perception for Norwegian and Danish production platforms.

The results revealed specific demographics between the two groups of offshore employees. The Norwegian offshore employees possessed longer experience of working offshore—32% had worked more than 20 years offshore compared to 20% of the Danish respondents. Eighty-six per cent of the Danish respondents worked permanently on the same installation, compared to 70% of the Norwegian respondents.

Analyses of t-tests indicated that Norwegian offshore employees have more positive perceptions of safety, safety management, and involvement than Danish offshore employees. Norwegian offshore employees were more motivated by safety and were more likely to prioritise safety over production than the Danish offshore employees. The Danish employees exhibited more positive system perceptions than the Norwegian employees.

When comparing the risk perception between those two groups, the Norwegian offshore employees scored higher on the scale for risk perception compared to the Danish employees. Differences across the groups were found for both personal and process risks. However, the eta squared did not exhibit a strong difference between the samples; only the dimension safety management and involvement displayed medium strength. Those results are interesting because Norwegian employees had more positive

perceptions of safety, which should result in the lower risk perception. The survey is not able to explain why those differences occurred. One of the explanations may be the years of experience within the sector. The Norwegian offshore employees had in general longer work experience, which gives higher probability of being involved in an accident yourself or experiencing your colleagues having accidents. This can influence the subjective perception of risk.

The study showed that the relation between safety climate and risk perception was as expected. The better safety climate scores predicted lower risk perception. However, again differences between countries were seen. As regards the Danish sample, only the dimension safety versus production had an impact on employees' perceived risk perception, however the impact was small. In the Norwegian sample all three dimensions of safety climate had impact on risk perception, but as in the Danish sample the impact was small. Once again, based on the survey it is impossible to explain why those differences occurred, but further research with focus on qualitative methods could be useful to explain differences.

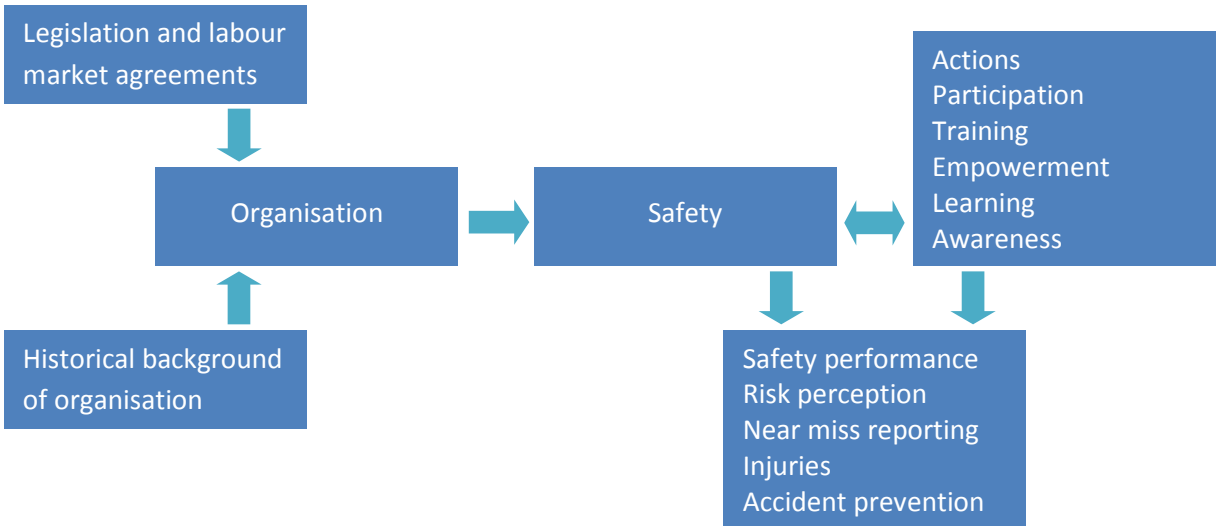
Discussion

This chapter includes a discussion of the overall results of the manuscripts published as part of this thesis in relation to the research questions presented in the introduction:

1. ***How do organisations within the Danish oil and gas industry involve safety representatives in safety work?***
2. ***How do organisations within the Danish oil and gas industry learn from their near-misses?***
3. ***Which organisational and individual factors influence risk perception of the Danish offshore employees?***
4. ***How are risk perception and attitudes regarding safety distributed among Danish and Norwegian offshore employees?***

To answer each question, different study designs and strategies were employed. The conceptual model (figure 6) presented in the introduction was a starting point for this thesis. However, the results of the studies showed that association and interaction between the elements of the model are much more complex and not linear as it was shown. In the following, the four main issues will be discussed.

Figure 6 Conceptual model



The results are discussed in four sections that resemble the four research questions: a) the involvement of safety representatives in safety work within the Danish oil and gas industry, b) learning from near-misses, c) relationship between risk perception and organisational and human factors and c) the relationship between safety climate and risk perception.

Involvement of safety representatives in safety work within the Danish oil and gas industry

As mentioned previously, the oil and gas industry is a high-risk industry, which underlies its high focus and priority on safety. Risk and the consequences of potential accidents impact the companies within the oil and gas industry but can also have a broader societal impact; therefore, the authorities regulate production and safety through the Danish legislation. The Danish legislation offers guidelines on how to obtain safety on the installations, but it only provides guidelines. Thus, each company must decide how to fulfil their safety obligations (, 2012a; , 2012b). One of the important elements of Danish legislation is the participation principle, which means that companies are obligated to involve representatives from employees' and management side in the safety organisation. The duties and rights of safety organisations were presented in the chapter about industrial context and emphases participation in planning of safety and health activities. The participation in safety work was examined in the first article with focus on safety representatives' involvement. The results showed that there were differences in which degree the safety representatives participated in safety work. Company C involved their safety representatives to a greater extent than company A and B. Those results are quite interesting in the light that all companies are underlined the same legislation, but the interpretation of the legislation is different. One of the explanations could be the organisational, structural and historical background of each organisation and their understanding of culture.

As presented in the second chapter on the industrial context, there are three operators within the Danish sector, and each operator has a different way of fulfilling its safety obligations. Company A is a public limited company with the state as its major shareholder and a generally flat management structure. This company has some features of a publicly owned company. The company has taken over production installation from another company and adopted the other company's working practices and procedures. The company is in an on-going process of creating their own working practices and procedures. Company B is privately owned with a background in the maritime industry and has a more hierarchical management structure. Company C is a private foreign company with a background in the oil and gas industry, and it also has a flat management structure. For companies A and B, oil and gas production is not their primary production but only a part of their enterprises, which influences their organisational structure and can affect safety.

Safety representatives from company A experience problems with support and the legitimacy of their role from management, but they also experience openness and a flat structure within the organisation, leading to the possibility of discussing issues. The involvement of safety representatives in planning safety in this company is limited to some degree.

The results from the study and analysis in the first paper suggest that company A is somewhere between the interpretative and functionalist approaches but with a tendency towards a functionalist approach. The safety representative had limited support from management and a limited influence on safety planning, which suggests a more functionalist approach. The company is under constant development; sometimes, there are not very clear lines, and changes in the working practice also suggest a lack of a clear identity and remnants of the heritage from the company that they acquired.

The organisational culture of company B, its maritime background, is more geared toward a functionalist approach with its more hierarchical management structure. This management structure affects the involvement of the safety representatives in safety issues. In this company, the involvement and influence of safety representatives were somewhat limited, and because of this limitation, some of the safety representatives have stopped working as safety representatives.

Company C has a structure that could be characterised as an interpretative cultural approach, where the safety is created in the day-to- day interactions, and the employees are the agents who actually influence the structure of safety. In this company, the safety representatives are highly involved in planning safety campaigns. The safety representatives also received supplementary courses in communication and conflict management.

One of the important elements of involving the safety representatives in safety is giving them resources like education (learning) and time. Learning is a quite important element of empowerment, which helps safety representatives to be involved to a greater extent and to be more effective in accident prevention. Learning at the individual level presented in this thesis includes several aspects such as learning in communities of practice (e.g., production installation), role, and empowerment. These elements are interconnected and interrelated. The results from the first article showed that learning at the individual level is a challenge for safety representatives. The unclear roles and different expectations for the safety representative from management and colleagues create both challenges and possibilities for the safety representatives to create and learn their role through daily interactions with others. The possibility lies in the opportunity to influence the role and create the role in their way. However, the role must be accepted by management and colleagues, and having different understandings of the role of safety representatives can cause conflicts (Goffman, 1959; Mead, 1962). The management structure provides different possibilities for empowering offshore employees and safety representatives. The results of the first article showed that company C, which involved their safety in safety representatives and provided supplementary courses supported the empowerment of their safety representatives better compared with the two other companies.

Social learning describes how environmental and cognitive factors interact to influence human learning and behaviour and focuses on learning in the community of the practice. However, the results showed some limitations for this type of learning. The safety representatives from companies A and B participated in an accident investigation course, but they never had the opportunity to apply this knowledge. Their role in accident investigation was limited to participating as an observer or reading the investigation report. Improving the qualifications of the safety representatives resulted in better individual empowerment and more effective involvement in safety; however, there were differences between the companies in terms of how many possibilities the safety representative had to improve safety. In company C, the safety representatives had more involvement and ownership compared to the safety representatives from companies A and B.

Learning at the individual level is also influenced by and closely connected to the organisational culture. In company B, which had features of a functionalist cultural perspective with top-down coordination, there was little focus on empowerment and agents' possibilities to change the structure. In this approach, the role of the safety representative tends to be inspired by a functionalist approach, with prescribed and static expectations for the safety representative position (Abercrombie et al., 1984). The consequences of the functionalist approach could mean that safety representatives focus more on their role as an ombudsman (helping the company comply with health and safety requirements) than as a spokesperson who protects the interests of the employees (Hovden et al., 2008). The results from the first article indicate that the safety representatives focused somewhat more on the ombudsman role, which was in accordance with the leaders' expectations, whereas the employees prioritised their role as a the spokesman. In contrast, the safety representatives and management placed a relatively low priority on the spokesman role, possibly due to the lack of specifications for this role from the legislation and the interactions of the safety representatives with members of management, who emphasised the ombudsman role. In company C, the safety representatives had more influence and involvement in safety than in the two other companies. The more interactive cultural approach resulted in more empowered safety representatives, who had more influence on safety than the offshore employees in companies A and B. The role of the safety representatives was created through daily interactions with colleagues and management.

In general the challenge of the learning process at the individual level is to provide safety representatives with efficient qualifications, awareness, and empowerment while also introducing structural changes that will support the learning process within communities of practice. This challenge was emphasised by Aaro and Lund in their article about evaluating safety intervention. Their review of different interventions showed that safety campaigns or interventions without structural changes have a limited effect on safety (Lund & Aaro, 2004).

Another element of participation of safety representatives in safety work was time to do the job as safety representative. The problem is due to the fact that safety representative has two jobs – one as a regular employee and one as a safety representative. Some of the safety representatives experience difficulties with their foreman to get time to do safety work. The dilemma is that management stated that safety representatives have all the time they need to perform safety work, but they also have a job to complete.

To some degree, all three companies had difficulties with finding the balance between the safety representatives' work as employee and as safety representative, which could indicate the wrong signals about the priority of safety representatives' involvement in safety and discourage the employees to stand for election.

In general the involvement of safety representatives in safety is still challenging for the Danish oil and gas industry. However, it differs as to how good the companies handle it. Safety representatives could be used as a "useful" tool for accident prevention, but this resource is still not recognised by the companies. The major problem is that if safety representatives, who by the legislation should be involved in safety work, are not involved, the involvement of employees will be even more challenging. The employees' lack of involvement in safety can have influence on the accident prevention; because lack of involvement could result in lacking ownership of safety by the employees and in that way influence their behaviour in a negative way. The main task of the organisation is to "empower" their employees.

Learning from near-misses

Learning from near misses is part of the organisational learning, but also a part of the safety management system. Organisational learning describes the ability of an organisation to use its experience during an incident to improve the organisation and prevent additional incidents (Kolb, 1984). In this thesis, organisational learning was examined using the Kjéllan model and Van Court Hare hierarchy (Kjellén, 2000a; Van Court Hare, 1967a).

The learning process occurs in practice, which is created by the organisational culture. This thesis focuses on learning from near-misses. The results of the second article showed that learning from incidents occurs, but is primarily ad hoc and not very systematic. Serious incidents contribute mainly to learning, but the challenge is the minor frequent incidents, which appear occasionally. Learning from these minor incidents is quite limited.

Another challenge connected to learning from incidents is the underreporting of near misses, which is related to personal behaviour. Companies A and B had some problems with underreporting. Some employees, particularly the employees of the contracting companies, were afraid to report near misses due

to personal behaviour. Underreporting was caused by not only anxiety; but also the tedious reporting system. The system is too demanding, and slow internet connections are also a barrier. Another barrier related to the reporting system for near misses is that the system primarily serves as a data collection system; only to a lesser degree does it serve as a lead indicator in a proactive monitoring strategy. The use of near misses as lead indicators on offshore installations must be seen as a proactive approach for monitoring safety. By definition, safety performance indicators must include measures of root causes and the safety-related performance of the production process. Only in this way can safety performance indicators serve as reliable instruments for monitoring safety on offshore installations. However, these performance indicators must be based on practical or scientific evidence of the causal relationship between the indicators used and the unwanted outcomes (Dyreborg, 2009; Leveson, 2011).

One important element in the learning process and the development of organisation culture, as emphasised by both Kjellén and Drupsteen, is feedback and follow-up of actions taken (Drupsteen et al., 2012; Kjellén, 2000a). However, the results of the second article showed that this element is partially limited in the companies and thus serves as a barrier for future learning. The companies invested little time in evaluating the actions taken. Some of the respondents from the companies A and B mentioned limited resources for evaluating the safety actions. Company A had difficulties in completing the actions. Near-miss reports offered recommendations based on the actions, but the deadlines for these actions were typically moved. Furthermore, there was little control as to when the action should take place. Feedback and follow-up are important elements of the organisational learning process, and the absence of these elements is a barrier for accident prevention (Kjellén, 2000a).

Comparing learning at the organisational level with the historical development of safety research, presented within an introduction, the oil and gas industry has been through some of the developmental steps. The oil and gas industry has improved their equipment, reduced risks through design, and implemented safety management systems and procedures. The safety culture is an important issue within the companies, and the companies devote significant resources to improving safety culture and focussing on human error. However, the focus is still mostly on human error and not so much on the interaction between the human and system.

Within the oil and gas industry, zero vision plays an important role in Denmark, and there is a strong belief that all accidents are avoidable. Zero vision focuses on having zero injuries, and companies try to obtain this status through safety campaigns, training, and learning from incidents. However, the focus has been on improving the behaviour of the individual through safety campaigns and training and not so much on the structural changes. In Norway, the heavy focus on this behaviour-based approach to accident prevention has been criticised (Tharaldsen, 2011). The analyses of near misses within the Danish oil and gas industry indicate some of the same tendencies. The analysis of near misses related to personal behaviour indicated

that the focus is on more behaviour-based approaches, such as discussing the issues during safety meetings and creating new procedures, as opposed to finding the root causes and focusing on structural changes. Several examples within oil and gas industry have shown that focusing only on individual behaviour and the number of lost-time injuries (LTI) does not necessary lead to a safe work environment. One example is the Taxas City Refinery explosion in 2005, which resulted in 15 fatalities and more than 170 injuries. At the time of the accident, BP had a very low LTI statistic and focused intensely on personal behaviour; however, this approach to safety still did not prevent this incident (U.S.Chemical Safety and Hazard Investigation Board, 2007). The same disconnect was observed at Water Horizon, where BP had a statistic of seven years without personal injuries. A gas leak on the Norwegian sector in 2002 on Snorre Alpha is yet another example. Just before the incident, a questionnaire about safety climate was conducted on the platform and actually showed a good attitude toward safety and a general positive picture of the safety, but the subsequent investigation showed that some procedures were not followed (Antonsen, 2009b). These examples show that focusing on behaviour-based approaches alone is not always the best solution, and that a more holistic approach that integrates safety during the production process should also be part of accident prevention. The zero vision within the oil and gas industry is very positive and clearly an advantage within the industry. This focus on safety can affect the employees' awareness and improve safety and accident prevention (Frick & Walters, 1998; Reilly, Paci & Holl, 1995; Walters, 1996). However, focusing on the statistics to obtain the aim of zero accidents might remove attention from the complexity of working safely and hide the most important issues - learning from the incident and preventing accidents. This focus may also influence the reporting culture, where employees would consider reporting in light of the statistic. The challenge of zero vision is learning from incidents and obtaining an open and honest reporting culture. The results of the thesis have shown that not all companies succeeded in achieving a no-blame culture.

Relationships between risk perception and organisational and human factors

The third article focuses on the relationship between the organisational and human factors and risk perception. The article focuses on two different kinds of the risk perception: risk perception of occupational hazards and risk perception of process incidents. The results show that the more individual oriented factors have an influence on risk perception of occupational hazard, while the factors influencing risk perception of process incidents are more related to organisational factors. However, the measurement of the risk perception can be problematic. The problem is that we as human beings are not able to predict risk; we build our risk perception on subjective experience. Human beings have been exposed to risk for centuries, risk is an integral part of our lives and a challenge of the contemporary society, but also high risk industries are to understand the social nature of risk. The challenge lies in the understanding of how individuals address risk issues, and how they make decisions based on their knowledge, and how it can influence safety (Glendon, Clark & McKenna, 2006). Risk perception reflects the employees' subjective judgment of the

probability of process incidents at the installation, such as gas leaks, explosions, or fires, and the probability of work accidents. The subjective perception of risk can vary from employee to employee over time, and several factors influence this perception, such as experience with injuries within the last 12 months, which increases the risk perception. Subjective risk relates to individual feelings of danger or safety. The interpretation of risk perception can be difficult, because the risk perception of the offshore employees is a picture of their understanding of risk. On the one side the risk perception could be an indicator of problems on the installation; but on the other side it could be also an underestimation of real risk and lacking awareness. The relation between formal estimated risk and subjective risk perception is not very clear. However, Rundmos' results show that risk is perceived "correctly" in accordance with the objective risk (Rundmo, 1996a). Rundmo found out that employees who had experienced accidents themselves felt less safe. On the other side, Rundmo also found an association between risk perception and the amount of injuries on the installation. The employees on the high-injury platforms felt less safe than the employees on the low-injury platforms (Rundmo, 1995). On the other side, the results of Bye and Lamvik (2007) showed different results. In their study they have compared the formal estimation of risk with subjective risk perception on board small fishing boats and offshore service vessels. Their results show discrepancy between formal risk estimation and subjective risk perception especially in relation to small fishing vessels. Their explanation is that risk perception can be learned as a part of social interaction and could be interpreted as a cultural phenomenon. In their explanation they are using the theory of Douglas and Wildawsky. According to this theory risk perception will reflect the individual's social and natural environment, which could result in underestimation of the risk perception. This underestimation could be necessary to survive or to cope with the job. In their conclusion, they focus on the importance of information for the organization about the discrepancy between formal and subjective risk perception (Bye & Lamvik, 2007).

Even though the measurement of risk perception is complex and could be difficult to interpret, it would still be useful for the companies to know how their employees feel about safety and which factors that have influence on their risk perception. Some of those factors could be improved and in that way prevent accidents. Risk perception could be a starting point for discussion in the organisations about acceptable risk and safety awareness.

Risk perception and attitude to safety among Danish and Norwegian offshore employees

The fourth article focuses on the distribution of risk perception and the attitude to safety among Danish and Norwegian offshore employees. As mentioned before, the measurement of risk perception is difficult to interpret. The same counts for the measurement of safety climate because the measurement is conducted on the individual level and mostly compared with aggregated accident level (Fleming et al., 1998; Flin et al., 1996; Mearns & Flin, 1995; Tharaldsen, 2011; Tharaldsen et al., 2008). However, in the

fourth articles, the analyses at the aggregated level could not be calculated due to missing data, particularly from the Norwegian shelf.

In general, higher perceived risk on platforms is associated with lower safety climate scores (Bracht, 1999; Fleming et al., 1998; Mearns et al., 2001b; Mearns et al., 2003; Rundmo, 1996a; Rundmo, 1996b; Rundmo & Sjoberg, 1996; Tharaldsen et al., 2008). Comparison of Danish and Norwegian offshore employees showed that Norwegian offshore employees perceive greater risk compared with Danish employees. This result is interesting because the Norwegian offshore employees had a more positive perception of safety than the Danish offshore employees. The survey data cannot explain these differences. A possible explanation was found in the demographical differences between the two samples. In the fourth article, a comparison between the two samples showed that Norwegian offshore employees had been employed offshore for a longer time than Danish offshore employees, and as a consequence of this they had experienced more accidents than the Danish employees. However, the two groups could define risk differently. Tierney (1999) emphasised that risk perception is socially constructed and involves social and cultural factors (Tierney, 1999). Thus, Danish and Norwegian offshore employees could interpret risk perception in different ways based on different social and cultural factors.

Another difference between Danish and Norwegian offshore employees is the safety climate dimensions and their impact on risk perception. Three dimensions, safety management and involvement, safety versus production, and system perception, were used in the regression model. For the Danish sample, only the 'safety versus production' dimension was associated with risk perception, while for the Norwegian sample, all three dimensions had an impact on risk perception. The reason for these differences is unknown and difficult to estimate based on the survey data. One explanation could be that Danish and Norwegian offshore employees understood the question differently. To determine why the Danish and Norwegian offshore employees differed on their perception of safety and risk, a more comparative study with a qualitative focus is needed to examine safety and risk perception in a more in-depth manner than quantitative studies can provide. Cultural differences could also be an explanation for this result. Studies on the differences between Swedish and Danish construction employees have indicated that there are cultural differences in working practices and their impact on safety campaigns (Spangenberg, Baarts, Dyreborg, Jensen, Kines & Mikkelsen, 2003; Spangenberg, Mikkelsen, Kines, Dyreborg & Baarts, 2002).

Summary

This chapter presented the main results in the light of the theoretical framework. The results of the articles have shown that the Danish oil and gas industry has focus on safety and makes some efforts to prevent accidents; however there are still barriers such as participation of employees in safety and learning. The learning processes, both at the individual and organisational level, are still challenging, and the

organisations do not obtain the full benefit from these processes. Learning should take place at all levels, and structural changes should follow the changes in the employees' awareness and qualification levels. Empowerment, ownership, and participation in safety are also important; more engaged and empowered employees can improve safety and make the employees more responsible for their own and others' safety. A community-based approach, which has been successful for health promotion, could also be useful in accident prevention within the Danish oil and gas industry (Bracht, 1999; Minkel, 2002). The community approach emphasises the importance of participation, involvement, and empowerment in changing the community. The members of the community participate actively in the structural changes, and some studies on safety representatives have indicated that participation is an important issue for accident prevention (Reilly, Paci & Holl, 1995; Walters, 1996; Walters & Nicholas, 2007).

The historical background of the organisations and their management structure impact the cultural approach, which determines accident prevention. This result highlights the importance of including the historical background in accident prevention. The prevention of accidents should consider the historical background and cultural approach of the company. The importance of these considerations also relates to the duality of the structure: the historical background builds the frame within which the employees act; however, this frame also acts as a barrier. Thus, it is important to integrate the cultural perspective into accident prevention and be aware that accident prevention occurs in a certain company-specific context. In other words, an intervention that improves safety in one company does not necessary have the same impact in another company.

The results showed that accident prevention is highly complex and that there are many interactions between the different levels compared to what was presented in the conceptual model. Based on the results and analyses of this thesis, Figure 7 has been developed to illustrate the complex conceptual model in detail.

Safety is an integrated part of the organisational culture, and the background of an organisation influences not only the culture of the organisation but also its way of organising safety and learning from incidents. This conceptual model is an example of the complexity of accident prevention within an organisation and emphasises the importance of applying more complex interventions that focus on both training the employees and changing procedures. The community-based approach utilising the five steps proposed by Bracht (1999) could be a useful method for implementing more complex accident prevention strategies because it considers the context of the community and involve community members when identifying problems and prioritising which initiatives should be taken (Bracht, 1999).

Figure 7 New version of the conceptual model

One useful way of preventing accidents could be a different way of defining the organisational culture. Analysing the cultures of the companies from the perspective of integration, differentiation, and fragmentation presented by Richter and Koch, all companies want to have an integrative culture with shared values and attitudes toward safety (Richter & Koch, 2004). However, the differentiation perspective could be more useful for accident prevention because different groups, e.g., workers on the installation, may perceive safety differently (Richter & Koch, 2004). The differentiation approach could thus focus on how subgroups can obtain the same safety results but in different ways.

Conclusions

The aims of this thesis were:

- to identify the possibilities and challenges for accident prevention within the Danish oil and gas industry
- to contribute new knowledge on accident prevention to a high-risk industry that could be useful for other sectors

To address this aim, four research questions were posed:

1. *How does the organisation within the Danish oil and gas industry involve safety representatives in safety work?*
2. *How does the organisation within the Danish oil and gas industry learn from their near-misses?*
3. *Which organisational and human factors influence risk perception among Danish offshore employees?*
4. *How are risk perception and attitude to safety distributed among Danish and Norwegian offshore employees?*

The answers to these questions were addressed in four articles that used different theoretical frameworks and methods. The thesis is the first to explore accident prevention within the Danish sector and contributes new knowledge about accident prevention in the Danish oil and gas industry. The thesis is based on different data sources, providing a more detailed picture of how safety representatives participate in safety, learning from near-misses and employees' attitude to safety in comparison with using a single data source. This thesis uses a sociological theoretical framework to address the complexity of accident prevention (Berger & Luckmann, 1999; Giddens, 1984; Goffman, 1959; Mead, 1962). Despite some limitations, the sociological perspective provides some explanations of the processes that are found within organisations. Inspiration from sociology and health promotion research is useful in safety research, which is practical research without a meta-theoretical framework.

The first article explored the role of safety representatives, their participation in safety, and the dilemmas associated with their role. This study concluded that the role of safety representatives is unclear and that safety representatives find themselves caught between legislative demands and conflicting expectations from colleagues and management. The Danish legislation and Danish industries focus on the collaborative aspect of the safety representative role, which impacts how the role is viewed. The role of the safety representative is primarily associated with solving small issues and problems rather than protecting the

interests of the representative's colleagues. This focus on small issues is caused by both legislation and the policies of the individual companies; only one of the companies included their safety representative to a much larger extent than the other companies. This study emphasised several dilemmas, such as the time required to ensure a safe work environment, lack of support from management, and lack of involvement in safety planning.

The second article focused on learning from near-misses. The companies involved in this study have procedures in place and comply with them; however, near miss reports are still not optimally used as learning tools. One of the barriers is the underreporting of near-misses, particularly near-misses related to personal behaviour. The study indicates several reasons for underreporting: unclear definitions of near-misses, employees' fear of reporting and a too-demanding reporting system. As currently designed, the report systems are aimed at gaining an overview and registering the reports, which limit the possibilities of learning from these incidents.

The third and fourth articles examined the association between risk perception, safety climate/organisational factors, and human factors. The third article showed that the organisational and human factors affect the risk perception of offshore employees. The more individual factors, such as safety behaviour, work experience, or experience of injuries, influence the risk perception of occupational hazards, while the priority of safety versus production influences the risk perception of process incidents. The study also showed that the risk perceptions of offshore employees for both categories appear to be influenced by organisational factors, such as satisfaction with safety measurement (e.g., detection systems) and working conditions.

The fourth article identified differences in risk perception between Danish and Norwegian offshore employees. The Norwegian employees have a more positive perception of safety and management involvement in safety than the Danish offshore employees. However, the risk perception for both process incidents and injuries is higher among Norwegian offshore employees than Danish offshore employees. Although the study found differences in the risk perceptions of these two populations, the differences were quite small.

Based on the results of the articles and discussion in this thesis some possibilities and challenges in accident prevention within the Danish oil and gas industry could be highlighted.

The possibilities are as follows:

- Focus on safety: The oil and gas industry focuses on safety and has managed to decrease the accident rate over the period of the 20 years. The focus on safety includes many activities, such as training

employees, safety meetings, and safety campaigns, which together improve awareness and safety within the oil and gas industry.

- System of procedures: The oil and gas industry has developed a system of procedures, including guidelines for the employees to safely perform their jobs, perform risk assessments, or report incidents or accidents. The procedures are a part of a safety management system and are integrated into daily practice.
- Reporting system: All companies have developed a reporting system in which accidents and incidents are reported. Depending on the severity analysis, some reports are used to learn from the experience.
- Safety organisation: All companies had developed a safety organisation with frequent meetings. Safety representatives who are chosen by the employees are part of this organisation and could be a useful tool for accident prevention.
- Reporting culture: To some degree, the employees report incidents and accidents to improve safety and improve leaning from incidents, but also to keep focus on safety.
- Safety awareness among employees: Training and intense focus on safety make the employee more aware of risk and more focused on safety, which impacts safety in general.

The challenges of accident prevention within the Danish oil and gas industry are as follows:

- Organisational culture: The culture of the companies can be a barrier for the development of new safety initiatives. Organisational culture is not easy to change, and companies show differences as to how they prioritise safety and how much they involved their employees.
- Lacking focus on structural/organisational factors in accident prevention: The analyses of near misses showed that most solutions for incidents were improving deviations, changing procedures, or implementing safety meetings. Few solutions involved general structural changing, such as changing the working conditions. Most of the training focused on individual issues, such as behaviour, and did not make the connection between individuals and their working environment.
- Fragmented view/unsystematic accident prevention: The companies under investigation focused on small issues; there is need for a more holistic view on accident prevention, and it should not focus on a certain issue.
- Lacking support from management: Several studies reiterated the importance of support from management to obtain better safety; in the study on safety representatives, the results showed that the safety representatives in some of the companies lacked support from the management for their safety duties.
- Lacking long-term strategies for accident prevention: Companies focus on safety and organise safety

campaigns, but more long-term strategies (e.g., what we want to obtain, how we get there, what type of activities should be undertaken in the next five years, and how we will evaluate our action) are missing.

- Lacking evaluation and follow-up: the oil and gas companies begin many actions to improve some deviations that are recognised by near-miss reports, but activity regarding follow-up and evaluations of whether the action fulfilled the aim and was implemented well are lacking.
- Lacking some degree of empowerment/participation/ownership among employees: The employees need to be empowered and to be more involved in safety work so that they can feel more ownership. This problem was described in the study on safety representatives and their participation in safety.

This thesis highlighted some aspects of safety management system and accident prevention. However, as the study is the first one about the Danish oil and gas industry the thesis contribute with new knowledge about safety and accident prevention within Danish oil and gas industry. One of the issues which are also important in contribution of new knowledge is the generalisability of the results: can these results be transferred to other industrial sections or other countries? The answer is twofold. Some elements, such as the focus on safety, risk assessment, safety management system, and intensive training of employees, could be transferred to other industries, such as construction. Other industrial sectors could learn from the oil and gas industry's experience with safety. However, there are also some barriers. One of the barriers is the nature of the oil and gas industry; thus, some experiences or lessons that have been learned are only related to the oil and gas industry and cannot be transferred to other industries. Another barrier is the importance of the culture within the organisations, including safety, reporting, and learning from incidents; these lessons could be difficult to learn in other industries if their culture differs significantly. The last element that makes generalisability rather difficult is the Danish context, particularly the organisation of the labour market, which is quite unique. The Danish labour market model is characterised by collaboration between the authorities (State), employers, unions, and common agreements between these parties to regulate labour (Due, Madsen & Jensen, 1993). This condition makes it difficult to transfer the results to other countries in which the labour market does not have the same conditions. Despite these barriers, the Danish industry in general can use some of the elements of accident prevention and learn from the oil and gas industry experiences. One of the examples could the new windmill industry, which has to some degree the similar working condition as the oil and gas industry, which could draw some benefits from the experiences within the oil and gas industry.

This thesis has presented and discussed some of the factors that influence accident prevention in the Danish oil and gas industry from a sociological perspective. The overall conclusion is that the Danish oil and gas industry has already made some efforts to prevent accidents, but there is still room for improvement.

This thesis highlighted several issues which are important in accident prevention. One of them is the complexity of accident prevention, which influences the actions taken. There is need for seeing accident prevention as a complex process, and it must be acknowledged that several factors influence safety, which creates the need for complex intervention programs that focus on both qualification of the employees and their attitude toward safety and structural changes. Even through the thesis highlighted the importance of learning from experience (in this case near-miss) the learning is not enough, because learning to some degree is a reactive way of preventing accidents. In the long run preventing accident is about being proactive and being able to prevent things before it can happen; make a proper risk assessment, but to a great extent also to involve the employees and give them adequate qualifications so they can work safely. Accident prevention is also about priority of safety in word and deed; not focusing only on behaviour based approach, but combining it with the "proper" safety management system, management involvement and support and structural changes (Glendon et al., 2006). Accident prevention is also about sharing knowledge of good examples and research. This thesis gives answers to some aspects of accident prevention, but there is still need for more research about how the organisations prevent accidents with more focus on the good examples and possibilities. In the future research focus should also be on evaluation of the interventions that have been conducted within the oil and gas industry and to study the different factors that influence accident prevention and safety, such as leadership or procedures.

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