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Behind Safety Violations

Understanding the antecedents of safety-compliant behaviour in the oil and gas industry

Thesis for the degree of Philosophiae Doctor

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Safety is not an intellectual exercise to keep us in work. It is a matter of life and death. It is the sum of our contributions to safety management that determines whether the people we work with live or die.[1]

[1] Brian Appleton, technical assessor to the public inquiry into the Piper Alpha disaster (quoted in Kletz, 2001: 120).

Table of content

1. Introduction

1.1 Background and research objective

Since the first exploration well was drilled on the Norwegian Continental Shelf (NCS) in 1966, both the authorities and the oil and gas industry have been repeatedly reminded of the high risks and the multitude of different hazards involved in petroleum production. The Petroleum Safety Authorities' (PSA) safety statistics are a clear reminder of this: after nearly five decades of production, occupational and major accidents in the offshore activity have caused the death of 268 workers (PSA, 2012b). The majority of these happened in the period up to 1980 and culminated with the capsizing of the drilling rig Alexander Kielland which killed 123 workers. Since then it is generally acknowledged that safety has been given far more attention within the industry and that the risk level has gradually reduced (Kongsvik et al., 2012; Ryggvik, 2003; Wiig, 2004). For example, the number of fatalities per 100 million working hours dropped from 3.3 in the period from 1990 to 1999 and to 0.5 in the last five-year period (PSA, 2012b).

Despite the fact that the development within the Norwegian petroleum industry has been considered a success (Ryggvik, 2003), accidents and near misses with catastrophic potential still happen, and when they do the costs could be considerable for the workers involved, for the companies, for the environment and for society. High potential incidents such as the blowout on the Snorre Alpha platform in 2004, the collision of the Big Orange XVIII vessel in 2009 and the well kick on the Gullfaks C platform in 2010 are all reminders of this. Hence, there is a continuous need for improvements. Such improvements require knowledge, in particular knowledge about why things go wrong.

One essential source for such knowledge is investigations led by the regulatory authorities (e.g. PSA, 2009b, 2010a, 2011b) and in-depth analyses conducted by safety researchers into accidents and near misses on the NCS and other oil and gas incidents internationally (e.g. Austnes-Underhaug et al., 2011; Hayes, 2012; Schiefloe et al., 2005; Sutton, 2012; Wright, 1994). What these investigations and analyses demonstrate, more than anything, is that accidents, even those with a relatively limited extent of loss, are seldom caused by one single causal factor. Rather, it is a multitude of different technical, behavioural and organizational factors and the unique combination of these that contribute to the accident causation scenarios. The blowout on the Snorre Alpha platform on the NCS in 2004, which under slightly different circumstances could have resulted in a catastrophe similar to the Piper Alpha and Deepwater Horizon disasters, is illustrative of this. The causal analysis of the blowout (Schiefloe et al., 2005) concluded that an unfortunate combination of several different factors made the incident possible. Some of these were insufficient planning of work operations, extensive corporate reorganization, inadequate technical maintenance and a constant production pressure.

Despite the fact that most accident investigations and analyses point to a well of different causal factors, some are more frequently occurring than others and are thus identified across different types of accidents. According to Walker et al.'s (2012) analysis of 108 fatal accidents and 174 high potential incidents in 75 companies within the International Association of Oil & Gas Producers (OGP), one of the most common direct causes is violations of safety rules and procedures.

Walker et al.'s findings are not unique. Several other studies and accident analyses across a range of different industries report that procedural violations, especially those committed by front-line workers and others with safety-critical responsibilities, are a common causal factor (e.g. Austnes-Underhaug et al., 2011; Hopkins, 2011; Hudson et al., 1998; Lee and Harrison, 2000; Mason, 1997; Reason, 1987). Within the mining industry, for example, Lenné et al. (2012) have found that non-compliant actions can be identified as a contributing factor in 57% of workplace accidents, and within the aviation industry Helmreich (2000) has found that more than half of the observed errors that result in undesired aircraft states are caused by violations of written procedures.

Accidents and near misses within the Norwegian oil and gas industry do not represent any exception to this. Violations of safety regulations have, for example, been ranked as the most important cause of collisions between offshore service vessels and offshore installations on the NCS (Kvitrud, 2011; Kvitrud et al., 2012). Also, investigations of accidents and near misses conducted by the Petroleum Safety Authority Norway (PSA) repeatedly identify a lack of compliance with rules and procedures as a central contributing factor (e.g. PSA, 2009a, b, 2010a, 2011a, b). In fact, it is hard to find PSA investigation reports that do not point to safety violations as a significant causal factor. The investigation of the Snorre Alpha blowout, for example, revealed that 28 different violations contributed to the blowout and that three of these 'were direct triggering factors that caused the incident to occur' (PSA, 2005b: 26).

Another example of an incident with a catastrophic potential is the collision between the well stimulation vessel Big Orange XVIII and an unmanned water injection facility on the Ekofisk field in 2009, where the ensuing PSA investigation report concluded that a lack of compliance with resting time regulations, the requirement to monitor all activity in the safety zone and requirements related to the safe entry of vessels, contributed significantly to the collision (PSA, 2009a).

The well-recognized importance of violations as a central contributing factor to accidents and near misses across different industries, and the fact that this also applies to the Norwegian oil and gas industry, forms the point of departure for this thesis. However, rather than focusing on violations as a cause of mishaps and thus embracing aberrant behaviour as a meaningful and satisfactory explanation of bad outcomes, violations are primarily dealt with as a symptom and a consequence of deeper organizational deficiencies. Thus, this thesis aims to go behind safety violations, as indicated in the title. This implies that a *system perspective* is applied. In addition, violations are addressed from a different and hopefully more constructive viewpoint than that which is common within accident investigations and traditional safety research, which tends to pay more attention to conditions that hinder safety rather than to conditions which foster safety (Hollnagel, 2012). In this thesis this is done by putting more explicit focus on safety compliance rather than on safety violations. This implies that the main emphasis will be on acts that are in accordance with prevailing procedures, instead of acts that are contrary to procedures. In line with Antonsen et al. (2008) it is believed that addressing safety violations from such a point of view has a greater potential when it comes to shedding light on the conditions that can facilitate a safe balance between formal prescriptive regulations and the way work is actually carried out.

With a system perspective as the guiding principle for empirical enquiry, and the Norwegian oil and gas industry as the primary research context, ***the main objective of the thesis then is to go behind safety violations and to examine and identify the conditions that affect the propensity to act in accordance with prevailing rules, procedures and regulations***. With this objective as a specified course of action, the empirical and theoretical work in the thesis aims to add new knowledge about the antecedents of safety-compliant behaviour within the oil and gas industry. Such knowledge is believed to be important, especially for future development of effective proactive measures which aim at improving safety compliance within this particular industry. Hopefully, it will also be of importance for other industries where safety is a significant concern and where rules and procedures constitute a central part of the safety management system.

Such knowledge should also be a contribution to safety research and to the broader, more theoretically oriented sociological (and social psychological) traditions – where different explanations of the causal relationship between context and behaviour have been a fundamental topic for disciplinary debates for decades (Mouzelis, 1995). Having said that, it should also be noted that the research objective and the empirical research of the thesis are highly related to a particular sort of sociological explanation, namely contextual explanations. Typically, contextual explanations seek to describe the behaviour attached to some element (an individual, an enterprise, a group) by the characteristics of its environment, and not the other way around – how individuals and groups create the environment they are a part of (Stinchcombe, 1987). This implies that the empirical work primarily is focused on how environmental conditions affect compliance with safety regulations, and that, to a lesser extent, it is focused on how individuals or groups create their own norms for safe work performance (even though this is also recognized as an important research topic).

1.2 Structure of the thesis

The thesis is structured as follows. In the remainder of chapter one, the research questions that have been developed to shed light on the main objective will be presented. Also, a brief description of the research context which constitutes the empirical basis of the thesis will be presented. The object of the study (safety compliance) will be described and discussed in detail in chapter two, followed by a presentation of the theoretical perspective (the system perspective) and a discussion of previous research in chapter three. Chapter four presents a description of the research designs and the different research methods that have been employed in the empirical work of the thesis. A short summary of the research findings is presented in chapter five, and is followed by a discussion and conclusion in chapter six. An extended presentation of the empirical work and the research findings is to be found in the appendix, where the four research articles that constitute the fundament of the thesis are attached.

1.3 Research questions

The main objective of the thesis is relatively broad. Thus, it invites a multitude of different research questions with a basis in various theoretical and practical problems. In addition, the Norwegian oil and gas industry is not limited to one type of work context. Several different types of contexts exist, such as fixed offshore installations, floating drilling rigs, supply bases, onshore gas-receiving terminals and offshore supply vessels, to mention but a few. Thus, the main objective of the thesis also invites empirical studies of different work contexts. Further, the term ‘safety compliance’ is, in principle, not only restricted to individuals and individual behaviour at the front line of work organizations. It is also a term that is applicable to the enterprise level, since the behaviour of an enterprise as well as the behaviour of an individual or a work group is regulated by a set of national safety regulations and internal procedures. Thus, the main objective of the thesis also invites empirical studies of safety compliance at different organizational levels.

Despite these many possible directions for empirical investigations, some boundaries have been set. After (1) a broad literature review which was aimed at identifying gaps and promising avenues for further research in the existing research works and (2) an examination of relevant investigation reports and accident analyses, four distinct, but still complementary research questions were formulated. These four questions were investigated in four separate studies and the results of the empirical investigations were presented in separate research articles (attached in the appendix). The three first research questions are related to front-line workers' compliance with company internal safety rules and procedures, whereas the last is related to enterprises' compliance with national safety regulations.

The first research question has its starting point in one of the few extensive review studies on the subject of violations and compliance, conducted by Alper and Karsh (2009). Based on previous research, their study identified six categories within the organizational context that affect the level of safety compliance among front-line workers: (1) individual characteristics, (2) information/education/training, (3) design to support worker needs, (4) safety climate, (5) competing goals and (6) problems with rules. Alper and Karsh's review study is highly relevant to the topic of this thesis because it represents a condensed account of the conditions which previous studies have identified as important for workers' propensity to act in accordance with prevailing safety rules and procedures. Their review is, however, based on studies within sectors other than the oil and gas industry, with a predominance of studies from the aviation sector and the health care sector. Thus, it would be valuable for the objective of this thesis to examine the extent to which the main findings within other sectors also apply to the oil and gas industry. This is done by asking: ***To what extent can the variation in safety-compliant behaviour among front-line oil and gas workers be explained by explanatory variables that are found to be relevant within other sectors?*** This research question is addressed in article #1.

The second research question is related to a common topic within safety compliance research, namely leadership and the impact that leadership practices have on front-line workers' propensity to act in accordance with safety rules and procedures. Previous research on this topic has primarily focused on the safety-specific dimensions of leadership (e.g. monitoring, correction, and reward for safe behaviour), whereas few studies have examined the more general dimensions of leadership (e.g. trust, cooperation, and involvement), and how such dimensions are related to workers' compliance with rules and procedures (Hofmann and Morgeson, 2004). One such general dimension which is of particular interest is leadership involvement (i.e. the degree to which leaders are involved in subordinates' work operations), and the impact that such involvement has on subordinates' safety compliance. In accident investigations and analyses, a lack of leadership involvement in work operations is often identified as an important cause of non-compliance among front-line workers because it is assumed that it hinders leaders to reveal unsafe work practices (e.g. Hayes, 2012; PSA, 2005a). Further, safety management literature frequently claims that active and hands-on supervision is of vital importance to ensure that work is carried out in accordance to rules and procedures (e.g. Weick and Sutcliffe, 2007). However, few studies have attempted to explore and test such claims empirically. Thus, the second research question that is asked is: ***How does leadership involvement in work operations influence safety compliance among front-line oil and gas workers?*** This research question is addressed in article #2.

The purpose of the third research question is to shed light on a notable research gap in safety compliance research. Whereas the vast majority of previous research has focused on safety compliance as a product of appropriate safety motivation and safety attitudes, and thus has been concerned with identifying the organizational conditions that affect such motivation and attitudes, this research question deals with knowledge of rules and procedures as an important prerequisite for compliance. Knowledge of rules and procedures certainly reduces the probability of unintentional non-compliance (Reason, 1997), but few studies have attempted to investigate how organizational conditions influence such knowledge (Barber, 2002). Thus, the third research question that is asked is: ***How do the contextual aspects of work affect front-line oil and gas workers' knowledge of rules and procedures?*** This research question is addressed in article #3.

As already described, the fourth research question differs from the first three as regards the level of analysis. Instead of focusing on how company internal conditions affect individual safety compliance, this question deals with how company external conditions affect compliance with national safety regulations at the enterprise level. Empirically speaking, however, these two levels do not function independently of each other as previous research has found that enterprises which have established a well-functioning safety management system that meets legal obligations promote safety-compliant behaviour among front-line workers (Torp and Grøgaard, 2009). However, whereas the majority of previous research has focused on safety compliance (or non-compliance) at the individual level and effective measures which can be taken to improve individual safety compliance, few studies have paid similar attention to the enterprise level. This implies that few studies have examined why some organizations follow safety regulations while others do not, and that few studies have aimed at identifying effective compliance-enhancing measures at the enterprise level (Baldock et al., 2006). This research gap is the origin of the fourth research question which turns its focus to labour inspections and their impact on enterprises' compliance with safety regulations. Labour inspections are among the most fundamental instruments applied by the regulatory authorities to ensure compliance with existing safety legislations. Despite that, relatively few studies have examined whether such inspections actually have any impact on enterprises' legislative compliance. Thus, the fourth research question that is asked is: ***What effect do labour inspections conducted by regulatory authorities have on enterprises' compliance with safety regulations?*** This research question is addressed in article #4.

1.4 The research context

The first three research questions in this thesis are all addressed on the basis of three separate empirical studies conducted among front-line workers employed (or hired as contractor workers) by one large Norwegian oil and gas company, Statoil. The last research question, however, is addressed on the basis of an empirical study conducted within the Norwegian Labour Inspection Authority (NLIA). Within these two organizations, four different research contexts have been selected for empirical studies:

- Offshore service vessels, Statoil (research question 1)
- Offshore platforms, Statoil (research question 2)
- Maintenance and modification work, Statoil (research question 3)
- Labour inspections, NLIA (research question 4)

Together, these research contexts provide a wide and thorough access to information on the subject of safety compliance. Before continuing on to the description of each of these contexts, it might, however, be beneficial to introduce Statoil, the main source of the empirical data, in brief and give a short description of the central position that compliance with safety rules, procedures and regulations has within this organization.

Statoil was established as a state-owned petroleum company in 1972 after the discoveries of commercially profitable oil and gas fields on the NCS in the late 1960s. In parallel with the Norwegian oil and gas industry in general, the following four decades represent a history of continuous growth for Statoil. One year after its establishment, the company had 54 employees, in 1977 it had 504 employees and ten years later it exceeded 10,000 employees (Kongsvik, 2006). In 2013, Statoil is a fully integrated public limited petroleum company which, after the merger with the oil and gas division of Norsk Hydro in 2007, employs approximately 23,000 employees. The Norwegian Government holds 67% of the shares. It is the leading operator on the NCS, among the world's largest net sellers of crude oil and condensate, the world's largest offshore operator and the second largest gas exporter to the European market (Statoil, 2013).

The high activity level and the many potential hazards included in the activities that Statoil performs imply that this is a company that is exposed to a wide range of risks that could result in significant losses. Hydrocarbon leakages, falling objects, fires, explosions, loss of well control, blowouts and hydrogen sulphide emissions are all examples of such risks. Thus, the focus on risk management in order to ensure safe operations is a high priority area (Statoil, 2013).

One important element within this priority area is the company's *compliance and leadership model* (CLM). This model is not a short-term campaign, but a general description of and a written requirement for how work shall be performed within the company (Statoil, 2011). Like any other petroleum company, Statoil's work operations are highly regulated by internal rules and procedures and CLM is a strategy implemented for the purpose of ensuring compliance with these. The model places a particular emphasis on leadership and the role that leaders have in enabling subordinates to perform their work safely and in accordance with the prevailing procedures. All employees in Statoil, all contractors and all subcontractors are obliged to plan, execute and evaluate their work according to CLM (also known as the *A-standard action pattern*). CLM as such is not examined specifically in this thesis, but it is mentioned here just to underline that compliance with rules and procedures represents an important part of the system of safety barriers and controls in Statoil. The model is also illustrative of the fact that the company's safety philosophy relies heavily on achieving safe operations through governing workers' behaviour, as previously described in Antonsen's (2009) safety culture study of Statoil.

1.4.1 Offshore service vessels

The first research question, concerning the relevance of previous safety compliance research conducted within other sectors, is addressed on the basis of a survey designed to monitor safety and working environment issues among employees working on offshore service vessels chartered by Statoil.[2] The vessel fleet consists of 85 vessels which all operate on the NCS. Each vessel has two work shifts (four weeks on duty and four weeks off), so the total number of shifts within the fleet, and within the study population, is 170. A work shift consists of approximately 10-15 seamen. Typically, this includes a captain, a first officer, a second officer, engineers, sailors, an electrician and a steward.

Virtually all work operations conducted by the crew are regulated by an extensive body of regulations which includes Statoil's company-specific procedures, the ship owners' internal procedures, national and international rules, guidelines, manuals and best practices. This, and the fact that the risk level is considered to be high on board offshore service vessels (Kongsvik et al., 2012) implies that they are highly relevant for safety compliance research. The relevance of such research is also strengthened by the fact that few, if any, studies have aimed at identifying the conditions that affect safety compliance among front-line personnel on board these vessels.

[2] The survey was conducted as a part of a larger research and development project at NTNU Social Research Ltd, Studio Apertura. The project was financed by Statoil Marine.

Three different types of vessels are included in the study: anchor handling vessels, platform supply vessels and standby vessels. These vessel types serve different functions on the shelf, and to some extent the types of risks included differ with respect to the vessel type. The anchor handling vessels' primary function is to move drilling rigs from one location to another. In brief, these operations include rig towing, positioning, anchor lifting and seabed anchoring. Chains and wires under high tension represent a significant risk during anchor handling operations, and could cause serious harm to crew members as well as affecting the stability of the vessel. The capsize of the Norwegian anchor handling vessel *Bourbon Dolphin* while anchoring the drilling rig Transocean Rather off the coast of Shetland in 2007 is a reminder of this. Eight seamen were lost in the accident.

Standby vessel and supply vessel operating outside the Troll A platform. (Photo: Anette Westgard/Statoil)

The platform supply vessels serve another important function within Statoil's logistic chain. These vessels transport equipment, bulk products, hazardous chemicals and supplies to and from offshore supply bases and offshore installations. Lifting operations with cargo containers and bulk-loading hoses close to offshore installations, often under challenging weather conditions, represent a substantial risk of personal injuries on these vessels. Owing to the fact that they operate close to the installations, these vessels are also relatively frequently involved in platform collisions and contacts (Kvitrud, 2011). Such incidents have a catastrophic potential and can actually affect the stability of the offshore installations.

The last type of vessels included in the study, the standby vessels, is responsible for the installations' emergency preparedness in case of the need for quick evacuation. In addition these vessels have guard duties which involve protecting the installations from drifting vessels or other hazards. These vessels do also operate close to the installations.

Thus the risk of collisions is present, as is the risk of personal injuries during emergency exercises and real-life situations.

1.4.2 Offshore platforms

The second research question, which regards the influence that leadership involvement has on safety compliance among front-line oil and gas workers, is addressed on the basis of a multi-sample survey designed to monitor effectiveness and safety in Statoil during the merger process of Statoil and Hydro in the period between January 2009 and October 2010. The survey was conducted six times among all employees in Statoil, but the second research question is only addressed on the basis of responses from offshore workers employed on Statoil's offshore platforms (i.e. onshore workers and workers employed outside Norway were excluded from the analysis).


Statoil's Gullfaks C platform in the northern part of the Norwegian North Sea. (Photo: Øyvind Hagen/Statoil)

Offshore oil and gas production is a high-risk industry and the dangers of fires, explosions, gas leakages, oil spills, blowouts and other hazards are always present. The capsize of the Alexander Kielland platform on the NCS in 1980, the Piper Alpha disaster in the British sector of the North Sea in 1988, the Montara oil spill off the northern coast of western Australia in 2009, and the Deepwater Horizon blowout in the Gulf of Mexico in 2010 all serve as reminders of the degree of risk related to offshore operations. No major accidents with loss of human lives have occurred in recent years on the NCS, but incidents with a major accident potential have occurred. One example of this is the already described blowout on the Snorre Alpha platform in 2004. Another example is the well control incident on the Gullfaks C platform in 2010, which, just like the Snorre Alpha blowout, was found to be triggered by work practices that were not in line with written procedures (Austnes-Underhaug et al., 2011).

Because of the high risks involved in offshore oil and gas production, particular attention has been paid to the prevention of major disasters and occupational accidents since the very beginning of this industry (Sutton, 2012). An extensive development of national and international safety regulations and guidelines and company internal rules and procedures are examples of such preventative measures (Ryggvik, 2003). Thus, work operations on offshore platforms today are highly regulated by procedures, and it is recognized that the safety level within these complex work systems to a large degree depends on human behaviour and adherence to safety procedures (Mearns et al., 2001). Therefore, this is also an industry where human risk management systems pay considerable attention to safety compliance. Statoil's offshore platforms are no exception to this, exemplified with the already described *compliance and leadership model*. Hence, they should be highly relevant for a study which explores the relationship between leadership and safety compliance.

1.4.3 Maintenance and modification work

The third research question, concerning how the contextual aspects of work affect front-line workers' knowledge of rules and procedures, is addressed on the basis of a qualitative on-site interview study of contractor workers from a maintenance and modification company. The specific company studied here is kept anonymous. It should, however, be mentioned that this company is a relatively large actor within the Norwegian oil and gas industry which carries out maintenance and modification work both onshore and offshore. The tasks and operations that this company performs vary considerably with respect to the complexity and risks involved – from advanced sub-sea operations, restoration of pressurized systems and large-scale modification projects, to simple routine tasks, such as minor repair and revamp projects. Half of the workers

Kollsnes, one of Statoil's gas receiving terminals, treats gas from the Troll, Kvitebjørn and Visund fields in the North Sea (Photo: Helge Hansen/Statoil) interviewed perform their work on one of Statoil's offshore platforms and the other half on one of Statoil's onshore gas receiving terminals.

At present, maintenance and modification of onshore and offshore production facilities within the Norwegian petroleum industry is a growing industry. This is due to the fact that the production facilities are ageing and because there has been a significant decrease in investments in new offshore installations and onshore plants. However, the economic margins are relatively low within this part of the petroleum industry because of a rapidly growing number of actors, and thus an increased competition (Sasson and Blomgren, 2011).

Contract based maintenance and modification work within the Norwegian oil and gas industry is highly relevant with respect to safety compliance research for several reasons: firstly, contractor workers represent a particularly large group of workers within this industry. On the NCS alone, almost 70% of all offshore personnel are employed by contractors (PSA, 2006); secondly, contractor work in general, and maintenance and modification work in particular, is a high-risk part of this industry. In fact, contractor workers represent the group of workers that perform the most hazardous work operations and are most frequently involved in accidents within the petroleum industry (PSA, 2012a; Walker et al., 2012); thirdly, maintenance and modification work, both onshore and offshore, is highly regulated by a relatively extensive set of rules and procedures. The extent and complexity of these regulations, makes questions related to procedural knowledge, and the origins of such knowledge, particularly important.

1.4.4 Labour inspections

The fourth research question, which deals with the impact that labour inspections have on enterprises' compliance with safety regulations, is examined on the basis of two field experiments conducted within the Norwegian Labour Inspection Authority (NLIA). The two field experiments measure this impact by a comparison of inspected and previously uninspected enterprises with respect to their level of compliance with national safety regulations.

The NLIA is a government agency under the authority of the Ministry of Labour with approximately 600 employees. The overall mission of the inspectorate is to ensure safe and healthy work environments and secure employment conditions by assuring that the enterprises comply with the existing workplace regulations. The main instrument applied by the NLIA is on-site inspections of enterprises which aim to control and enforce compliance with the national working environment regulations. Typically, some guidance and information is offered by the inspectors during an inspection, but four different coercive measures are available when dealing with enterprises that do not comply with the relevant regulations. These are formal orders, coercive fines, shutdown of operations and reports to the police. Formal orders are written orders to correct eventual violations within a limited time period and coercive fines could be imposed if the orders are not complied with. Shutdown of operations and reports to the police are typically imposed if the life and health of the employees are in imminent danger or in cases where the breaches of the regulations are serious. Formal orders represent the most widely applied coercive measure. Of the 15,000 inspections conducted in 2011, roughly 60% resulted in one or more formal orders (NLIA, 2012).

The NLIA's jurisdiction area is the land-based sectors of work. This implies that legal

Two fatal accidents occurred on the semi-submersible drilling rig Scarabeo 8 at Westcon Yard in Ølensvåg in 2009 and 2011. Both were investigated by the NLIA (Photo: Håvard Sæbø) issues related to workplace safety and health within offshore oil and gas activity are inspected and controlled by the Petroleum Safety Authority (PSA). However, the NLIA's jurisdiction area, and thus the inspectorate's labour inspection activities, includes several areas of work that are involved in the petroleum industry, such as the offshore supply bases, the petroleum plants' mechanical workshops, the ports where loading/unloading of supply vessels is conducted, and the yards where maintenance and modification of offshore drilling rigs is carried out. Hence, a study of the NLIA's labour inspections and the impact that the inspectorate's inspections have on enterprises' compliance with national safety regulations is highly relevant to a significant part of the oil and gas industry.

2. From safety violations to safety compliance

As already described, safety violations are in the current thesis addressed from a different viewpoint than that which is common within accident investigations and conventional safety research. This is done by putting a more explicit focus on the counterpart of safety violations, namely on safety compliance. That is, the thesis is more concerned with identifying and explaining the conditions that are favourable to rule-following than with conditions which provoke rule-breaking. This implies 'looking at what goes right' rather than 'looking at what goes wrong', to use Hollnagel's (2012: 3) words.

Traditionally, however, safety violations have been addressed from the opposite position. That is, from the 'looking at what goes wrong' position (for some early contributions, see for example Ames, 1935; Heinrich, 1931; Hersey, 1936; Karn, 1961; Slocombe, 1941). The fact that the current thesis takes the reverse point of view does, however, not by any means imply that safety violations fall completely out of scope. Actually, safety violations constitute the vital background and starting point of the thesis. It is therefore essential to make it clear what a safety violation actually is (and how violations are understood in this thesis), before returning to an explanation and discussion of the concept of safety compliance.

2.1 Safety violations

So what is a safety violation? Despite the importance of this question there is no straightforward answer to it – as several different definitions exist throughout the research literature. Some of these are presented in Table 1. The definitions share some similarities, but there are also some noteworthy differences between them. As regards similarities, each definition stresses that there must be some rules, procedures, instructions, regulations, guidelines, or best practices present to be violated. In addition, each definition specifies that a violation involves actions that are contrary to these. As regards differences, some of the definitions stress that the rules, procedures, instructions etc. must be written, whereas others make no such restriction.

Table 1
Different definitions of safety violations

Reference	Definition
Alper and Karsh (2009: 740)	'An action that is contrary to a rule.'
Amalberti et al. (2006: 66)	'Violations are deliberate deviations from standard procedure.'
Barber (2002: 83)	'Deliberate deviations from safe practice.'
Beatty and Beatty (2004: 528)	'Intentional acts contrary to advice or best practice guidelines.'
Bener and Crundall (2008: 334)	'Violations are defined as deliberate deviations from those practices believed necessary to maintain the safe operation of a potentially hazardous system.'
Hobbs and Williamson (2002a: 158)	'An intentional deviation from procedures or good practice.'
Hudson et al. (1998: 1)	'Violations are deviations from the rules, procedures, instructions and regulations developed for the safe and efficient operation (or maintenance) of equipment, plants etc. Deviations from good practice, even when not laid down formally, may also be regarded as violations. Breaches in these rules can be either unintentional or deliberate.'
Lawton (1998: 77)	'Violations are defined as behaviours that involve deliberate deviations from the written rules.'
Mason (1997: 288)	'Violations can be defined as any deliberate deviations from the rules, procedures, instructions or regulations introduced for the safe or efficient operation and maintenance of equipment. This applies to all levels, from an operator through high-level management.'
Mason et al. (1995: 3)	'Violations are any deliberate deviations from the rules, procedures, instructions and regulations drawn up for the safe or efficient operation and maintenance of plant or equipment. Breaches in these rules could be accidental, unintentional or deliberate.'
Parker et al. (1995: 1036)	'The deliberate infringement of some regulated or socially accepted code of behaviour.'
Reason (1997: 72)	'Violations are deviations from safe operating procedures, standards or rules. Such deviations can be either deliberate or erroneous.'

Lawton (1998: 77), for example, defines violations as 'deliberate deviations from the written rules', whereas Barber (2002: 83) defines them as 'deliberate deviations from safe practice'. 'Safe practice' is, however, a vague and roomy term and there is usually no definite answer of what a safe work practice actually is (Battmann and Klumb, 1993). Typically, it is only possible to decide whether an act or a decision is safe with the benefit of hindsight; that is, after something has gone wrong (or right, for that matter). To be more clear-cut, safety violations in the current thesis are therefore more narrowly defined, as actions that are contrary to *written* safety instructions (e.g. formal rules, procedures, regulations etc.). This also implies that acts that are only contrary to social norms or informal codes of safe behaviour are not treated as safety violations here.

Another significant difference between the definitions in Table 1 has to do with the intentionality of the actor. For example, in Beatty and Beatty's (2004) and in Lawton's (1998) definitions it is stated explicitly that a violation is an intentional act. This implies that only deliberate acts of rule-breaking are seen as violations. In Reason's (1997) definition, however, violations are seen as acts that could be both deliberate and erroneous. Hence, Reason's definition is similar to that of Alper and Karsh (2009: 740) who define a violation as 'an action that is contrary to a rule', regardless of the degree of intentionality. This is also how violations are understood in this thesis. That is, an action is defined as a safety violation if it is contrary to a written safety instruction, irrespective of the intentionality of the actor.

This definition is rather general and it could serve as a framework for all kinds of safety violations. However, as Reason (1990, 1997, 1998, 2008) has argued, there is a need to differentiate between different subtypes of violations and to distinguish between violations and other types of aberrant behaviour. Basically, Reason (1997) describes two different types of violations; intentional and unintentional violations (see Figure 1). The intentional ones are deliberate violations of procedures which are known and understood by the actor, such as knowingly breaking procedures to get a job done with less effort, or, for example, because the procedures are considered impractical in a given situation. In Reason's (1987) study of the Chernobyl disaster (which is also the study that represents the starting point of systematic research on safety violations), it was

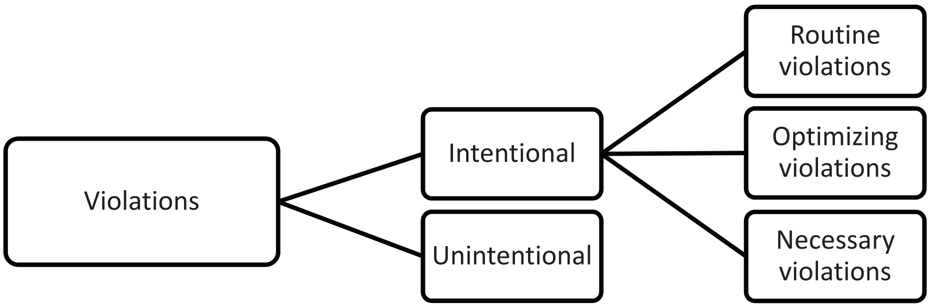

Figure 1
A taxonomy of safety violations, adapted from Reason (1997)

found that all of the five major violations committed in the initial phase of the disaster fell into this category.

The unintentional ones are violations of procedures of which the actor has no awareness or knowledge and therefore operates without any reference to, such as operating hazardous machinery in breach of written instructions because the operating instructions for some reason are not known or understood by the operator. In such instances, a violation has been committed without the actor being sufficiently aware of the relevant rules or procedures, and not, for example, because non-compliance has been perceived as an easy pathway towards a goal.

A relevant example of this is an accident on the drilling rig West Epsilon in the North Sea in 2007, where a 30-inch casing (weighing more than eight tons) fell down from the lifting collar and crushed the roof of the drilling hut and ended up in the driller's chair. The following investigation report stated that the direct cause of the accident was that the lifting collar was not properly closed and locked when the casing was lifted. That is, the lifting operation was not conducted in accordance with the prevailing procedures. The same investigation report, however, also stated that the operators involved in the accident had no information about how to operate the locking mechanism correctly because the relevant procedures were not available on the rig (PSA, 2007b). Hence, the breach of the procedures was committed unintentionally.

Despite the distinction between intentional and unintentional violations, both should, according to Reason (1997) be distinguished from malevolent acts, such as sabotage, in which both the act and the damaging consequences are intended. Also, they should be distinguished from acts of human error, such as slips, lapses and mistakes, which arise from cognitive and perceptual failures (though the distinction between errors and violations can often be blurred, see Reason and Hobbs, 2003).

Reason's taxonomy of safety violations does not offer a further classification of unintentional violations, but as regards intentional violations the taxonomy distinguishes between three major categories, based on their origins. These are routine, optimizing and necessary violations. According to Reason (1997), routine violations are typically triggered by organisations that rarely sanction violations or reward compliance (similar to what Gouldner (1954) four decades earlier described as *mock bureaucracies*). In practice, routine violations involve corner-cutting at the skill-based level of performance. That is, choosing the path of least effort between the start and endpoint of a given task. To use Hollnagel's (2009: 13) words again, this implies deliberately choosing 'efficiency' at the expense of 'thoroughness', because it involves a minimum of time, expense, effort or waste.

Optimizing violations on the other hand are triggered by personal rather than task-related reasons. That is, they are typically motivated by personal desires to optimize non-functional goals (e.g. violating for the thrill of it) and are, as such, unrelated to the functional aspects of the task. According to Reason (1997), this type of violation is characteristic of particular demographic groups, mainly young males.

Necessary violations, in contrast, are not related to any particular demographic group or personal desires such as least effort or thrill, but to deficiencies within the organization or particular work situations. These deficiencies, such as lack of adequate tools or equipment, make violations inevitable in order to get the job done. Hence, these types of violations are, at least from the actor's point of view, committed with necessity.

Reason's taxonomy of safety violations is primarily a categorization of violations committed by individual workers or groups of workers, not by organizations. Such individual violations are typically identified among sharp-end workers in the proximal phase of a workplace accident (Wagenaar, 1998). In the present thesis, however, it is important to underline that the term ‘safety violation’ is not limited to individual behaviour. Rather, it is a term that is considered to be applicable and relevant to the organizational level as well. The main focus in the empirical work, though, is on individuals (or sharp-end workers, to be more precise), as only one of the four research questions deals explicitly with the organizational level.

2.2 Safety compliance

As mentioned briefly above, the systematic study of safety violations within organizational safety research was brought to the fore after the worst accident in the history of commercial nuclear power plants: the Chernobyl accident in 1986 (Hudson et al., 1998). The International Atomic Energy Agency’s (IAEA) investigation of the accident found that several specific violations of safety-critical procedures made the disaster possible (IAEA, 1986; see also IAEA, 1992). Some of these, it was concluded, were located at the level of the individual operator, and others were located at the organizational level.

These conclusions were picked up and discussed by Reason (1987) in his review of the human and organizational elements involved in the accident, a review which rapidly motivated other researchers not only to investigate violations in isolation, but also to examine how they are provoked by social and cultural influences within the organizations (e.g. Battmann and Klumb, 1991, 1993; Hudson et al., 1998; Lawton and Parker, 1998; Mason, 1997).

In recent years, however, and similarly to this thesis, researchers within this area have shown an increased interest in identifying conditions that promote safety compliance rather than in simply identifying violation-provoking conditions (e.g. Griffin and Hu, 2013; Kapp, 2012; Larsson et al., 2008; Lu and Yang, 2011; Neal and Griffin, 2006; Pousette et al., 2008; Torp and Grøgaard, 2009). This shift in focus represents a transition from a negative and reactive approach, towards a more positive and proactive approach. A shift which, on a broader thematic level and with inspiration from the positive psychology movement (Seligman and Csikszentmihalyi, 2000), has been frequently requested within organizational research as a whole (Luthans, 2002) and within some of organizational research's specific sub-disciplines such as leadership research (Avolio et al., 2009) and safety research (Hollnagel, 2012). But what exactly does the term 'safety compliance' mean and is there really a positive linear relationship between safety compliance and safety? This will be discussed below.

2.2.1 Safety compliance defined

In safety research, the term 'safety compliance' is often referred to as one of two components of the more general term 'safety behaviour'. The other component is safety participation. Whereas safety participation refers to behaviour that supports safety in the wider organizational context, such as attending safety meetings, contributing to voluntary safety work, helping co-workers and making suggestions to improve safety, safety compliance is usually regarded as being the basic safety activities that have to be carried out by individuals in order to maintain safety at work (see Griffin and Neal, 2000; Neal and Griffin, 2002).

Thus, safety compliance (see Table 2) is frequently defined in line with Neal et al. (2000: 101) as behaviour which 'involves adhering to safety procedures and carrying out work in a safe manner'. This implies that safety compliance is related to what Borman and Motowildo (1993), within the work performance literature, refer to as 'task performance', whereas safety participation is related to what they refer to as 'contextual performance'.

Again, however, and similarly to some of the definitions of 'safety violations', Neal et al.'s (2000) frequently cited definition of safety compliance is relatively broad and not well specified. In principle, it can be interpreted as a kind of all-embracing definition which covers all types of behaviour that is carried out safely – whatever that might be. To be more precise, safety compliance in the current thesis is therefore understood as behaviour that is in accordance with the prevailing formal safety instructions. This definition is narrower than that of Neal et al. (2000), and more in line with, for example, Masia and Pienaar (2011: 3) who define safety compliance as 'the extent to which employees adhere to safety standards, procedures, legal obligations and requirements.' However, in this thesis the term is not restricted to *employees'* compliance with company internal safety rules and procedures – it also includes *enterprises'* adherence to national safety regulations developed by regulatory bodies (as is also specified in Zohar's (2008) definition of safety compliance in Table 2).

Table 2
Different definitions of safety compliance

Reference	Definition
Heidenstrøm (2011: 23)	'Safety compliance is the employee's willingness to follow rules, procedures, and regulations established by the organization in order to create a safer work environment…'
Inness et al. (2010: 279)	'… behaviours focused on meeting minimum safety standards at work, such as following safety procedures and wearing required protective equipment'
Mahmood et al. (2010: 3)	'Safety compliance explains the core activities that need to be carried by employees to ensure the area are protected from injuries, such as complying with safety rules and safety procedures'
Masia and Pienaar (2011: 3)	'Safety compliance is the extent to which employees adhere to safety standards, procedures, legal obligations and requirements.'
Mullen and Kelloway (2009: 257)	'Safety compliance involves following required safety policies…'
Neal and Griffin (2002: 70)	'The term safety compliance is used to describe the core activities that need to be carried out by individuals to maintain workplace safety. These behaviours include adhering to standard work procedures and wearing personal protective equipment.'
Neal et al. (2000: 101)	'Safety compliance involves adhering to safety procedures and carrying out work in a safe manner.'
Niskanen et al. (2012: 1929)	'Safety compliance is defined as rule-following in core safety activities…'
Størseth (2007: 190)	'… adherence to safety policies.'
Winter et al. (2010: 12)	'… core activities required to maintain a safe work place.'
Zohar (2008: 381)	'Safety compliance involves adherence to rules and procedures, developed by the company and/or regulatory bodies.'

2.2.2 Safety compliance and safety

As seen in the introductory chapter, accident analyses and investigations regularly conclude that accidents and near misses are caused by violations of safety regulations. Thus, through the wisdom of hindsight (but without regard to the bias that ex post facto insight might give) there is established a clear negative relationship between safety violations and workplace safety. Does this also imply that there is a positive linear relationship between safety compliance and safety, and that hazardous work systems would be safe if only people and organizations complied sufficiently with the relevant procedures and regulations? In the current thesis this is an important question, which has also been recently discussed by safety researchers elsewhere (e.g. Besnard and Hollnagel, 2012; Bieder and Bourrier, 2013; Dekker, 2006; Grøtan, 2014; Hale and Borys, 2013a, b; Hopkins, 2011; Kletz, 2001; Reason, 2008; Townsend, 2013; Weick and Sutcliffe, 2007). As will be described below, there is, however, no definitive and clear-cut answer to it.

One part of the answer lies in the myriad of quantitative studies that document a negative relationship between rule-following (both at the enterprise level and the individual level) and different types of adverse safety outcomes, such as accidents, injuries and near misses. Cheng et al. (2010), for example, have found that enterprises' level of compliance with national safety regulations is negatively related to the frequency of occupational accidents. That is, the more compliance with labour safety laws, the less occupational accidents. As regards the individual level, Goldenhar et al.'s (2003) study of construction workers has documented that workers who report high levels of safety compliance also experience a fewer number of near misses. The same study also found an indirect negative relationship between safety compliance and occupational injuries through self-reported physical symptoms. Comparable findings have been made in Jiang et al.'s (2010) study of petroleum workers, which found that employee's safety compliance was related to lower levels of workplace injuries and near misses. Similarly, Zacharatos et al. (2005) and Nahrgang et al. (2011) have found a significant negative relationship between safety compliance and injuries/near misses (the more compliance, the less injuries/near misses). These findings are also supported in two review studies on the topic by Clarke (2006) and Christian et al. (2009). In sum, the quantitative studies therefore support the notion of a positive linear relationship between safety compliance and safety. That is, the more compliance the better for the state of safety.

Another part of the answer to the question about the relationship between safety compliance and safety, and an important supplement to the findings in the quantitatively oriented studies, lies in the fact that safety rules and procedures have certain apparent limitations. Although rules and procedures in general are important as instructions for guiding behaviour in relation to dangers and hazards, their most fundamental limitation is that 'there will always be bad rule situations and no rule situations', as stressed by Reason (1997: 74). More precisely, this means (1) that there will always be situations in which the prescribed line of action of a rule or procedure for some reason is not favourable to safety, and (2) that there will always be situations which are not covered by rules or procedures. In the first situation (bad rule), compliance will make things worse and hence reduce safety. In the second situation (no rule), compliance is irrelevant – i.e. it must be replaced with some sort of improvisation (or no action at all). These two limitations make the notion of a positive linear relationship problematic, as they imply that compliance with procedures is not always beneficial for safety – often not even being an available option.

One example of the fact that compliance is not always beneficial for safety and that mere compliance can have fatal consequences, is the disaster on the production platform Piper Alpha in the British part of the North Sea in 1988, where 167 rig workers died and only 61 survived (Wright, 1994). Contrary to what one might believe, the investigation of the disaster demonstrated that most of the workers who died complied strictly with the emergency procedures and assembled in the accommodation area when fires broke out. Catastrophically, the accommodation area was directly in line with a subsequent devastating explosion, meaning that most of those who had complied with the emergency procedures and the training they had previously gone through did not survive. Those who jumped into the sea on the other hand, and in doing so also disobeyed the emergency procedures, survived (Punchard and Higgins, 1989; see also Reason, 2000b).

Another example from the oil and gas industry is the already described blowout and near loss of the Snorre Alpha platform in the Norwegian part of the North Sea in 2004 (Schiefloe et al., 2005). Even though a long list of non-compliances contributed to the blowout, it was, paradoxically enough, a deliberate and well-considered deviation from written procedures that contributed to stopping the leak and put the platform back into service (Besnard and Hollnagel, 2012). This deviation meant that the platform manager decided to remain aboard the platform together with a team of well workers in order to plug the leaking well with concrete, despite the fact that the safety procedures clearly stated that the platform must be fully evacuated when the stability of the whole installation is threatened. Applying these procedures, however, would have left the leak unplugged and as a consequence the platform could have suffered the same fate as the Piper Alpha and Deepwater Horizon. However, the crew who despite the procedures were left on Snorre Alpha managed to stop the leak and put the platform back into normal operation.

The two examples above clearly illustrate that, under certain circumstances, non-compliance can be better than compliance and thus that the notion of a positive linear relationship between compliance and safety is challenging. As Besnard and Hollnagel (2012) have previously highlighted it is therefore important to underline that…

The Snorre Alpha Platform is still in service today, almost ten years after the blowout (Photo: Rune Johansen/Statoil)

…safe operations cannot be ensured by rigid and blind compliance. Instead, they require that operators assess the adequacy of, and adapt, procedures to operational conditions. (Besnard and Hollnagel, 2012: 4)

In the current thesis, this point is recognized as important, but with respect to the research objective it falls out of the scope of the thesis to examine and determine under which conditions non-compliance is safe or not. A fundamental assumption in the thesis – and in line with, for example, Hopkins' (2011) thorough discussion of the topic – is, therefore, that compliance with safety rules and procedures under most, but not all, conditions represents safe practice. At the same time it is recognized that safety is a product of numerous interrelated known and unknown elements and that compliance with safety rules and procedures is only one of these. Alone, however, rule-making and compliance is not enough to *ensure* safe operations – and in many instances merely being in compliance simply implies achieving a minimum level of hazards management (Manuele, 2003). This opinion is also reflected in a frequently cited safety culture guide elaborated by the International Atomic Energy Agency, where it is emphasized that…

Organizations with a mature safety culture focus more on the overall goals and key points than only on compliance with procedures. (IAEA, 1998: 4)

3. The system perspective

As indicated in the introductory chapter, a system perspective is applied as the guiding principle for the empirical work of the thesis. In this chapter it will be explained what this means. In addition, an account and a discussion of previous research that has been carried out within the frames of a system perspective will be offered.

3.1 Second stories of failure and success

According to Reason (2000a), human behaviour in organizations (be it safe or not) can be viewed in two different ways – either through the person perspective or through the system perspective. Each of these has their own basic model of behaviour causation, and these models give rise to different philosophies of how human behaviour should be managed within an organization. With regard to unsafe acts, the person perspective typically focuses on the workers at the front line of the organization and sees such acts as being caused primarily by mental processes, such as carelessness, forgetfulness, inattention and recklessness. Thus, the associated preventive measures are directed towards the individual level – as for example disciplinary actions or campaigns that appeal to people's morals, conscience or fear. The system perspective, on the other hand, sees the same acts as consequences rather than causes, with their origins in contextual rather than individual factors. Thus, within the system perspective the fundamental assumption behind eventual preventive measures is that 'though we cannot change the human condition, we can change the conditions under which humans work' (Reason, 2000a: 768). Hence, preventive measures guided by the system perspective typically focus on working conditions, such as time pressure, inadequate equipment, impractical procedures etc., rather than on individuals and their attributes.

The person perspective and the system perspective, Reason (1993) argues, coincide with two overlapping ages of safety research, namely the human error age and the socio-technical age, respectively. The human error age followed after the technical age (in which the focus was on technical measures and causes), and had its origins in the 1930s 'when it became apparent that human beings are capable of circumventing even the most advanced engineered safety devices' (Reason, 1993: 7). The sociotechnical age made its entry in the 1980s in the aftermath of some major accidents within complex but assumedly well-defended systems, such as Chernobyl, Bhopal, Zeebrugge and Piper Alpha.[3] Applied in the safety research field, the sociotechnical perspective highlights that the sources of safety challenges do not belong solely to either the technical or the human spheres. Instead the causal relationship, it is argued, is to be found in the interactions between the technological, organizational and human spheres. Thus, human behaviour is not seen as solely determined by individual differences, but as highly influenced by the technological and organizational system within which it occurs. This idea constitutes the essence of the system perspective and it is important to note that this influence is seen as relevant not only in order to understand failures and substandard behaviour, such as violations, but also in order to understand success and normal behaviour, such as compliance (Reason, 1993).

The person perspective and the system perspective constitute two fundamentally different types of explanations in safety research and have been referred to with different metaphors by safety scholars. Dekker (2006: 1), for example, refers to the person perspective as the 'Old View' and the system perspective as the 'New View'. The essence of the old view, he claims, is that human actions are seen as acts that are conducted in a vacuum. Hence, errors and violations, for example, are interpreted as acts caused by unreliable people, whereas safe and compliant acts are seen as acts conducted by well-intentioned people. According to the old view, complex systems would therefore be fine were it not for the unpredictable behaviour of unreliable people. Thus, Dekker also refers to the old view as 'The Bad Apple Theory', which reflects the opinion that it is usually bad individuals in otherwise perfect systems that cause bad things to happen. Consistent with this, Woods et al. (2010: 5) use another metaphor as they refer to the person perspective as 'first stories' and the system perspective as 'second stories', indicating that the person perspective (The Bad Apple Theory) only scratches the surface of a multifaceted and deeper story. Within this deeper second story human errors and violations only represent the starting point of scientific inquiry.

[3] The concept of sociotechnical systems was coined already in the 1950s by Trist and Bamforth (1951), but according to Reason (1993) decades passed before safety researchers realized the full value of the concept for accident prevention and safety research.

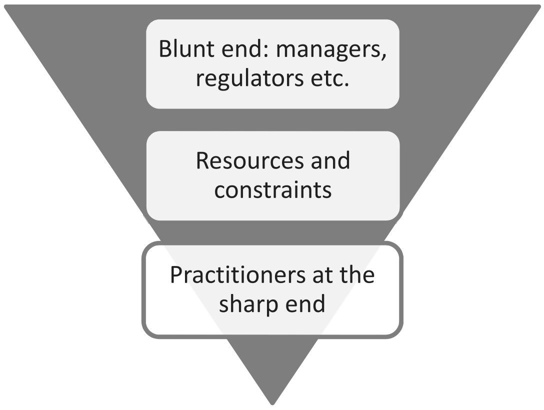

Figure 2
The sharp and blunt end of complex organizations (adapted from Woods et al., 2010)

An essential notion of Woods et al.'s second story is the idea that complex organizations have a sharp end and a blunt end, and that both must be taken into account in order to fully understand how safety is shaped and created (Figure 2). The sharp end of an organization constitutes the part of the organization that operates close to or in direct contact with some hazardous process. Within the oil and gas industry, this group of front-line personnel typically consist of occupations such as crane operators, drillers, derrick men and maintenance personnel. The blunt end, on the other hand, typically consists of 'regulators, administrators, economic policy makers, and technology suppliers' who 'control the resources, constraints, and multiple incentives and demands that sharp-end practitioners must integrate and balance' (Woods et al., 2010: 8). Thus, within the second stories perspective it is, according to Woods et al., essential to study and understand how activities (as, for example, those related to rules and procedures) conducted at the sharp end are influenced and constrained by activities at the blunt end (as, for example, leadership practices, established production goals etc.).

Again, the already described investigation of the nearly fatal accident on the drilling rig West Epsilon in 2007, where a 30-inch casing fell and crushed the roof of the drilling hut, is a relevant example (PSA, 2007b). The investigation revealed that the very reason why the sharp-end personnel at the rig operated the drilling equipment in breach of the relevant procedures was not because of recklessness, forgetfulness or any other psychological failings among the personnel (first story). Rather (second story), the non-compliant acts were explained by the fact that the responsible managers and the part of the organization (blunt end) that should have provided correct information and relevant procedures to the drilling personnel (sharp end) failed, and that the sharp-end workers for that reason had to carry out the drilling operation without all the relevant procedures at hand. It can thus be argued, in Woods et al.'s (2010) terms, that it was the interplay, or the lack of interplay, between the sharp and the blunt end that caused the front-line operators to act as they did, i.e. in breach of the relevant procedures.

Another essential notion of the second story as a metaphor of system explanations is the idea that it is a story not only of failure, but also one of success. That is, the interplay between the blunt end and the sharp end can explain failures as well as successes, accidents as well as normal operations, aberrant human behaviour as well as normal human behaviour, violations as well as compliance. None of these extremes, Woods et al. (2010) argue, can be understood by examining the sharp end in a vacuum. Hence, they claim that the study of aberrant behaviour cannot be separated from the study of normal behaviour:

> *When error is seen as the starting point for study, when the heterogeneity of errors (their external mode of appearance) is appreciated, and the difference between outcome and process is kept in mind, then it becomes clear that one cannot separate the study of error from the study of normal human behavior and system function.* (Woods et al., 2010: 25)

3.2 Getting the balance right

Different metaphors aside, the essence of the system perspective is that both safe and unsafe acts must be examined and understood in light of the context within which the acts occur. Hence, the system perspective is typically concerned with factors that often are distant (both in time and place) from the actual behaviour of front-line personnel, as, for example, decisions made by management, leadership practices, socialization, employee involvement, organizational complexity, the quality and clarity of safety procedures and so on.

According to Wagenaar and van der Schrier (1997) the positive aspect of the system perspective is that it highlights the relationship between the behaviour of sharp-end workers and factors that management can control. Thus, they argue that it holds a potential for generating adequate knowledge on how to, for example, prevent violations and then consequently, how to improve safety compliance. Conversely, they argue that the person perspective lacks this potential because it fails to identify the causal connection between employee behaviour and operational conditions, in their own words:

> *Portrayal of substandard behaviour as freak events does not lead to prevention, because it denies the relationship between the behaviour of employees and anything management can control. Relating unwanted behaviour to situational factors opens up the possibility of prevention, because the working situation is largely under the control of management.* (Wagenaar and van der Schrier, 1997: 27)

Similar arguments have also been adopted by other safety scholars (some of whom have already been mentioned, e.g. Dekker, 2006; Woods et al., 2010), but does the fact that the current thesis applies a system perspective mean that I am of the opinion that (1) the person perspective has no real value or (2) that it is in some deep conflict with the perspective applied in this thesis?

The short answer to both of these two questions is ‘no’. Actually, it is believed that personal qualities do matter, and in line with Reason (2008: 103) it is believed that; ‘to think otherwise is to fall prey to “learned helplessness” – saying to oneself “What can I do? It’s the system”’. Empirical studies do also support this argument. That is, there is a correlation between certain personal qualities (demographics and psychological characteristics) and safety behaviour, including safety compliance. Chan et al.’s (2002) study of the effect that workers’ age has on compliance with safety procedures is an example of this. Ashton’s (1998) correlational study of personality traits and different workplace delinquencies, such as non-compliance, is another. Salgado’s (2002) study of the big five personality dimensions and deviant behaviour at work is a third example, and Mount et al.’s (2008) study of the relationship between individual conscientiousness and safety violations a fourth. (For a review study on the relationship between personality factors and safety behaviour, see Clarke and Robertson, 2005).

Chan et al. (2002), Ashton (1998), Salgado (2002) and Mount et al.'s (2008) studies, or any other study that focuses on intrapersonal explanations, are not by any means in conflict with the theoretical perspective applied in this thesis. It would be more reasonable to say that the clear-cut demographical/psychological perspectives that these writers apply are complementary to the perspective applied in this thesis. That is, they shed light on the same empirical phenomenon, but from a different angle. Moreover it is believed that this difference in angles opens up different practical insights and different theoretical contributions which together contribute, hopefully, to a more profound understanding of the study object.

Also, it is believed that the two perspectives (at least in principle) can be combined, in the sense that both can be integrated into one and the same empirical analysis. Zhou et al.'s (2008) quantitative study of safety compliance within the construction industry is an example of this. Their study explores both the effect of individual variables such as work experience and education on the one side, and the effect of contextual variables such as management commitment and workmates' influence on the other. Another example is Wallace and Chen's (2006) quantitative study of safety compliance among 254 repair generalists where the effect of both personality and group safety climate was explored. There is also one example of such a combination in the current thesis, as the effect of the offshore service vessel workers' age and job experience is explored in combination with contextual variables, such as safety climate and procedure quality, in the empirical work related to the first research question (article #1). However, the overriding perspective of the thesis is purely systemic and thus focused on how environmental conditions affect compliance.

3.3 Safety compliance and the system perspective: previous research

Within the Norwegian oil and gas industry, the system perspective is often denoted as the MTO perspective (Man, Technology and Organization) and within this industry it is today widely acknowledged that both technological, organizational, and human factors (and in particular the interplay between these factors) are important elements in the establishment of safe operations (Schiefloe and Vikland, 2007). In the current thesis, however, it would be fair to say that first and foremost it is the relationship between man and organization that is in focus, and that the importance of technological aspects, such as the physical work environment or the standard of technical equipment, is not explored with the same depth. Furthermore, the thesis is to a certain degree also about the relationship between the organization and its external environment, as the fourth research question deals with the effect that external actors (labour inspections) have on enterprises' compliance with safety regulations. Hence, it could be argued that an *open system perspective* (which holds a long tradition within organizational research, e.g. Emery, 1969, Katz and Kahn, 1966, Trist, 1969) is applied, since a part of the system's environment is also taken into account.

Since the essence of the system perspective is that behaviour, be it substandard or not, must be examined and understood by the characteristics of its environment, the study of safety compliance within this perspective is to a large degree about identifying the contextual antecedents of safety-compliant behaviour and in so doing pointing out factors that are of importance in preventive work. As follows from the main objective presented in the introductory chapter, this has also been the essence of the empirical work within the oil and gas industry in this thesis. But before continuing to the empirical part of the thesis, a short and condensed review of previous research within this field will be presented.

The review is structured around some the most important previously identified antecedents of safety-compliant behaviour. This means that the review is not meant to be completely exhaustive; it is the basic parts of previous research that will be presented and discussed. Research related to individual safety compliance will be reviewed first, and then a shorter review of research related to safety compliance at the enterprise level will be presented.

3.3.1 Safety culture and safety climate

As already described, the systematic study of safety violations within organizational safety research was brought to the fore in the aftermath of the Chernobyl accident in 1986 (Hudson et al., 1998), as the International Atomic Energy Agency's investigation report stated that a combination of several procedural violations made the disaster possible (IAEA, 1986). The very same report also had a great influence on safety researchers in another way as it launched the now frequently applied term 'safety culture' – not only to describe the root cause of the disaster, but also to describe the organizational background and environment within which the procedural violations were committed (Sorensen, 2002).

In the academic safety literature, the term 'safety culture' has numerous different definitions (e.g. Cooper, 2001; Cox and Cox, 1991; Fernández-Muñiz et al., 2007; Pidgeon, 1991), and there is no universal agreement about what to include in the concept (Antonsen, 2009). However, safety researchers seem to agree that safety culture is about the employees' shared attitudes towards safety and managements' priority of safety in the organization (Choudhry et al., 2007). In addition, it is (in line with the conclusions of the Chernobyl investigation) regularly claimed among safety culture scholars that there is a causal relationship between safety culture and the safety-related behaviour of employees (Törner, 2008). Thus, safety culture is also frequently seen as an important organizational antecedent of workers' risk-taking behaviour and propensity to act in accordance with prevailing rules and procedures (e.g. Cui et al., 2013; Fleming, 2012; Geller, 2001; Mearns and Flin, 1995; Mearns et al., 2001; Vinodkumar and Bhasi, 2010). Reason (1998) for example, claims that organizations with…

> *…a poor safety culture will encourage an atmosphere of non-compliance to safe operating practices. Violations are likely to be most common in organizations where the unspoken attitudes and beliefs mean that production and commercial goals are seen to outweigh those relating to safety.* (Reason, 1998: 297)

During the last two decades a significant number of studies have been carried out in order to test such claims. These studies are typically quantitatively oriented (psychometric questionnaire studies) and the term 'safety climate' is usually applied in favour of 'safety culture'. Safety climate can be defined as the set of perceptions that employees share regarding safety in their work environment (Zohar, 1980), and measures of safety climate typically reflect the extent to which employees perceive safety as valued within their organization (Griffin and Neal, 2000). Hence, safety climate measures are often regarded as a snapshot of the underlying safety culture (Flin et al., 2000), and the measures typically consist of several factors such as workers' perception of safety training, safety management, safety policies, safety equipment, and safety communication.

The assumed causal connection between safety culture and safety compliance is highly supported in studies of safety climate, as several safety climate studies across a well of different industries and national cultures have demonstrated that a positive safety climate promotes safety-compliant behaviour. Agnew et al.'s (2013) study of safety climate and worker safety behaviours in Scottish hospitals, Lu and Yang's (2011) study of safety compliance within the Taiwanese passenger ferry industry, Sinclair et al.'s (2010) study of individual safety performance among US retail workers, and Cavazza and Serpe's (2009) study of the use of personal protective equipment within the Italian mechanic, textile and food industry are all examples of this. In Alper and Karsh's (2009) review of previous research on safety violations and compliance, the positive link between safety climate and safety compliance is also one of the more consistent findings. Identical findings are also made in two other review studies by Clarke (2006) and Christian et al. (2009). On the basis of empirical findings, it is therefore no exaggeration to say that the positive relationship between safety climate and safety compliance is relatively firmly established. Thus, in the empirical work related to the current thesis' first research question, the impact that safety climate has on safety compliance among offshore service vessel workers has been in focus (article #1).

As regards causal explanations as to why safety climate positively influences workers' safety compliance Neal and Griffin's (2004) so-called 'framework for conceptualizing safety climate and safety behaviour' is frequently applied. According to their theoretical framework the positive relationship between safety climate and workers' safety compliance is a result of the role that the safety climate plays as a frame of reference that provides clues to sharp-end workers about the overall importance of safety in their organization or work group. Zohar (2010) explicates this by adding that it is within this frame of reference that employees receive, interpret and make sense of signals from a complex net of different sources (e.g. colleagues, policies, rules, practices) about what sort of role behaviour is expected, supported and rewarded. Employee behaviour, Zohar argues, will then tend to align with these perceived expectations. Hence, safety climate is often considered to be of importance for employees' *motivation* to act in accordance with safety rules and procedures. As Neal and Griffin (2004: 19) put it: 'safety climate reflects a psychological environment that provides a motivational antecedent for safety behaviours'. In addition, safety climate is also considered to be of importance for workers' *knowledge* about risk and safety, and in combination *safety motivation* and *safety knowledge* is believed to constitute the causal mechanism between safety climate and safety compliance (Neal and Griffin, 2004) as illustrated in Figure 3. This is also widely supported in empirical studies (e.g. Griffin and Neal, 2000; Kwon and Kim, 2013; Sinclair et al., 2010; Vinodkumar and Bhasi, 2010).

Despite the fact that safety climate/culture is considered an important contextual antecedent of safety-compliant behaviour, this perspective is not without its critics. According to Reiman and Oedewald (2004), for example, one of the major drawbacks of the safety culture perspective, such as that applied within safety climate studies, is that the safety culture concept is often presented as an organizational characteristic separately from other characteristics of the organization, such as the organizing of work, technology and the organizational structure. Moreover they claim that this separation reduces the safety culture concept to refer only to aspects of the organization that are known in advance and are clearly connected to safety, such as safety training, safety communication and safety values. This, they argue, results in a loss of the holistic

Figure 3
The assumed relationship between safety climate and safety compliance (adapted from Neal and Griffin, 2004)

viewpoint which originally was sought within the organizational culture approach. Hence, they claim, that safety culture or safety climate models occasionally imply that safety can be studied and promoted as something that is detached from the composition of the work system as a whole (see also Choudhry et al., 2007 and; Kongsvik et al., 2010 for a discussion on this topic).

In line with Reiman and Oedewald's (2004) arguments, Antonsen (2009) argues for a broadening of the scope of safety culture and climate research. Instead of looking solely at the safety-specific aspects of the culture, Antonsen recommends that one should also examine the way organizational culture as a whole may influence safety. Within climate/compliance research this has been done to a certain, yet limited, degree by researchers who have investigated the relationship between more general (non-safety-specific) climate variables on the one side and safety compliance on the other (e.g. DeJoy et al., 2004; Parker et al., 2001). Larsson et al.'s (2008) study of safety compliance among Swedish construction workers is one of these. The results of their study showed that the overall organizational climate exerted a significant impact on safety compliance. Hence, they concluded that climate factors which were not safety-specific (such as clearly stated job descriptions, feedback on work performance, influence over one's own work etc.) constitute important conditions for safety compliance.

Findings, such as those made by Larsson et al. (2008), are important since they indicate that workers' safety behaviour is a highly integrated part of the overall organizational functioning and that it can be managed much as other aspects of worker performance. Hence, the findings point to the necessity of expanding the safety culture and climate tradition with a more general organizational approach. However, few safety compliance studies have been concerned with such an expansion, and even fewer within the oil and gas industry. Thus, in the current thesis' article #2 such an expansion is included, by examining how some general work climate dimensions mediate the relationship between leadership and offshore workers' safety compliance.

3.3.2 Leadership

Another common research topic in studies of safety compliance is that of leadership. In some of these studies leadership is considered a sub-dimension of safety climate (e.g. Biggs and Banks, 2012), in others a predecessor of safety climate with indirect links to safety compliance (e.g. Schutte, 2010), and in still others as a separate explanatory variable with direct links to safety compliance (e.g. Lu and Yang, 2010).

Regardless of this difference, the vast majority of the leadership studies have one thing in common – they put focus on the safety-specific dimensions of leadership, such as leaders' safety objectives, their role-modelling behaviour with regard to safety and their reward of subordinates for safe behaviour (e.g. Griffin and Hu, 2013; Inness et al., 2010; Kapp, 2012; Zohar, 2002). Typically, these studies fall into two different groups. The first group of studies applies a behaviouristic model, built on the principles of operant conditioning (Skinner, 1969), and investigates the relationship between leaders' safety rewards and monitoring behaviour on the one side and subordinates' safety compliance on the other (e.g. Krause et al., 1999; Zohar, 2002; Zohar and Luria, 2003). Since these studies are preoccupied with the reinforcement of safe behaviour through rewards and monitoring, they are usually referred to as applying a safety-specific *transactional* leadership perspective (i.e. a direct focus on the transactions or exchanges that take place between leaders and subordinates). The second group of studies applies a more indirect behaviouristic model and puts the focus on safety-specific *transformational* leadership practices. Both transactional and transformational leadership practices are characterized by an exchange of values between leaders and subordinates, but within the latter the exchange is in the form of intangible values such as closer relationships with subordinates, shared values, and visions (Sarros et al., 2002). In addition, safety-specific transformational leadership is, among other characteristics, characterized by leaders who display concern for the safety and well-being of employees, and who stand out as clear and positive role models for their staff by working in a safe way themselves (Kapp, 2012).

In general, studies that stress the safety-specific dimensions of leadership give support to the assumption of a positive causal relationship between the safety-related behaviour of leaders and their subordinates' compliance with safety rules and procedures (Hofmann and Morgeson, 2004). Hence, in the empirical work related to this thesis' first research question, which deals directly with the relevance of previous research, the impact of safety leadership among offshore service vessel workers is examined (article #1). In that study, however, leadership is not treated as a distinct explanatory variable, but as a sub-dimension of safety climate.

The impact of leadership is also emphasized in the empirical work related to the thesis' third research question, which deals with the relationship between organizational context and oil and gas workers' knowledge of rules and procedures (article #3). The most explicit and extensive focus on leadership, however, is to be found in the examination of the second research question (article #2). As described in chapter 1.3, this research question addresses the fact that previous leadership studies have primarily focused on the safety-specific dimensions of leadership, and that the more general dimensions of leadership (such as trust, cooperation and involvement) and these dimensions' impact on workers' safety compliance are often overlooked. Some studies focus on these more general dimensions of leadership (e.g. Yagil and Luria, 2010), but at large the research effort on this topic is limited – and even more limited within the oil and gas industry (some exceptions exist, see for example O'Dea and Flin, 2001). Consistent with Hofmann and Morgeson's (2004) review of previous safety leadership literature it is therefore believed that the impact of leadership should be examined from a broader point of view than that which is common:

> *…it is important, when either reviewing or investigating the relationship between leadership and safety, to move beyond the safety-specific literature to consider the broader leadership literature. This is important because it may yield additional insight into how leadership can impact safety.* (Hofmann and Morgeson, 2004: 170)

3.3.3 Procedure quality

As already described, Reason (1997) stresses that there will always be situations which are not covered by rules, and that there will always be situations in which the prescribed line of action of a rule or procedure for some reason is not favourable to safety, and that compliant actions under such circumstances can be unsafe.[4] Compliance with rules and procedures can, however, also be associated with limitations related to the quality of the rules and procedures themselves. For example, in Antonsen et al.'s (2008) study of safety compliance on an offshore supply base, the importance of comprehensibility, accessibility and accuracy is emphasized. This implies, Antonsen et al. argue, that if compliance with rules and procedures is to be expected, the employees must, as a minimum requirement, understand the language used (comprehensibility), have access to the information (accessibility), and be provided with a relatively clear-cut description of the relevant tasks (accuracy).

This might seem self-evident, but several practical safety guides and empirical studies claim that procedure quality is a real challenge – even in industries which rely heavily on written safety instructions. In Simpson et al.'s (2009) guide to understanding human error in mine safety, for example, it is emphasized that safety rules frequently are far from being appropriate, practical, well written and well communicated, and that this is often at the expense of compliance. Laurence's (2005) questionnaire study of Australian mineworkers supports this view. When asked to indicate their reasons for not complying with the safety rules, close to 35% of the mineworkers in Laurence's study reported that it was due to some sort of problems with the rules (regarding for example complexity, extent and lack of plain language). The negative relationship between rule complications and safety compliance is also a significant finding in Alper and Karsh's (2009) review of previous research on safety violations and compliance within industries other than the one which is in focus in this thesis. The relationship between procedure quality and safety compliance is therefore explicitly dealt with in the empirical work related to the first research question in this thesis (article #1).

As Antonsen et al. (2008: 7) argue, procedure quality, understood as comprehensibility, accessibility and accuracy is important because it contributes to enhancing workers' knowledge of the safety procedures and thus 'reduces the probability of unintentional violations'. The importance of appropriate knowledge and the relationship between knowledge and unintentional non-compliance is also highlighted by other writers, such

[4] Compliance with bad rules is, by Reason (1997: 75), referred to as 'mispliance'.

as Reason (1997) and Lawton (1998). Except for the obvious relevance of procedure quality, however, few studies have been concerned with identifying the conditions that influence workers' knowledge of rules and procedures (Barber, 2002). Considering the fact that a larger proportion of actual accidents in the oil and gas industry are linked to unintentional violations rather than to intentional violations (Walker et al., 2012), there is little doubt about the need for more research on this topic within this particular industry. As described in chapter 1.3, article #3 therefore deals with the relationship between organizational context and front-line oil and gas workers' knowledge of rules and procedures.

3.3.4 Employee involvement

According to Bourrier's (2005) comparative studies of compliance with safety procedures in French and American nuclear power plants, there are three critical ingredients related to the design and adjustment of procedures that appear to be important for strengthening the match between the written procedures and actual work practices. First, she argues, there should be feedback from the lower levels to the upper levels of the organization. Second, adjustment and design of procedures should be based on the views and experiences of those who are directly involved in applying the procedures, i.e. sharp-end workers. Third, the time interval between worker feedback about necessary procedural adjustments and actual adjustments should be as short as possible.

These three ingredients all point to one common denominator, namely that active involvement of employees in safety-related activities is a crucial element when the goal is to make sure that work operations are carried out without inappropriate discrepancy from written procedures. Bourrier (2005) is, however, by no means on her own in stressing the importance of such involvement. Mohamed (2002) for example, claims that employee involvement is a most essential ingredient in a climate that favours safety compliance:

> *…management must be willing to devolve some decision-making power to the workforce by allowing them to become actively involved in developing safety interventions and safety policies, rather than simply playing the more passive role of the recipient.* (Mohamed, 2002: 376)

In the research literature this is also a highly supported view. One example of this is Ludwig and Geller's (1997) experimental study of professional drivers' compliance with traffic regulations. In their study it was found that drivers who were allowed to participate in formulating safety goals complied more than did drivers who had had the same goals assigned to them with no opportunity to discuss or influence the goals. Another example is Vinodkumar and Bhasi's (2010) study of safety behaviours within the process industry. Their analysis demonstrated that employee involvement in safety activities (such as participating in safety goal setting and identifying safety problems) correlated highly (r=0.40) with safety compliance. A third example, which is particularly relevant for the type of industry studied in this thesis, is Antonsen et al.'s (2008) already described study of safety compliance on a Norwegian offshore supply base. In their study, which was designed to evaluate a change project that aimed at the increased use of procedures, it was found that workers' influence on the design of new procedures (in addition to procedural simplicity) was *the* most critical success factor for improved compliance.

Given the research evidence, the importance of employee involvement in safety-related activities is hard to question. Other scholars, however, have stressed that employee involvement should not only be limited to safety-specific topics, such as participation in the design of safety procedures or safety goals. Barling et al. (2003), for example, have claimed that job autonomy and involvement in a broader sense is also important. Autonomy and involvement, they claim, improves job satisfaction which in turn has a positive effect on workers' safety compliance. This positive relationship between employee involvement on the one hand, understood as control over their own work activities, and safety compliance on the other, is also emphasized by Cooper (2001) when he claims that:

> *Increasing people's opportunity for control over their work activities leads to greater acceptance of the necessity and the desirability of safety rules, which results in safety belonging to everyone. This also provides the motivation for people to conform to safety rules in spirit as well as in the letter of the law.* (Cooper, 2001: 208)

Nevertheless, there is not much empirical research on the relationship between employee involvement in this broader sense and safety compliance, at least not within the oil and gas industry. In the empirical work related to the second research question of this thesis, however, the impact that employee involvement has on safety compliance is explored to some extent (article #2). There, employee involvement (and competence) is treated as a part of the offshore workers' work climate.

3.3.5 Job demands and resources

In the decades that have passed since Karasek (1979) introduced his now frequently applied and cited *demand-control model*, there has been a growth of empirical evidence showing that the combination of high job demands and low job resources is an important precursor of psychological strain and work-related illness (Bakker, 2007). One example of this is Schaufeli et al.'s (2009) longitudinal study of managers in the telecom industry which showed that the combination of increased job demands (such as work overload and time pressure) and decreased job resources (such as social support and feedback) is a significant predictor of both emotional burnout and sickness absenteeism (for earlier, but similar findings see e.g. Melamed et al., 1991; Taris et al., 1999). Another example is Pekkarinen et al.'s (2013) recent study of nurses in Finland which demonstrated that high job demands were associated with higher levels of musculoskeletal symptoms, and that job resources (in particular social support) helped to buffer against the negative effects of high job demands.

Though research on occupational health has long been influenced by Karasek's (1979) model and its modified successors (e.g. Karasek and Theorell, 1990), it is only recently that the model has had a direct impact in research on safety behaviour and safety outcomes (Hansez and Chmiel, 2010). The results, however, are noteworthy and important for the topic of the current thesis. For example, Nahrgang et al. (2011) have found full support for the demand-control model in their meta-analytic investigation of the relationship between job demands/resources and safety compliance. This implies that high job demands combined with low job resources were negatively related to safety compliance in their study. Turner et al.'s (2012) cross-sectional study of health care staff, however, only found empirical support for a significant positive relationship between high job resources and safety compliance, but no significant negative relationship between high job demands and safety compliance. On the other hand, Hansez and Chmiel's (2010) study of employees within the energy sector found that job demands had a negative effect on safety compliance and job resources a positive effect. This study also revealed some of the possible causal mechanisms between job demands/resources and safety compliance, since the effect was found to be indirect – through strain and motivation. Hence, they concluded that the findings imply that it is important in future studies of safety compliance to include variables that extend beyond the safety-specific ones. As described earlier, this is done in article #2 of this thesis, but job demands and resources are not explicitly dealt with there.

A more explicit treatment of this thematic is to be found in the empirical work related to the first research question (article #1). There, however, job resources are excluded, whereas job demands are included as a part of the safety climate construct. To include job demands in safety climate constructs is not an uncommon choice. According to Flin et al. (2000) the job demand dimension (or work pressure) is, in fact, among the five most common sub-dimensions of the safety climate construct, and according to Zohar (2010) job demands (or the balance between different demands, such as safety vs. efficiency) is a key feature of an organization's safety climate. It could therefore be argued that safety compliance research that applies Karasek's (1979) demand-control model to a certain degree is related to safety compliance research that applies some sort of a safety climate model.

3.3.6 Systematic HSE activities: safety compliance at the enterprise level

According to Cooper's (2000) theoretical model for understanding and analysing safety cultures, both individual and contextual factors affect workers' safety behaviour – including compliance. One element within the set of contextual factors that Cooper specifically emphasizes is the organization's safety management system. Thus, he stresses the importance of 'examining the degree to which safety management systems actually influence people's behaviour' (Cooper, 2000: 126). Despite its importance though, he underlines that too little is known about the causal relationship between the quality of safety management systems and workers' safety behaviour. More recently, however, and as mentioned briefly in the introduction, a study conducted by Torp and Grøgaard (2009) supports Cooper's emphasis. Torp and Grøgaard's study, conducted among Norwegian motor mechanics, demonstrates that companies which have established a well-developed health and safety management system that meets legal obligations promote safety-compliant behaviour among the sharp-end workers. Thus, there is, as expected out of Cooper's (2000) model, empirical support for a causal relationship between company compliance and individual compliance, where the former constitutes an important framework condition for the latter.

The findings of Torp and Grøgaard (2009) imply that variation in individual safety compliance, at least partly, can be explained by variation in company safety compliance – i.e. the degree to which the enterprise meets the legal requirements relating to safety at work. Hence, understanding the antecedents of individual safety compliance will benefit from an improved understanding of the factors that affect company safety compliance. Independent of this, investigating the factors that affect company safety compliance is a topic worthy of study in its own right, as it is correlated to more objective safety performance measures – such as, for example, occupational accidents (Cheng et al., 2010). Accident investigations do also repeatedly point to enterprises' lack of compliance with legal requirements relating to safety at work as a significant contributory factor (Hansen, 2010). This is also the case within the Norwegian oil and gas industry (e.g. PSA, 2009a, b, 2010a, b, 2011a, b). This illustrates the fact that research on safety compliance should not be limited to the individual level. Despite this, few studies have focused on the enterprise level. This implies that few studies have examined why some organizations follow the legal requirements relating to safety at work while others do not (Baldock et al., 2006).

There are some exceptions though. For example, Saksvik et al.'s (2003) study of Norwegian companies' compliance with regulations related to systematic health and safety activity found that large enterprises fulfilled more of the requirements of the regulations than did small enterprises, and that enterprises within the public sector were more compliant to the regulations than those within the private sector. This is consistent with Wright et al.'s (2005) review of previous research on the topic. Another study, conducted by Baldock et al. (2006), of small British enterprises, found that management training and experience, use of external assistance with respect to health and safety topics, enterprise size, and membership of trade or business associations were significant factors which were positively related to rule compliance at the organizational level. Thus, the studies of both Saksvik et al. (2003), Wright et al. (2005), and Baldock et al. (2006) indicate that poor compliance with safety regulations at the organizational level arises from a limited access to health and safety resources.

With direct relevance to the fourth research question of the thesis, Baldock et al. (2006) did also find that enterprises which had been inspected by regulatory authorities were far more likely to comply with safety regulations, compared to enterprises which had not been inspected. In fact, among a number of other variables tested, labour inspections were found to be the variable with the most positive influence on organizational safety compliance.

The positive impact of labour inspections is supported in some other studies (Andersen et al., 2009; Wright et al., 2000), but the findings of these studies are limited by the fact that self-reported data forms the basis of the analyses. Hence, the studies are vulnerable to positive bias. In addition, the cross-sectional study design of these studies makes inferences regarding cause and effect relationships difficult. For these reasons, Hillage et al. (2001) have recommended experimental research designs when evaluating the impact of labour inspections. The study of labour inspection effects, presented in article #4, is based on such a research design.

4. Research design and methods

4.1 The main lines

According to Guthrie (2010), four different types of social science research can be identified – pure, applied, policy and action. *Pure research* is concerned with scientific outcomes in isolation, and the purpose of this type of research is to make discoveries that are of interest to scientists and science, and to make theoretical progress. *Applied research*, on the other hand, is concerned with topics that have some type of potential for practical application, but the research design does not offer a particular way of implementing the results. *Policy research*, Guthrie describes, is based on practical issues that are of interest to those who make decisions about them – as for example studies that investigate the effect of governmental policies. The last type, a*ction research*, is usually initiated to solve a concrete problem or to improve practical action within a limited area (for example an organization), by applying scientific theories and methods to analyse the situation and by implementing real measures to improve the situation. In line with action research's pragmatic philosophical groundings it has thus been argued that the credibility and validity of action research should be measured according to whether actions that arise from it actually solve the practical problem at hand (Greenwood and Levin, 2007).

Guthrie's (2010) categorization is, of course, a simplification of reality as few real studies can be unambiguously localized within one of the four categories. Nevertheless, considered on a continuum (Figure 4) it makes sense to classify research with respect to its emphasis on practical action – or at least with respect to its *intended importance* for practical action. This is also the case for the research and the different research designs of the studies included in this thesis.

As described in the introductory chapter, the empirical work of the thesis aims to generate knowledge that is of practical importance – especially for actors within the oil and gas industry. This is also reflected in the design of each study and in the choice of research methods. In the main, all of the studies are designed with the purpose of examining the conditions that are of importance for a particular type of practical action

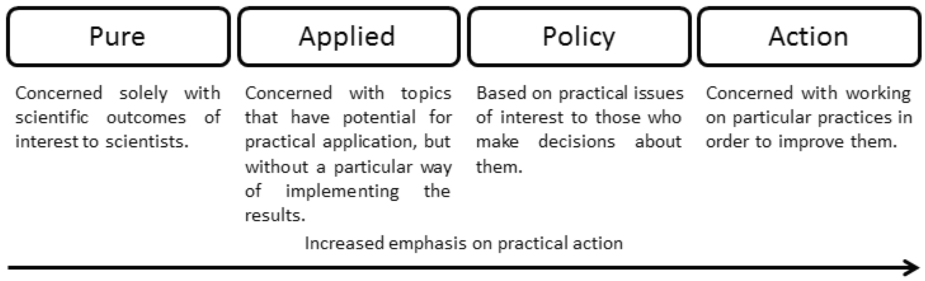

Figure 4
Types of social science research (adapted from Guthrie, 2010: 5)

– safety compliance. Then, the research methods applied are chosen to support this purpose. Furthermore, the particular conditions that the studies are designed to examine are first and foremost of the manageable type – the ones that (at least in principle) can be managed and controlled – not the ones that are fixed and immovable. Unlike action research, however, none of the studies included in the thesis are designed to manipulate these conditions with the intention of improving a concrete situation. Thus, it could be argued that the studies fall (or at least that they aim to fall) close to Guthrie's *applied research* category. That is, they are designed to shed light on 'topics that have potential for practical application, but without a particular way of implementing the results' (Guthrie, 2010: 5).

This classification of the studies included in the thesis is, however, only partly true. Each of the four studies is also designed with the purpose of making a theoretical contribution, either by testing hypotheses on the basis of previous theory and research (deduction) or by moving from specific observations to theory expansion (induction). Hence, it would be fair to say that the studies included in the thesis fall somewhere between pure and applied research. However, one of studies – the one which deals with the impact of labour inspections (article #4) – is a typical example of policy research; it deals with the effect of a particular governmental policy instrument and it aims (as will be described later) to provide data for decision-makers. Additionally though, that particular study also aims to offer a theoretical and scientific contribution by referring more to gaps in previous safety compliance research than to the information needs of the governmental decision-makers. Hence, in Guthrie's terms it would be fair to say that the labour inspection study is a combination of policy research and pure research.

Although the aims and the principal lines of each of the studies are highly related, they draw upon both qualitative and quantitative methods and a variety of different research designs – from field experiments, via questionnaire surveys, to semi-structured interviews. Such a combination of different research methods is often referred to as 'mixed method research' (e.g. Tashakkori and Teddlie, 2003) or 'triangulation' (e.g. Denzin, 1970). According to Johnson and Onwuegbuzie (2004), the pluralistic approach of mixed methods research has its philosophical partner in pragmatism (e.g. Dewey, 1920) since the research methods are chosen on the basis of what works best for answering a given research question and not on the basis of some extreme ontological or epistemological position (e.g. constructivism or positivism). In the following, a brief description of the design and methods of each of the four studies will be offered. A more comprehensive description is included in each of the four research articles.

4.2 Research question 1: the offshore service vessel study

As mentioned in the introductory chapter the first research question, concerning the relevance of previous safety compliance research within other industries, is addressed on the basis of a self-report questionnaire survey designed to monitor safety and working environment issues on offshore service vessels chartered by Statoil. This is a questionnaire that was developed by Studio Apertura, the research institute where I work, in 2000 and it has (with some revisions and adjustments) been employed for data collection within the same population every second year since then.

The study included in this thesis is based on data collected in the period from August to November 2010. The questionnaire consisted of 73 items related to topics such as safety management, accident reporting practices, risk exposure, work practices and compliance with safety procedures, and nine items related to demographic characteristics. A total of 2,022 questionnaires were distributed to all 170 work shifts and 1,108 questionnaires were returned from 113 different shifts. On the work shift level this gives a response rate of 66%, and on the individual level a response rate of 55%. The individual response rate is, however, a conservative estimate, since the number of questionnaires distributed exceeded the size of the population.

Among the respondents, sailors (30%) constituted the largest occupational group, followed by officers (24%), engineers (18%), apprentices (8%), captains (8%), stewards (6%) and electricians (5%). As regards type of vessel, the largest group of respondents worked on supply vessels (46%), followed by respondents who worked on anchor handling vessels (32%) and standby vessels (21%).

Before analysing the data, and consistent with the research question, an examination of earlier research was conducted to identify variables that previously had been recognized as important in explaining variation in safety-compliant behaviour. At this stage, it was not deemed important to focus solely on contextual (system) variables. Alper and Karsh's (2009) review of the topic was considered particularly relevant as it offered a condensed collection of previous research. Also, their review study revealed that few studies of the topic have been conducted within the oil and gas industry (and to my knowledge – there have been none on offshore service vessels).

On the basis of previous research, and in particular Alper and Karsh's review study, four hypotheses were formulated. One of these was derived from the extensive body of safety climate research (e.g. Cavazza and Serpe, 2009; Lu and Tsai, 2010) which shows that a positive safety climate promotes safety-compliant behaviour. Another one was derived from research that emphasizes the negative effect that unclear procedures (procedure vagueness) has on safety-compliant behaviour (e.g. Elling, 1987; Laurence, 2005). These two hypotheses, which explicitly deal with systemic conditions, were combined with two hypotheses that deal with individual attributes. These were related to the vessel workers' demographic attributes and were derived from research which demonstrates that age (e.g. Gyekye and Salminen, 2009; Lu and Yang, 2011) and job experience (e.g. Hobbs and Williamson, 2002b) are positively related to safety compliance.

Two items from the survey were used to measure age and job experience and 18 items were used to measure safety climate and procedure vagueness. The 18 items were selected on face value and previous research (in particular Flin et al., 2000) and included statements such as 'safety has first priority in the shipping company where I work', 'sometimes I feel forced to continue working, although safety can be threatened' and 'the procedures are difficult to understand/vaguely formulated'. In order to uncover the underlying factor structure of the 18 items and to reduce the number of items to a manageable size, a first order and a second order exploratory factor analysis (EFA) was conducted (Meyers et al., 2006). These analyses revealed that the second order factor *safety climate* and the first order factor *procedure vagueness* were two distinct constructs.[5]

The dependent variable, safety compliance, was measured by one single item. This item was formulated as a statement regarding compliance with safety procedures ('I always follow the procedures') with which the respondents were asked to indicate agreement or disagreement by either ticking the statement or by not ticking the statement. This was coded as yes = 1 and no = 0, respectively.

Regression analysis was conducted to test the hypothesized relationship between the set of independent variables and safety compliance. Since ordinary least squares (OLS) regression is not appropriate when the dependent variable is dichotomous (as is the case here), binary logistic regression (BLR) was chosen to test the hypotheses. BLR is a statistical method which has expanded from its origins in biomedical research to research within the social and behavioural sciences. It has become so widespread that Huck (2004: 438) predicts that 'it may soon overtake multiple regression and become the most frequently used regression tool of all'. Unlike OLS, the BLR allows one to test whether or not a set of independent variables can predict the probability of a case falling into the higher value (i.e. the value 1) on the dependent variable (Meyers et al., 2006) – in our case, the probability of a given individual reporting that he/she always follows the procedures on board the vessel.[6]

[5] The results from the second order EFA was checked by confirmatory factor analysis (CFA), as recommended by Milfont and Duckitt, J. (2004).

[6] All analyses were conducted with SPSS 18.0 software.

4.3 Research question 2: the offshore platforms study

Similar to the first research question, the second research question, regarding the influence that leadership involvement has on safety compliance among front-line offshore platform workers, is also addressed on the basis of a self-report questionnaire survey. As described briefly in the introductory chapter this is a questionnaire survey which originally was designed to monitor effectiveness and safety during the merger process of Statoil and Hydro in the period between January 2009 and October 2010. The survey was conducted six times among all Statoil's employees. Hence, six separate data analyses were conducted for each sub-sample and in addition one analysis for the total sample. The questionnaire consisted of 39 items related to a varied set of local workplace factors such as leadership, risk, roles, safety practices, job satisfaction, and safety compliance.

The total sample consisted of 10,003 respondents working on one of Statoil's (at that time) 28 different offshore installations. The size of the six different sub-samples varied from 1,316 in May 2010 to 2,068 in October 2010. The mean response rate for all six samples was 65%, but this varied from a low of 52% in January 2010 to a high of 86% in October 2010. Among the respondents in the total sample 88% were men. This is representative of the gender distribution on the NCS as a whole, where approximately 90% are men (PSA, 2012c). As regards age, 57% of the respondents in the total sample were above 45 years, 32% were between 36 and 45 years, and 12% were below 36 years.

Prior to analysing the data, a review of previous research concerning the relationship between leadership and safety compliance was conducted. As has been described earlier, this review revealed that previous research on the topic has primarily focused on the safety-specific dimensions of leadership (e.g. Biggs and Banks, 2012; Kapp, 2012; Krause et al., 1999; Lu and Yang, 2010; Mullen and Kelloway, 2009; Zohar, 2002; Zohar and Luria, 2003) and that the more general dimensions of leadership have not been examined with similar depth. There is, however, reason to believe that a broader set of leadership actions, such as the degree to which leaders are involved in the sub-ordinates' work operations, must be taken into account in order to more fully understand the relationship between leadership and safety compliance. The studies of for example Mattila et al. (1994), Fleming et al. (1996), and O'Dea and Flin (2001) demonstrate that supervisors who are close to the sharp end of the work operations and have a cooperative and participative relationship with their subordinates generate more safety compliance within their work group. Investigations of accidents within the Norwegian offshore oil and gas industry point in the same direction, (e.g. PSA, 2005a, 2007a, 2011a). Thus, it was hypothesized that leadership involvement will positively influence safety compliance. In addition to this direct effect it was also hypothesized that the effect of leadership involvement would be indirect, by affecting the work climate constructively and that a positive work climate in turn would have a positive influence on safety compliance. Three separate work climate dimensions (and thus three separate hypotheses) were emphasized: (1) workers' competence and involvement, (2) role clarity, and (3) follow-up of contractors (Figure 5 summarizes the full hypothetical model).

Sixteen items from the survey were used to measure the constructs included in the hypothetical model. In order to uncover the underlying latent factor structure of these items and in order to reduce the number of variables to a manageable size, EFA was conducted on the first sample (the sample from January 2009). Then five separate confirmatory factor analyses (CFA) were conducted on the remaining five samples to evaluate the replicability of the factor structure generated by the EFA. All the CFAs

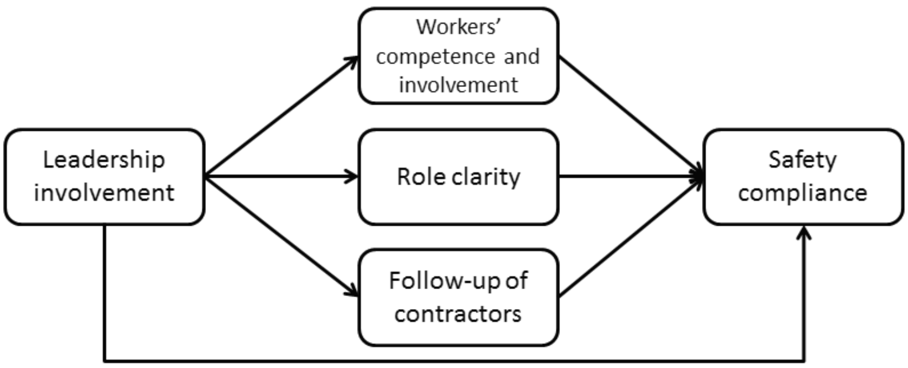

Figure 5
The hypothetical model applied in the offshore platforms study (article #2)

confirmed that the same factor structure that the EFA had uncovered could also be replicated in the five succeeding samples. The leadership involvement factor included items such as 'my leader participates actively in planning and preparing the work', and the safety compliance factor included items such as 'if we are uncertain about the execution of risk-exposed tasks, we always execute a safe job analysis (SJA)'. Items such as 'I am able to utilize my expertise and abilities in my present position', 'the responsibilities of my position are unambiguously documented', and 'in my unit we closely follow up suppliers/contractors we work with', were related to the three work climate dimensions – workers' competence and involvement, role clarity, and follow-up of contractors, respectively.

In order to assess the four hypotheses (which corresponds to the paths between the constructs in Figure 5), multiple regression analysis was found not to be appropriate as it is incapable of assessing models with latent variables[7] and indirect relationships (Meyers et al., 2006). Since the latent variables consisted of several manifest variables[7], neither path analysis was found to be appropriate. Path analysis is usually used to assess paths between constructs, but its use is limited to variables that are operationalized by only a single measure (Maruyama, 1997). The four hypotheses were therefore tested by structural equation modelling (SEM) – one test for each measurement period and one for the total sample.[8]

SEM is a statistical technique which combines path, factor, and regression analyses and is suitable for testing direct and indirect relationships between a set of latent variables. The SEM consists of a *measurement model*, which describes the connections between the latent variables and the manifest indicators that comprises them, and a *structural model*, which describes the (causal) relationship between the latent variables (Tomarken and Waller, 2005). Typically, the two models are estimated in one go, the so-called one-step strategy. However, this strategy could cause problems because if the complete

[7] *Latent variables* are variables which are not directly measurable by a measuring instrument (e.g. social class, intelligence, satisfaction, safety compliance etc.). Instead they are measured by a set of indicators, i.e. *manifest variables* (e.g. questions in a questionnaire). See for example Blunch (2008).

[8] The EFA and its accompanying analyses were conducted using SPSS 18.0 software. The CFAs and the structural model assessments were conducted using AMOS 18.0 software.

model does not fit the data it is complicated to find out whether the lack of fit arises from the measurement model or from the structural model. Thus, Blunch (2008: 162) recommends a two-step strategy: 'first analyze the model as a confirmatory factor analysis model and then put in the one-headed arrows and analyze the full model'. Blunch's recommendation was followed in the test of the four hypotheses, i.e. first the CFAs, then the assessment of the causal relationships between the constructs.

4.4 Research question 3: the maintenance and modification work study

Unlike the first two research questions (and unlike the majority of previous safety compliance research), the third research question is addressed on the basis of a qualitative study. As mentioned in the description of the research context, the study consisted of interviews of contract workers employed by a large maintenance and modification company which operates within the Norwegian oil and gas industry. The purpose was to identify, categorize and gain a comprehension of the most significant factors that affect these workers' knowledge of safety rules and procedures. That is – to gain a deeper understanding of the factors that hinder or facilitate such knowledge.

As discussed briefly in the introductory chapter, such insight is believed to be important for several reasons. First, previous research primarily has been concerned with factors that affect workers' attitudes and motivation towards safety compliance and less with the factors that affect their knowledge of rules and procedures (Barber, 2002). Thus, on the basis of Reason's already described distinction between intentional and unintentional violations and their different origins, it could be argued that the accumulated insight into the root causes of intentional violations far exceeds the accumulated insight into the root causes of unintentional violations, and that a more complete understanding of the antecedent of safety-compliant behaviour will benefit from reducing this research gap. Secondly, such insight is believed to be important because in fact (as described in chapter three) a larger proportion of actual accidents in the oil and gas industry are linked to unintentional violations than to intentional violations (Walker et al., 2012; see also OGP, 2013). This could indicate that appropriate knowledge of rules and procedures is a bigger challenge than the attitudes towards following them.

The particular branch of the oil and gas industry that this study deals with, and the respondents interviewed in the study were selected by means of purposive sampling (Patton, 2002). This means that the branch and the interviewees were not selected randomly, but on the basis of some particular characteristics – some predefined criteria. Four such criteria were set. The first criterion was that the selected branch of the oil and gas industry had to be highly regulated by safety rules and procedures. The second was that the particular branch had to be high risk. The third was that the respondents selected had to be sharp-end workers who directly interact with some type of hazardous process. The last criterion was that some variation between the respondents with respect to their professional background and experience was required in order to provide a rich collection of information. Based on the recommendations of Bailey (2007) it was also deemed necessary to have at least 20 respondents and then to add new respondents into the sample until little new information could be added to the analysis.

Based on these criteria (and with extraordinary and indispensable help from a gatekeeper in the company who provided me with full access to the field), 24 sharp-end workers from the maintenance and modification company were asked to participate in the study. Twenty-three of these were men, one a woman, and none of them refused to participate in the study. They were all interviewed on-site – at their workplace.

As described earlier, twelve of the participants worked offshore on a fixed production platform, and twelve worked onshore on a large gas receiving terminal. Within both onshore and offshore contract work, the use of subcontractors is frequent. This was also reflected in the study sample, as 10 of the respondents were employed by subcontractor companies hired by the contractor: five worked offshore and five worked onshore. Three different subcontractor companies were represented. All of these are also large-scale actors within the Norwegian oil and gas industry. As regards occupation, six of the onshore workers were mechanics/welders, three were scaffolding installers, two were electricians and one was an engineer. Three of the onshore workers also functioned as regional safety delegates/HSE coordinators, and two had supervisory responsibilities. Among the offshore workers eight were electricians/automation workers and four were mechanics/welders. Four of these also functioned as regional safety delegates, and two had supervisory responsibilities.

Questions related to safety, and in particular questions related to the respondents own safety behaviour, can be extremely sensitive within the oil and gas industry. Prior to the interviews all interviewees were therefore informed that their answers would be treated anonymously and in strict confidence, and that the recordings and the transcriptions would be stored on a secure server and deleted after use. The respondents were also informed that they could break off the interview whenever they wanted and refuse to answer questions they found too sensitive (none made use of this opportunity).

The interviews conducted were about one hour long, and they were semi-structured. Semi-structured interviews are usually used to identify factors, variables, items and attributes, and typically they combine the flexibility of unstructured and open-ended interviews with the rigidity of the structured interviews and the survey instruments (Schensul et al., 1999). In this study this was done by first producing an interview guide (attached to article #3) with some predefined open-ended questions and topics. Then, during the interviews, the order of the questions and topics was modified when appropriate, and questions were added, deleted, probed, and modified in order to elicit relevant and informative answers from the interviewees. This is typical for semi-structured interviews, because the basic assumption behind them is that 'the researcher does not know all the necessary questions regarding the topic and therefore cannot know in advance the full range of questions that will be needed' (Cargan, 2007: 108).

The interview guide (which can correctly be referred to as a 'guide' and not a rigid 'instruction') was developed on the basis of a pre-study with a length of about three months. This pre-study included several meetings and informal conversations with blunt-end representatives (senior managers and HSE managers) at the company's main office, and with sharp-end representatives at the gas terminal and the platform, such as installation leaders, supervisors, safety delegates, HSE personnel and craftsmen from different disciplines. In addition the pre-study included observations of actual work, both onshore and offshore, attendance at toolbox meetings, work permit meetings and safety rounds, and an examination of relevant documents such as the company's HSE policy, project contracts, work permits and work packages. A review of previous research and relevant literature was also included in the pre-study period.

There are numerous approaches for identifying and analysing emerging and recurring patterns and themes in qualitative data. In this study content analysis was employed. Content analysis has a long history within the social sciences and was first used as a method for analysing texts in, for example, newspapers, magazines, articles and political speeches, by reducing the complexity of a phenomenon into defined content categories. Basically, the purpose of a content analysis is to attain a condensed and broad description of the study object, and the end result of the analysis is (or should be) concepts and categories which describe the phenomenon (Harwood and Garry, 2003).

The type of content analysis that was employed in this study was open coding (Corbin and Strauss, 2008). Open coding is primarily an inductive content analysis. This implies that the findings and the thematic categories emerge out of the data and not from an already existing theoretical framework. By following the guidelines of Corbin and Strauss (2008), the method of open coding in the study of maintenance and modification work implied a process in which the interviewees' statements (which were recorded and transcribed) were given conceptual labels (statement by statement), based on their content. Then, by comparing similarities and differences between the labels, the statements and their corresponding labels were grouped under more abstract categories. These categories (or factors) were then named according to their core consistencies and meanings.

In contrast to the inductive character of the first part of the analysis, the second part had a more deductive character. This means that the appropriateness and authenticity of the content analysis and the thematic categories that had been developed were tested and affirmed. This deductive approach is recommended by Patton (2002), and includes a re-examination of the data which focuses particularly on identifying cases that do not fit the categories developed in the inductive part of the analysis.

4.5 Research question 4: the labour inspection study

As described briefly in the introductory chapter the fourth research question, regarding the impact of labour inspections, is addressed on the basis of two field experiments conducted within the Norwegian Labour Inspection Authority (NLIA). The design and implementation of the experiments are the end result of a project that I was responsible for in a period of more than two years, prior to my PhD scholarship. I was then employed at the NLIA as a health and safety adviser, and the goal of this particular project was (1) to assess and measure the (eventual) effect that labour inspections have on enterprises' compliance with health and safety regulations and (2) to present the (eventual) effect by means of a quantitative indicator.

In the period between 2008 and 2012 (when the project was active) all inspections performed by the NLIA were divided among seven different priority areas. These were (1) chemical hazards, (2) technical safety, (3) work-related musculoskeletal disorders, (4) work-related psychological disorders, (5) workplace adaption, (6) social dumping, and (7) young workers. The goal of the project was to develop five separate indicators for the first five priority areas. Hence, separate field experiments were conducted within each of the five priority areas. However, since the current thesis deals with safety rather than health-related issues or employment conditions, it is important to underline that the fourth research question is based solely on the field experiments linked to the two priority areas that are most clearly related to safety, namely chemical hazards and technical safety. Hence, the experiments that were conducted within the other priority areas are not referred to in the labour inspection study.

Essentially, an experiment is a form of research methodology which examines the effect that an independent variable has on a dependent variable by means of comparing two groups – an experimental group and a control group. The difference between the two groups is that the experimental group is exposed to the conditions of the experiment (i.e. the independent variable), whereas the control group is not. The independent variable is usually under the control of the experimenter and it is typically of the dichotomous type (e.g. treatment or no treatment). To assure comparability and to eliminate spurious variables, the two groups must be as equal as possible. This is usually obtained by means of random assignment, but it can also be obtained by matching pairs (Clarke and Dawson, 1999).

During the last five to six decades there has been a rapid growth in the use of experiments in the social sciences (Webster and Sell, 2007), in particular within social psychology, where some classical experiments have had a profound impact on the development of the research field (e.g. Asch, 1956; Milgram, 1963; Sherif, 1935). If conducted correctly, the experimental research design provides effect measures that have a high level of internal validity. That is, experiments enable relatively firm conclusions to be drawn with regard to the causal relationship between the independent and the dependent variable (Babbie, 2010). However, when they are conducted inside a laboratory with a high degree of artificiality, simplicity, and experimental control, the external validity (generalizability outside the laboratory) will typically be low (Walker and Willer, 2007). Within the social sciences, including safety science, the pure experimental design is therefore usually replaced with different types of quasi-experimental designs, where some of the characteristics of the true experimental design are altered (Shannon et al., 1999).

The two experiments that form the empirical basis of the labour inspection study were both conducted with a specific type of quasi-experimental design. This design is often referred to as the *post-test-only control group design* (Campbell and Stanley, 1963)[9] – which means that there were no pre-tests of the dependent variable (or any other variables) within the experimental groups or the control groups. In addition, the experiments were framed as field experiments, where the study objects were studied within their naturally occurring environment (not within a laboratory).

In both the chemical hazard experiment and the technical safety experiment the goal was to compare the level of compliance with national safety regulations in inspected versus previously uninspected enterprises. Thus, the difference between the experimental groups and the control groups was that enterprises within the former groups had been previously subject to inspections which either focused on chemical

[9] This design has also been referred to as *after-only measures and a control group*, see Robson et al. (2001).

hazards or technical safety (during the previous calendar year), whereas enterprises within the latter groups had never before been subject to labour inspections.

Assignment of enterprises to the experimental group in the chemical hazard experiment was done by means of randomization, where 100 enterprises were selected randomly from a list of enterprises that previously had been subject to inspections which focused on chemical hazards. Assignment of enterprises to the experimental group in the technical safety experiment was similar, but with one noticeable difference. First, 40 enterprises were selected randomly from a list of enterprises which had previously been subject to an inspection due to an accident. Then, another 40 enterprises which had previously been subject to a preventive inspection (not motivated by an accident) were selected. These last 40 enterprises were, however, not selected randomly, but by means of matched pairs. This means that each enterprise in the first group had a matching enterprise in the second group. Three variables were used as matching criteria: branch of industry, geographical localization and number of employees. The establishment of two experimental groups in the technical safety experiment mirrored the fact that two different types of inspections exist within this priority area – accident inspections and preventive inspections.

To assure comparability between the experimental groups and the control groups, the assignment of enterprises to the control groups was done by using matched pairs. This implied that enterprises which had not previously been subject to an inspection were selected to match those in the experimental groups. Again, the three variables, branch of industry, geographical localization and number of employees were used as criteria for matching. In total, 100 enterprises were selected to match those from the experimental chemical hazard group, and 40 enterprises were selected to match those selected from the two experimental technical safety groups.

In order to compare the experimental groups and the control groups, follow-up inspections were conducted by regular inspectors from the NLIA. During these inspections the inspectors applied a checklist to report the level of compliance with safety regulations within the enterprises. The checklists consisted of eight variables developed by the project group (one list for the chemical hazard experiment and one for the technical safety experiment – both are included in article #4). All eight variables were dichotomous, and were either assigned a 'yes', indicating compliance, or a 'no', indicating non-compliance. A 'yes' gave a score of 1, and a 'no' gave a score of 0. Thus, on the basis of the checklists all enterprises were assigned an index-score of between 0 and 8. This score was treated as a measure of compliance with safety regulations on the enterprise level (dependent variable), and was thus used to test whether inspected enterprises displayed a significantly higher level of compliance with safety regulations than did previously uninspected enterprises.

It is important to note that all variables in the checklists represented compliance with a specific relevant statutory demand. If an enterprise was assigned a 'no' on a given variable, this would therefore also generate a formal order. Hence, the potential for systematic errors, positive bias and reduced validity were reduced by the fact that a 'yes' or a 'no' would trigger a juridical consequence.

The statistical test employed in the chemical hazard experiment was the independent samples t-test (Field, 2005). The t-test tested whether the mean safety compliance index scores in the experimental group were significantly higher than those in the control group. A t-test was not appropriate in the technical safety experiment since the data consisted of three groups (the two experimental groups and the control group). Thus, a one-way ANOVA, which can test mean differences between three or more groups, was conducted (Field, 2005).

5. Summary of research findings

In the following, the research findings related to the four research questions will be summarized. First, the findings from the offshore service vessel study will be presented (article #1). This is followed by a presentation of the results from the offshore platforms study (article #2). Then the findings from the maintenance and modification work study (article #3) are presented, and lastly the results from the labour inspection study (article #4). The summary of the research findings will prepare for a more thorough discussion and conclusion in chapter six.

5.1 A multi-factorial approach (article #1)

The findings related to the first research question are published in the article titled *Antecedents of safety-compliant behaviour on offshore service vessels: a multi-factorial approach* (Dahl et al., 2013). Based on previous research within other industries, the aim of the article is to develop and test a research model which measures the relationship between a set of explanatory factors and safety compliance. This is relevant, not only for shedding light on the first research question, but also for the offshore service vessel industry in isolation – where such research has never previously been conducted and where a lack of safety compliance constitute a significant causal factor in for example collisions between vessels and petroleum installations (Kvitrud, 2011; PSA, 2011c). The developed model is multi-factorial and includes elements related to *the individual worker*, *the organization* (in terms of the vessels' safety climate) and *the body of procedures* that governs the vessel workers' work tasks.

In essence, three key findings were revealed by the already described binary logistic regression analysis (BLR). Each of these was related to the three elements of the research model.

As regards the individual worker, the BLR revealed that the older vessel workers are more compliant than their younger colleagues. This was as expected from the first hypothesis of the article and in accordance with previous findings from other industries (e.g. Gyekye and Salminen, 2009; Lu and Yang, 2011). Additionally, as regards the individual worker, it was found that job experience was significantly and negatively related to safety compliance. This finding was the opposite of what was expected from the article's second hypothesis and the literature review (e.g. Hobbs and Williamson, 2002b). Though significant, it should be noted that the effect that these individual variables were found to exert on safety compliance was relatively low. The vessel workers' age accounted for only 5.7% of the variation in safety compliance. When job experience was entered into the BLR, the explained variation increased slightly, to 8.6%.

A substantial increase in the explained variance (from 8.6% to 18.9%) was obtained when the first contextual variable was included in the regression model – safety climate.[10] The relationship between safety climate and safety compliance was found to be significantly and highly positively related. More specifically, the BLR demonstrated that vessel workers who perceived the safety climate on board their vessel as positive (i.e. safety climate = 5) had a predicted probability of reporting always to follow procedures of 67.7% (all other variables held constant with minimum values). For vessel workers who perceived the safety climate as negative (i.e. safety climate = 1) this probability was 1.3%. This finding is illustrated in Figure 6.

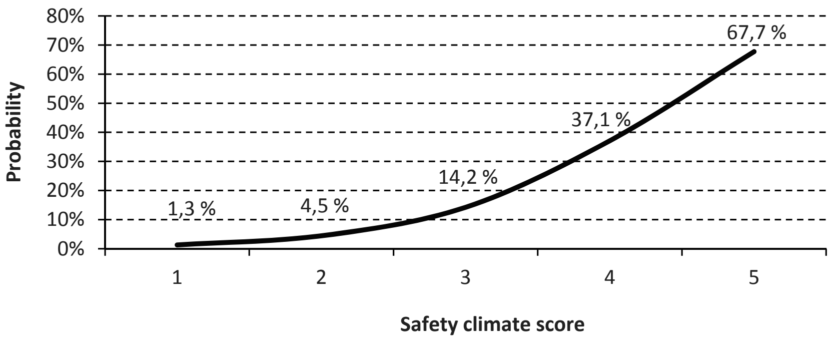

Figure 6
The probability of reporting always to follow safety procedures, predicted on the basis of the safety climate score (all other factors held constant, N=754, based on BLR-model 3, Dahl et al., 2013: 13)

[10] The second order factor *safety climate* consisted of five first order factors. These were: (1) *captain's safety leadership*, (2) *risk*, (3) *safety training*, (4) *general safety orientation on board*, and (5) *efficiency demands*.

The findings related to safety climate imply that vessel workers who perceive safety as valued on the vessel where they work have a far greater probability of reporting always working in accordance with the procedures. This is consistent with previous safety climate research conducted within other industries, as described in chapter 3 (e.g. Agnew et al., 2013; Cavazza and Serpe, 2009; Sinclair et al., 2010) and with review studies on the topic (Alper and Karsh, 2009; Christian et al., 2009; Clarke, 2006). The finding is also consistent with Zohar (2010) who asserts that the safety climate acts as a frame of reference for safety-specific behaviour, and that employee behaviour will tend to align with the sort of role behaviour employees perceive is expected, supported and rewarded within their work context.

As regards the body of procedures that governs the vessel workers' work tasks, the BLR revealed that the explained variation in safety compliance increased additionally when procedure vagueness was entered into the model (from 18.9% to 23.4%). As expected from the last hypothesis of the article and from previous research described in chapter three (e.g. Laurence, 2005), the BLR demonstrated that the more vague the procedures were perceived by the respondents the less frequent they reported that they always followed the procedures. More specifically, the BLR demonstrated that vessel workers who perceived the safety procedures as clear (i.e. procedure vagueness = 1) had a

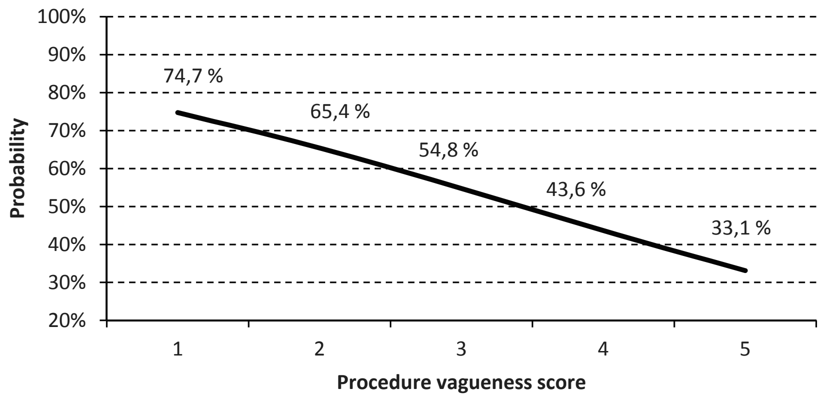

Figure 7
The probability of reporting always to follow safety procedures, predicted on the basis of the procedure vagueness score (all other factors held constant, N=754, based on BLR-model 4, Dahl et al., 2013: 13)

predicted probability of reporting always to follow procedures of 74.7% (safety climate held constant with maximum value, age and job experience held constant with minimum values). For vessel workers who perceived the safety procedures as vague (i.e. procedure vagueness = 5) this probability was 33.1%. This finding is illustrated in Figure 7.

In sum, the findings from the offshore service vessel study demonstrate that the multi-factorial research model, which was primarily built on research from sectors other than the oil and gas industry, has high predictive value within the oil and gas industry. As regards the first research question, the study therefore illustrate that safety-compliant behaviour among front-line oil and gas workers can be understood and explained (at least partly) on the basis of explanatory variables that have been found relevant within other industries. The study also implies that shipowners, captains, and other stakeholders within the offshore service vessel industry should consider increasing safety compliance from a broad multifactorial perspective.

5.2 Leadership involvement (article #2)

The article *Safety compliance on offshore platforms: a multi-sample survey on the role of perceived leadership involvement and work climate* (Dahl and Olsen, 2013), presents the results related to the second research question. As described earlier, previous research on the relationship between leadership and safety compliance has focused on the clearly safety-specific dimensions of leadership, such as monitoring, correction, and reward for safe behaviour (e.g. Inness et al., 2010; Kapp, 2012; Zohar, 2002), whereas few studies have focused on the more general dimensions, such as trust, cooperation, and involvement (Hofmann and Morgeson, 2004). The purpose of the article is therefore to examine the causal relationship between one such general dimension, namely leadership involvement, and safety compliance, and thereby also to shed light on the thesis' second research question. In the article, leadership involvement is operationalized as workers' perceptions of the degree to which leaders participate in the planning and preparation of work, follow up the execution of the work, and contribute to good cooperation among team members.

The structural equation modelling (SEM), which is described in section 4.3 and illustrated graphically in Figure 5, revealed that leadership involvement has a positive influence on safety compliance. This was found in all the six sub-samples (from January 2009 and till October 2010), and in the total sample. This indicates that the more involved offshore oil and gas leaders are in their subordinates' work the higher is the subordinates' (self-reported) propensity to work in accordance with safety procedures. This was as expected from the first hypothesis of the article. It was also consistent with what can be expected from accident investigations and analyses in the petroleum industry, where non-compliance is often seen as a result of lacking leadership involvement (Austnes-Underhaug et al., 2011; Hayes, 2012; PSA, 2005a). In addition, the finding was in accordance with the relatively limited amount of research that has been done in this area of safety leadership research, for example O'Dea and Flin's (2001) study of leadership in the UK offshore oil and gas industry. In their study it was found that high leadership involvement in work operations and frequent communication between workers and leaders was important for safety compliance. The direct effect of leadership involvement in the current study was, however, only moderate and not even significant in the fifth sub-sample.

Based on the SEM, leadership involvement seemed to have a more powerful indirect effect, by affecting the work climate positively – and in turn the work climate had a

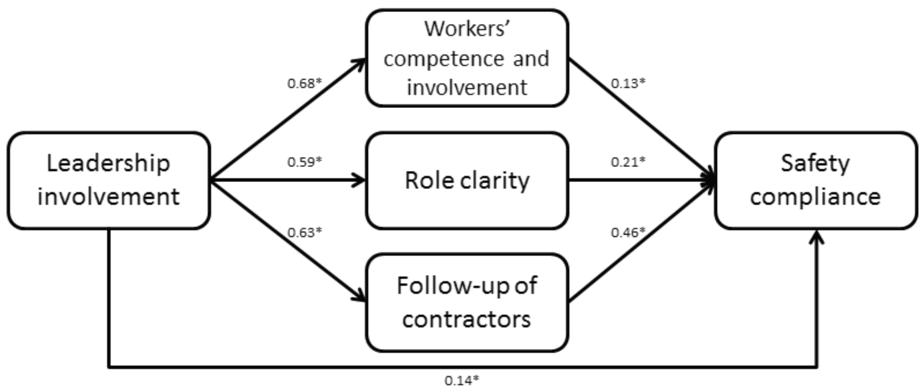

Figure 8
The hypothetical model applied in the offshore platforms study, with results from the SEM-analysis of the total sample. Path values are standardized beta coefficients. All paths are significant: *p<0.001 (adapted from Dahl and Olsen, 2013: 23).

significant influence on safety compliance. This finding is illustrated in Figure 8, which is the outcome version of Figure 5 (with path values estimated on the basis of data from the total sample, i.e. all six sub-samples). As can be seen from the figure, the indirect effect of leadership involvement is positive and significant through all three work climate dimensions. More specifically, this implies (1) that there is a powerful, positive and significant relationship between leadership involvement and all three work climate dimensions (the standardized beta values vary from 0.59 and to 0.68). This was as expected from the last three hypotheses of the study, and in accordance with, for example, Stringer's (2002) work climate research which demonstrates that leadership can explain up to 67% of the total variance in the work climate. The finding also implies (2) that there is a positive and significant relationship between the three work climate dimensions (workers' competence and involvement, role clarity and follow-up of contractors) and safety compliance (the standardized beta values vary from 0.13 and to 0.46). This finding was as expected from the last three hypotheses of the study. It was also in accordance with scholars such as DeJoy et al. (2004) and Reiman and Oedewald (2004) who have argued for a broadening of the scope of safety climate research which focuses primarily on the safety-specific aspects of the climate and not the broader climate characteristics.

More specifically, the finding was also in accordance with previous studies that have argued for a positive relationship between the work climate dimensions applied in this study and safety compliance. For example (a) the studies of Bourrier (2005) and Antonsen et al. (2008) have argued for a positive link between employee involvement and safety compliance, (b) Sneddon et al.'s (2006) study of UK offshore drillers has argued for a negative link between role ambiguity and safety compliance, and (c) Mearns et al.' (2003) study of safety management practices in UK offshore environments have argued that active follow-up of contractors is important for safety performance and compliance.

In summary, the results from the offshore platforms study draw attention to the important role that offshore leaders play as providers of a climate which fosters a high level of safety compliance. Furthermore, and relevant with regard to the second research question, the results of the study demonstrate that good safety leadership extends beyond the clearly safety-specific dimensions of leadership and that high leadership involvement in the work of employees is important. This finding also points to the need of offering offshore leaders sufficient time outside their offices and on the front line of operations.

5.3 Context and knowledge of rules and procedures (article #3)

The results from the qualitative study of maintenance and modification work, which deals with the third research question, are presented in the article *Safety compliance in a highly regulated environment: a case study of workers' knowledge of rules and procedures within the petroleum industry* (Dahl, 2013). As described earlier, the article points to the fact that previous safety compliance and violation research primarily has been concerned with factors that affect workers' attitudes and motivation towards following safety rules and procedures, whereas little research has been done on factors that affect workers' knowledge of rules and procedures. This imbalance is not new, safety violations and unsafe behaviour in general has long been seen as a product of improper attitudes and motivation (e.g. Heinrich, 1931; Slocombe, 1941). Hence, the focus has traditionally been on factors that can explain (and prevent) variation in these. For example, in the 1970s Andriessen (1978) claimed that…

> *…in normal work situations, work behaviour will probably be determined more by motivation because the pre-requisite knowledge and skills needed will usually be present as a result of selection and training. Whether work will be done more or less safely, will then be a matter of motivation.* (Andriessen, 1978: 364)

The results from the maintenance and modification work study quickly revealed that such claims, more than 30 years later, are not valid within the Norwegian oil and gas industry. This industry is highly regulated, but pre-requisite knowledge of rules and procedures cannot be taken for granted. As regards the actual level of knowledge, three groups of workers were identified in the interview material. The first group of workers (7 of 24 interviewees) reported active use of the IT-based safety management system (where all rules and procedures were accessible): they knew how to use it, they knew how to locate the relevant procedures, they frequently searched for updates and they regularly read through all relevant procedures they did not know well enough or had not understood. Formally, this was also expected from the workers. Because, in order to ensure that all workers have acquired the necessary knowledge of the rules and procedures that regulated a given work task, each worker involved in the task had to confirm, by signing the work permit, that a specified set of rules and procedures relating to the given work task were fully known and understood. This practice is common within the entire Norwegian oil and gas industry, and no workers are allowed to participate in a given work task without confirming up-to-date knowledge of the rules and procedures that govern the task (Norwegian Oil and Gas Association, 2013). However, interviewees identified within the second group (4 of 24 interviewees) knew how to use the safety management system and how to locate the relevant procedures within it, but they did not regularly check the system for updates, and rarely did they read through procedures they felt they did not know well enough or had not understood properly. As such, their knowledge of rules and procedures was medium. The third group of workers (13 of 24 interviewees), however, differed considerably from the two other groups. In addition to not checking the IT-based safety management system for updates, these workers seldom or never used the system at all and they did not know how to use it. Since all the relevant rules and procedures were available in the IT-based safety management system (and only there) their knowledge of rules and procedures was poor.

By analysing the interview material it was found that the onshore workers and the offshore subcontractor workers were overrepresented within this last group, and that eight different factors within the workers' work context could explain the variation related to knowledge of rules and procedures among the interviewees.

The first three of the identified factors were related to the IT-based safety management system itself, wherein the body of rules and procedures was assembled. The three factors were (1) *access* to the safety management system, (2) the *user-friendliness* of the system and (3) *training* in how to use it. For example, one of the main reasons why the onshore workers seemed to be overrepresented within the low-knowledge group was related to the fact that they lacked sufficient training and adequate access to the safety management system. This effect was negative, not only because these conditions were disadvantageous to the workers' practical skills in terms of how to use the safety management system and how to find the relevant procedures, but also because it signalled to the workers that an in-depth knowledge of rules and procedures was not as necessary as had been stated formally through their signature on the work permit.

The next three factors that were identified were related to the characteristics of the work itself and to the conditions of employment that the workers were bound by. The first of these factors was (4) *routinized work*. This means that interviewees who saw their work as being unpredictable and varied often reported that their acquired skills were not sufficient to solve their tasks in a safe way and that this increased their need to become familiar with safety rules and procedures. On the other hand, interviewees who saw their work as highly routinized often reported that the repetitive character of their work led to a reduced need for such familiarization. The next factor within the group of work characteristics was (5) *perceived risk level*. This means that interviewees who perceived the risk level in their work to be high were usually of the opinion that knowledge of rules and procedures was important for safe practice, whereas interviewees who perceived the risk level in their work to be low were more often of the opposite opinion. Several of the interviewees also reported that an increased and explicit management focus on risks could encourage more workers to realize the important role that rules and procedures play in risk reduction. The last factor related to the characteristics of work was (6) *subcontracting*. Subcontracting had a clear negative effect on knowledge of rules and procedures. This negative effect was primarily visible among the offshore subcontractor workers who frequently moved between different installations and worked for different operating companies. Their nomadic existence reduced their opportunity to become familiar with the operator-specific safety management system and the installation-specific body of rules and procedures. In addition they felt that their number-one priority was to perform the tasks they were hired for, and not to spend time making themselves familiar with a body of rules and procedures that might only be relevant for a limited period of time.

The last two factors identified in the analysis were related to the impact of social interaction. These were (7) *leadership influence* and (8) *co-worker influence*. As described earlier, the impact that leaders have on subordinates with regard to safety is well recognized. Thus, the emergence of the leadership factor in the interview material was not unexpected. Neither was the emergence of co-worker influence unexpected as previous research also has recognized the important role that co-workers play, in particular the influence that experienced workers have on newcomers (e.g. Choudhry and Fang, 2008; Mullen, 2004). The two factors worked in the same direction as they were both important for how the workers' perceived the true priority of knowledge of rules and procedures in the organization. For example, despite the fact that up-to-date knowledge of governing documentation was formally required through the work permit system, a lack of explicit leadership and co-worker focus on rules and procedures was frequently interpreted as implying that in-depth knowledge of rules and procedures was in practice not so important.

In summary, the findings from the maintenance and modification work study demonstrate that appropriate knowledge of rules and procedures depends on a multitude of factors within the workers' work context. The identification and categorization of these factors shed light on the third research question of the thesis. Moreover, the findings are believed to be important for understanding some of the contextual mechanisms that can underlie unintentional violations, since these per definition are caused by a lack of knowledge and understanding of relevant rules and procedures. The findings do also clearly illustrate that formal demands, such as requiring workers to confirm by signature that a specified set of rules and procedures is fully known and understood, are not at all sufficient to ensure adequate knowledge. Such formal demands must be followed up by measures which clearly communicate that knowledge of rules really is expected, supported, and rewarded (to repeat the words of Zohar, 2010 again).

5.4 Labour inspections and enterprise safety compliance (article #4)

The findings related to the fourth research question are presented in the article *Labour inspection and its impact on enterprises' compliance with safety regulations* (Dahl and

Søberg, 2013). Based on the two field experiments conducted within the Norwegian Labour Inspection Authority (NLIA) referred to in chapter four, the aim of the article was to examine the effect (if any) that labour inspections actually have on enterprises' compliance with safety regulations. As described earlier, this was done by comparing inspected versus previously uninspected enterprises with regard to their level of compliance with national labour safety regulations.

By analysing the scores on the eight-point safety compliance index, the results of the empirical analyses demonstrated that enterprises which had previously been subject to inspections by the NLIA exhibited a significantly higher level of compliance with safety regulations compared to enterprises which had previously not been subject to inspections. This result was found in both experiments, i.e. both in the *chemical hazards* experiment and the *technical safety* experiment.

More specifically, in the chemical hazards experiment the experimental group (enterprises which previously had been inspected by the NLIA) had a mean score of 6.70 on the eight-point safety compliance index, whereas the control group (previously uninspected enterprises) had a mean score of 4.85. This represents a 38.1% difference and the t-test confirmed that the difference was significant. In the technical safety experiment the difference between the groups was slightly smaller. The two experimental groups (preventive inspections and accident inspections) had a mean score of 6.10 and 6.03 respectively, whereas the control group had a mean score of 4.76. This implies that the two experimental groups on average scored 26.7% higher than the control group on the safety compliance index. The ANOVA (and an accompanying least significant difference test, LSD) confirmed that the mean score within both experimental groups was significantly higher than the mean score of the control group, but that there was no significant difference between the two experimental groups (see Figure 9 for a graphical illustration of the findings).

These findings were as expected from the hypotheses of the study, and also in accordance with the relatively limited amount of research that has been conducted in this area previously (e.g. Andersen et al., 2009; Baldock et al., 2006). In view of the fact

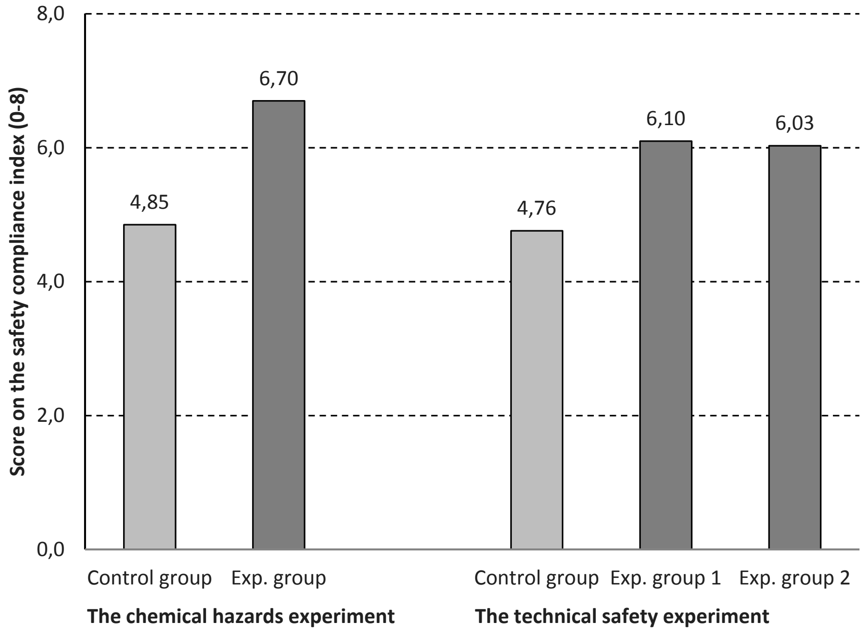

Figure 9
Results from the chemical hazards experiment (N=192) and the technical safety experiment (N=99): differences between inspected (the exp. groups) and previously uninspected enterprises (the control groups) on the safety compliance index (based on Tables 4 and 5 in Dahl and Søberg, 2013)

that comparability between the experimental groups and the control groups in both experiments was assured through matched pairs, it would also be reasonable to conclude that the difference between inspected and previously uninspected enterprises was caused by variation in the independent labour inspection variable and not by some spurious variable.

In summary, and relevant to the thesis' fourth research question, the findings from the labour inspection study indicate that labour inspections represent an effective governmental policy instrument in the regulatory authorities' effort to ensure compliance with existing safety legislations. Considering the fact that relatively few previous studies have examined the effect that company external factors in general, and labour inspections in particular, have on safety compliance, this result should be important.

6. Discussion and conclusion

The four research articles summarized in the previous chapter constitute the fundament of the thesis as they all address different aspects of the main objective. In this chapter, the key findings from the articles will be discussed in relation to the main objective. This discussion will be accompanied by a discussion of the theoretical and practical implications of the findings. Then, the methodological limitations of the studies will be addressed and discussed in relation to useful avenues for future research. This leads to the final conclusion of the thesis.

6.1 Key findings

6.1.1 Five key findings and the implications of these

Given the width of the main objective and the variation in data sources, research methods, and research contexts it is no surprise that the thesis entails several findings. Some of these have indirect relevance to the main objective of the thesis, such as the detection of a safety climate factor structure on board the offshore service vessels. Other findings have direct relevance, such as the impact that this factor structure was found to have on safety compliance. This last group of results represents the key findings of the thesis. Five of these deserve a more detailed description.

6.1.1.1 Leadership

The first key finding of the thesis is related to leadership. As described in chapter three, previous leadership and compliance research has primarily been concerned with the safety-specific aspects of leadership. In general, this type of leadership research indicates that leaders who emphasize, discuss, reward, monitor, and encourage safe performance generate safer performance within their work group, including increased safety compliance (e.g. Kapp, 2012; Lu and Yang, 2010; Zohar, 2002). The offshore service vessel study indicates that this is also transferable to the oil and gas industry. In that study, the captains' emphasis of safety issues was a part of the safety climate measure, and safety climate was, in turn, highly related to safety compliance. This indicates that safety-specific leadership behaviour can be viewed as a vital part of the safety climate and, thus, that it constitutes a vital part of the overall patterns and signals that employees use to sort out which type of role behaviour is (to use the words of Zohar, 2010 again) expected, supported and rewarded.

A similar effect of leadership can also be seen in the study of maintenance and modification work. In that study, the lack of an explicit leadership focus on rules and procedures, combined with a strong leadership focus on safe and attentive work performance, was by many of the interviewees interpreted as if safe work performance was dependent on experience alone and not at all on in-depth knowledge of rules and procedures. Thus, many of the interviewees interpreted signals sent from the leaders as if up-to-date knowledge of rules and procedures was not expected, despite the fact that they had to confirm by signature that all relevant rules and procedures were known and understood.

All in all, the offshore service vessel study and the study of maintenance and modification work imply that the signals that leaders send to their crew is of vital importance for how they interpret the necessity of compliance. However, not only is it important that leaders send clear signals about the *priority* of safety, but also that they send clear signals about the fact that also *knowledge* of rules and procedures is a real priority and not just a bureaucratic necessity symbolized by the signature on the work permit. This could result in the impression that the rules and procedures are only there to cover the company's back if something goes wrong. According to Tinmannsvik (2009) this is actually a common impression among oil and gas workers on the NCS. In her study roughly half of the respondents reported that some rules are only there to cover the managers' backs. Similar results are found on the UK Continental Shelf in a study by Chunlin and Chengyu (1999). 48% of the offshore employees in their study were of the opinion that some rules are only there to cover management's back.

As regards leadership and safety compliance, the offshore platforms study demonstrates that the importance of leadership can also be studied and understood from a general leadership approach. The results from the study indicate that good safety leadership extends beyond the clearly safety-specific dimensions of leadership, and that safety compliance is highly dependent on active leadership involvement in work operations.

Such involvement is characterized by leaders who participate in the planning and preparation of work, follow up the execution of the work, and contribute to good cooperation among team members. This finding adds additional insight into how leadership influences safety compliance and it implies that it is important to increase leaders' awareness of the importance of high involvement in the work of employees. It also implies that it is important to give offshore leaders sufficient time to spend on the front line of the operations. However, as underlined in the conclusion of the offshore platforms study, a study by Lamvik et al. (2008) on Norwegian offshore leaders has revealed that a recent increase in administrative work and bureaucratic routines represents a significant obstacle to high leadership involvement. 60% of the offshore managers in their study wished they could spend more time on the front line and 72% were of the impression that hands-on management would prevent accidents from occurring. These findings, combined with the results related to leadership involvement and safety compliance, indicate that operator companies on the NCS should assess the possibility of reducing the administrative responsibilities of offshore leaders.

6.1.1.2 Climate

The second key finding of the thesis is related to the concept of climate. In accordance with previous safety climate research (e.g. the review studies by Christian et al., 2009; and Clarke, 2006) the offshore service vessel study demonstrates that there is a positive relationship between safety climate and safety compliance. The study clearly illustrates the fact that the visible priority of safety in the organization is decisive for the safety-related behaviour of employees; those who perceive safety to have a low priority in the organization seems to be far less prone to work in accordance with safety procedures compared to those who perceive safety to have a high value. A favourable safety climate was found to be characterized by:

- Positive evaluations of the captain as a role model for safety work
- Low levels of perceived risk
- Positive evaluations of the time and priority given to safety training
- A positive perception of how safety is taken care of
- A positive evaluation of the relative priority of safety versus efficiency

The practical implication of this is that in order to improve the safety climate in a direction which is favourable for increased safety compliance, it is important to give these areas high and visible priority. This should signal to the crew that safety is a real priority in the organization, and thus, that this is also expected to be a high priority among the employees.

As regards the relationship between climate and safety compliance, the offshore platforms study also indicates that the more general aspects of the work climate must be taken into consideration. This finding is in accordance with, for example, DeJoy et al. (2004), Reiman and Oedewald (2004) and Antonsen (2009) who have argued for a broadening of the scope of safety culture and climate research by including more general (non-safety-specific) climate variables in the analyses. The offshore platforms study demonstrates that such general work climate characteristics are also of significance to the variation in safety compliance, and that the behaviour of leaders has a high influence on these characteristics. Such a climate is characterized by clearly stated roles, active follow-up of contractor workers, and workers who are involved in decisions related to their work situation and receive the training that is necessary to handle their work tasks.

6.1.1.3 Procedure quality and clarity

The third key finding of the thesis is related to the rules and procedures themselves. In accordance with, for example, Laurence (2005) and Antonsen et al. (2008), the findings from the offshore service vessel study clearly imply that creating a body of procedures is not sufficient to ensure compliance. The results from the analyses demonstrate that the propensity to act in accordance with safety rules and procedures is strongly determined by the perceived quality and clarity of the procedures. Considering the fact that the study also reveals that as much as 37% of the vessel workers find the procedures difficult to understand, this finding is assumed to be of particular significance to the industry.

This assumption is also strengthened by the fact that other studies within the Norwegian oil and gas industry demonstrate that there is a problem with procedure quality and clarity. For example, a study of Norwegian offshore workers conducted by Tinmannsvik

(2009) found that 37% were of the opinion that the procedures were written in a language that was difficult to understand, and that 70% were of the opinion that there is too much focus on developing new procedures and too little focus on familiarization of the already existing ones.

But how can procedure quality and clarity be ensured? There is no complete answer to this question and the offshore service vessel study in itself does not offer concrete guidance on this topic. The study of maintenance and modification work, however, points to some important areas – such as, for example, appropriate training, user-friendliness of and adequate access to the safety management systems. In addition, employee involvement in the design of procedures should be considered an important topic. As previously described, this has been highlighted in the studies of for example Antonsen et al. (2008), Bourrier (2005), and Mohamed (2002). Simpson et al.'s (2009) basic principles of procedure preparation in the mining industry may also be of importance and applicable to the oil and gas industry. These basic principles are (1) functional simplicity, (2) tailoring, (3) use of plain, positive language and (4) piloting. Simpson et al.'s principles might seem obvious, but in light of the findings related to the relationship between procedure vagueness and safety compliance they should be highly relevant.

6.1.1.4 Knowledge

The fourth key finding of the thesis is related to the factors that affect workers' knowledge of rules and procedures, an under-researched area of safety compliance research (Alper and Karsh, 2009; Barber, 2002). The study of maintenance and modification work demonstrates that adequate knowledge of rules and procedures is not a question about individual willingness or unwillingness. Rather, adequate knowledge seems to be highly dependent on contextual factors which hinder the workers from being active users of the safety management system (wherein the body of rules and procedures are assembled). These factors do also affect the workers' perception of how important it is to achieve greater knowledge of rules and procedures. In summary, the eight different factors that were identified in the study of maintenance and modification work and their paramount thematic categories are as follows:

- The safety management system
    - Access
    - User-friendliness
    - Training
- Work characteristics
    - Routinized work
    - Perceived risk level
    - Subcontracting
- Social interaction
    - Leadership influence
    - Co-worker influence

The identification of these factors has some important practical implications:

First of all, the identification of the factors related to the safety management system points to the importance of offering all workers adequate access to relevant rules and procedures and to the importance of receiving the necessary training that could enable them to locate and interpret the regulations. Access and training are certainly needed as practical tools, but proper access and training also signal that knowledge of rules and procedures is a real priority. In addition, as previously also stressed by Antonsen et al. (2008), the body of rules and procedures should be characterized by simplicity and user-friendliness.

Second, the identification of the factors related to the work itself and the workers' conditions of employment should be of significance. For example, the results clearly point to the importance of paying specific attention to nomadic subcontractor workers, and to the importance of recognizing that this group of workers needs to be offered extra time and resources. Furthermore, the results indicate that sharp-end workers' awareness of the importance of a high knowledge of rules and procedures could be improved by making them more conscious of the relationship between the procedures and the risks that they are meant to reduce. The results related to the work characteristics category also indicate that it is important to pay particular attention to knowledge of rules and procedures among workers who find their work to be routinized and predictable. As described earlier, workers who saw their work as highly routinized were of the opinion that knowledge of rules and procedures was not that important. In such instances it will also be important to ensure that the routines do not drift too far away from the initial written guidance, as previously also stressed by Snook (2000) and Dekker (2006).

Third, the identification of the factors related to social interaction points to the importance of giving particular attention to the signals that leaders send to their subordinates and to the influence that experienced workers have on newcomers. If adequate knowledge of rules and procedures is a goal, then high and visible priority of rules and procedures should be demonstrated by leaders and experienced workers. This signals that such knowledge is of real importance and not just a bureaucratic necessity.

6.1.1.5 Regulatory authorities

The fifth and last key finding of the thesis is related to a company external factor, namely labour inspections. The results from the labour inspection study show that previously inspected enterprises have a higher level of compliance with national safety regulations compared to previously uninspected enterprises. Few studies have paid attention to compliance at the enterprise level and even fewer have examined the impact that labour inspections have on enterprises' propensity to act in accordance with prevailing safety regulations (Baldock et al., 2006). Thus, this finding should fill a research gap within safety research and add new knowledge to our understanding of the impact of labour inspections. It should, however be stressed that this result is not only important and relevant for the research gap it fills, but even more so because the result per se says something about the value of the continued use of inspections in the regulatory authorities' effort for improved compliance. As such, this key finding could serve as a well-founded argument for the necessity of labour inspections in a period where the impact that labour inspections actually have is debated (Levine et al., 2012) and where funding cuts and a reduction in the frequency of labour inspections is a fact in many countries (Johnson, 2012; Tombs and Whyte, 2010, 2012).

The findings related to the effect of labour inspections also illustrate an important point previously made by Rasmussen (1997), namely that safety in organizations is a result of the interplay between actors operating on different societal levels and that the creation of organizational safety can hardly be seen as a pure product of company internal conditions. By this, he means that the state of safety within an organization cannot be fully accounted for by ignoring factors that are external to the companies.

6.1.2 Summary of key findings

From what has been described above it should be clear that the key findings of the thesis do not point in vastly different directions. In fact, they are highly related and they all point to one common denominator, namely that safety compliance is highly influenced by different environmental factors. This demonstrates that safety compliance cannot be fully understood without taking the context into consideration. In a highly regulated environment, such as the oil and gas industry, it is particularly important to be aware of this because it implies that safety compliance can be managed and that safety violations can hardly be seen as isolated from their surroundings.

6.2 Limitations and recommendations for future research

In order to shed light on the main objective of the thesis the choice of research methods has varied considerably – from content analysis of qualitative interview data, via comparative analyses of experimental data, to structural equation modelling of quantitative questionnaire data. The different data sources have also varied considerably with respect to depth and sample sizes – from an extensive study of more than 10,000 respondents to an intensive study of 24 interviewees. This combination of different research methods and data sources (referred to as ‘triangulation’, see Denzin, 1970 or ‘mixed method research’, see Tashakkori and Teddlie, 2003) is believed to represent a significant methodological strength of the thesis because the different methods can answer different questions and thus provide different insights regarding the research objective. As such, the combination of different research methods and data sources has therefore served a complementary function. Despite this, the research designs and the methods employed do also have some limitations which should be kept in mind when interpreting the findings. Three of these are particularly important.

First, the offshore service vessel study, the offshore platforms study and the study of maintenance and modification work are all based on self-report measures – either collected through questionnaires or through interviews. Hence, the data could be distorted by recall errors and inaccurate responses or by bias related to social desirability – that is, the tendency to answer questions in such a way as to represent oneself in a favourable light (Edwards, 1953). Bias related to social desirability could certainly also be a challenge in the labour inspection study, since people also engage in impression management of units other than themselves. Potential biases related to social desirability in the thesis could have been overcome if the findings had been underpinned by observations of actual work. In general, there is a limited use of observational methods in studies of safety compliance, where most studies rely on self-report measures. Future studies of safety compliance should thus consider observational studies and strive to develop reliable behavioural observation measures.

Second, the quantitative studies included in the thesis do not go into detailed analyses or explanations of causal mechanisms. For example, the labour inspection study demonstrates that labour inspections have a positive effect on the enterprises' compliance with safety regulations. However, the same study says less about why. The positive correlation between labour inspections and compliance can be interpreted as a result of enforcement actions and formal orders, but it would be just as valid to interpret the positive correlation as a result of guidance and information offered during inspection. The problem is that the study does not provide the necessary data for robust interpretations to be made with regard to this mechanism. Similarly, the offshore service vessel study demonstrates that there is a positive correlation between safety climate and safety compliance, but again a comprehensive causative explanation is difficult because the study does not offer detailed analyses of possible causal mechanisms. Such analyses depend on the introduction of mediator variables (such as, for example, *safety knowledge* and *safety motivation*: Neal and Griffin, 2004), because these can shed light on the relationship between the independent and dependent variables. It would therefore be valuable for future research to explore mediational models.

Third, none of the studies shed empirical light on the relationship between safety compliance and safety. As stated in chapter two, it falls out of the scope of the thesis to examine this relationship. Despite this, the implications of the findings would have been strengthened by a closer examination of the relationship between safety compliance and actual safety performance data, such as near-misses, lost time injuries, and hydrocarbon leakages. In general, safety compliance studies seldom include such data. It would therefore be useful for future studies to include safety performance data in the analyses. This would allow for a more comprehensive understanding of safety compliance.

6.3 Conclusion

Accidents at work are rarely the result of a single cause. Rather, they develop from a multitude of different causal factors and from a complex interplay between these factors. The purpose of this thesis has not been to examine this assembly of different technical, behavioural and organizational factors, but to follow one of them more closely – namely safety violations. This choice has not been random. Rather it is rooted in the fact that accident investigations and analyses regularly identify non-compliance as a significant contributory factor and that this is also the case in the type of industry that has been the focus of this thesis – the oil and gas industry.

With the Norwegian oil and gas industry as the primary research context, the main objective of the thesis with its accompanying research articles has been *to go behind safety violations and to examine and identify the conditions that affect the propensity to act in accordance with prevailing rules, procedures and regulations*. This has been done (1) by addressing safety violations from a viewpoint which is believed to be more constructive than that which is common within accident investigations and traditional safety research, which typically has been more concerned with the conditions that hinder safety than with the ones that nurture it. To the empirical inquiries of the thesis, this has meant an explicit focus on safety compliance rather than on safety violations. In addition, (2) the study objective has been analysed by the application of a system perspective. This has implied that the empirical research embedded in the thesis has been primarily concerned with investigating how contextual, and not how individual, aspects affect safety compliance.

The key findings of the thesis are highly related as they all clearly illustrate that safety compliance does not occur in a vacuum. Hence, they all point to the importance of taking the context into consideration. Within this context, the findings of the thesis point to some areas that need particular attention, such as the importance of a favourable safety climate, leaders who send clear messages about the priority of safety, leaders who stay close to the front-line activities, clarity in rules and procedures and unambiguity with regard to the importance of knowledge and understanding of rules and procedures. Similarly, the thesis illustrates that safety compliance at the enterprise level is also a result of the interplay between the organization and actors operating outside the organization, and thus that safety can hardly be seen as a pure product of company internal conditions.

Finally, it should be added that the findings of the thesis are not at all depressing. In fact they are really encouraging, because in essence they implicate that safety (like most other aspects of business) can be managed, and in particular that variations in safety compliance is not a result of mere chance and individual variations. Hence, the implications of the key findings of the thesis should be of importance for proactive measures which aim at improving safety compliance within the oil and gas industry. The findings and the practical implications of these should also be relevant to other high-risk industries, in particular to those where rules and procedures constitute a vital part of the system of safety barriers.

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Appendix – Four research articles

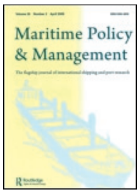
Article #1 Dahl, Ø., Fenstad, J., Kongsvik, T., 2013. Antecedents of safety-compliant behaviour on offshore service vessels: a multi-factorial approach. *Maritime Policy & Management*, in press.

Article #2 Dahl, Ø., Olsen, E. 2013. Safety compliance on offshore platforms: a multi-sample survey on the role of perceived leadership involvement and work climate. *Safety Science* 54, 17-26.

Article #3 Dahl, Ø., 2013. Safety compliance in a highly regulated environment: a case study of workers' knowledge of rules and procedures within the petroleum industry. *Safety Science* 60, 185-195.

Article #4 Dahl, Ø., Søberg, M., 2013. Labour inspection and its impact on enterprises' compliance with safety regulations. *Safety Science Monitor* 17 (2), 1-12.

Article #1 - Antecedents of safety-compliant behaviour on offshore service vessels: a multi-factorial approach.



Dahl, Ø., Fenstad, J., Kongsvik, T., 2013. Antecedents of safety-compliant behaviour on offshore service vessels: a multi-factorial approach. *Maritime Policy & Management*, in press.

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Antecedents of safety-compliant behaviour on offshore service vessels: a multi-factorial approach

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Procedure violations are commonly identified as an essential causal factor in maritime accidents. This also applies to the Norwegian offshore service vessel sector. This illustrates that there is a need to study compliance and non-compliance in a broad context and to explore the factors that affect the propensity to act in accordance with prevailing procedures. The aim of the present study was therefore to examine the antecedents of safety-compliant behaviour among workers on offshore service vessels operating on the Norwegian Continental Shelf. With reference to a survey of 1108 offshore service vessel workers, this was done by analysing the relationship between a set of predictor variables and a self-report measure of safety-compliant behaviour. Using binary logistic regression analysis, the present study revealed that the safety climate and the vessel workers' age were positively related to safety compliance, whereas job experience and perceived procedure vagueness were negatively related to safety compliance. Theoretical and managerial implications are discussed. In sum, the findings indicate that shipowners, captains and other stakeholders within the offshore service vessel industry should consider a broad multi-factorial approach to increase safety compliance.

1. Introduction

Organizational safety research has demonstrated that the level of compliance with rules and procedures is an important aspect of a work organization's state of safety, and that safety-compliant behaviour is influential in lowering the risk of accidents (Didla, Mearns, and Flin 2009). This also applies to the maritime industry, where procedure violations are commonly identified as a causal factor in accident scenarios such as collisions and groundings (Macrae 2009). However, in the quest for effective preventative measures, there is also a need to study violations and non-compliance in a broader context and to explore conditions that could lead to such unsafe acts. This implies investigating 'second stories' (Woods et al. 2010) and the multiple factors that could foster procedure deviations.

The present study is based on a survey of employees working on offshore service vessels operating on the Norwegian Continental Shelf (NCS) and explores the factors that can influence compliance in their work. Three different types of vessels are included in the study: anchor handling vessels, platform supply vessels and standby vessels. These vessel types serve different functions. The anchor handling vessels' primary function is to handle anchors for floating oil rigs, to tow the rigs to their locations and to anchor them up. The primary tasks for workers on board such vessels consist of operating cranes and winches with chains and wires under high tension and to navigate the vessel so that external forces

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acting on the ship during anchor handling is accounted for. The platform supply vessels transport equipment, bulk products, hazardous chemicals and supplies to and from onshore supply bases and offshore installations. Lifting operations with cargo containers and bulk loading hoses under challenging conditions close to offshore oil installations comprise the key task for workers on board supply vessels. The standby vessels are responsible for emergency preparedness and guard duties for the installations. During exercises and real-life situations hoisting and lowering of fast rescue crafts, deployment of oil spill equipment (oil booms, skimmers and tug boats) and rescuing personnel after evacuation of oil installations comprise the primary task for workers on board standby vessels.

Irrespective of the different functions that the vessels serve, they are all characterized by operating with complex and hazardous technology and equipment in harsh environments. Most work operations are also highly regulated by a number of rules and procedures.[1] Common guidelines for offshore supply and rig move operations have been developed on the European level, which prescribe detailed 'best practices' regarding these operations (NWEA 2009). On the national level, the Norwegian Oil Association and the Norwegian Shipowners' Association (2011) have developed an operations manual for offshore service vessels. Also, the different shipowners and petroleum companies have company specific procedures. A foundation for these procedures, guidelines and 'best practices' are international regulations provided by the International Maritime Organization, e.g. the Safety Of Life At Sea (SOLAS) convention and the International Ships Management (ISM) code. The extensive body of procedures combined with the high risk level implies that offshore service vessels are particularly relevant for studies assessing the antecedents of safety-compliant behaviour in the maritime industry.

The safety level in the offshore petroleum industry in Norway has generally improved since the 1990s, but offshore service vessels have lagged behind (Kongsvik et al. 2012). According to the Norwegian Maritime Directorate's database (2011), there were 12 fatalities on offshore service vessels from 2000 to 2010, including eight people lost when the *Bourbon Dolphin* capsized in 2007. In the same period, 777 people were injured. Although the number of occupational injuries significantly decreased in that period, offshore service vessels still represent one of the most dangerous working environments in the Norwegian petroleum industry.

In addition to occupational accidents and injuries, offshore service vessels also pose a threat in terms of major accidents. Collisions with petroleum installations, especially in loading/unloading situations, and damage to hydrocarbon-bearing pipes have the potential to start off a chain of events that could lead to loss of life, extensive property damage and serious environmental consequences. According to the Petroleum Safety Authority Norway (PSA 2011), there was a reduction in the frequency of collisions between offshore service vessels and fixed offshore installations between 1988 and 2001. The frequency of such collisions, however, increased between 2004 and 2010 on the NCS, in which 28 collisions between offshore service vessels and fixed offshore installations have occurred. Six of these were considered to have major accident potential.

From their investigations of such collisions, the PSA has concluded that a lack of compliance with procedures is one of the most frequently identified underlying causal factors (PSA 2011). This phenomenon is neither unique to the offshore service vessel sector nor restricted to accidents with catastrophic potential. Accident analyses and investigations routinely identify a lack of compliance with rules and procedures as a central contributory factor to accidents at work (Hopkins 2011).

The PSA explain the lack of compliance with procedures aboard the offshore service vessels by a poor safety culture within the vessel sector (PSA 2011). This explanation is plausible and it is also very much in accordance with Reason (1998), who claims that organizations with a poor safety culture tend to encourage an atmosphere wherein a lack of safety compliance among frontline workers evolves. Other lines of research, however, illustrate a need to broaden this explanation. First, the safety culture concept is not sufficiently specific about the mechanisms through which it affects the level of compliance or other aspects of organizational practices (Guldenmund 2007). Second, non-compliant behaviour can hardly be reduced to one single explanatory factor, such as safety culture. A comprehensive review study by Alper and Karsh (2009) demonstrates that the roots of non-compliant behaviour are linked to several different factors within the organization. Some of these factors are related to the individual worker, some are related to the organization and some are related to the procedures or rules themselves. Thus, the use of safety culture as a broad, all-embracing factor is a simplification, and could reduce the concept to a 'buzzword' (Rosness 2001) with a diffuse content.

In sum, this illustrates a need for more applicable knowledge about the measures which should be taken in order to improve the level of safety compliance within the offshore service vessel sector. To gain such knowledge, it is necessary to assess the antecedents of non-compliant behaviour or its opposite, the antecedents of safety-compliant behaviour. Based on previous research within other sectors, the present study aims therefore to develop and test a quantitative model which measures the relationship between a set of explanatory factors and safety compliance. The model is multi-factorial and measures characteristics related to the individual worker, the organization and the body of procedures in terms of offshore service vessels. The principal research model is presented in Figure 1. This model will be further extended and concretized with hypotheses in the next section.

2. Theoretical background and research hypotheses

As already outlined, the claim that accidents in work organizations are caused largely by a lack of compliance with rules and procedures is not unique to the offshore service vessel sector (Didla, Mearns, and Flin 2009; Hopkins 2011). Within the mining industry, for example, Lenné et al. (2012) found that non-compliant actions can be identified in 57% of accidents. Studies which assess a broader range of unsafe work behaviours often reach

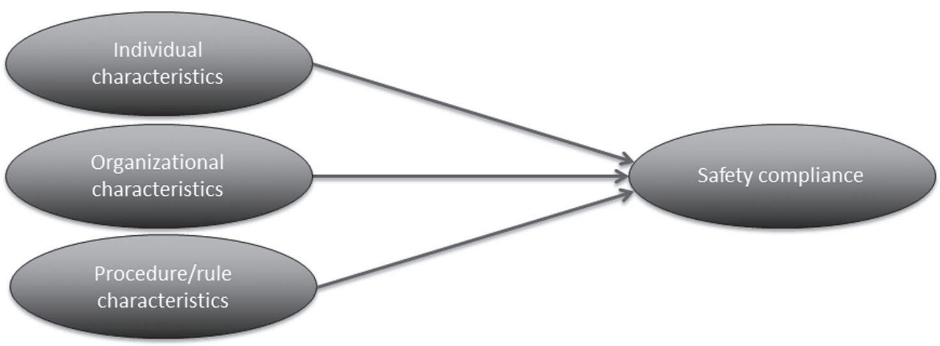

Figure 1. The principal research model of the present study.

even higher proportions. An example of this is a study of all occupational fatalities occurring in Australia over a 3-year period, which reported that unsafe work behaviour was involved in 91% of the fatalities (Willamson and Feyer 1990). The fact that unsafe work behaviour is a significant contributor to accidents in work organizations is, however, not a new finding. As early as 1931, Heinrich (1931) reported from case studies of 75 000 accident records that 88% of industrial accidents were caused by unsafe work behaviour.

The recognized significance of unsafe work behaviour in the aetiology of accidents has led researchers within the field of organizational safety research to increase their effort to identify the antecedents of such practices. A relatively large proportion of these studies focus on the antecedents of non-compliant or safety-compliant behaviour (Didla, Mearns, and Flin 2009; Cavazza and Serpe 2009; Johnson 2007; Lawton 1998; Lu and Yang 2011; Mearns et al. 2010; Neal et al. 2000; Pousette et al. 2008; Simard and Marchand 1997; Torp and Grøgaard 2009; Zhou et al. 2008). An important message from these studies is that non-compliant behaviour does not occur in a vacuum, but is largely shaped by social and cultural aspects within the organizational context (Didla, Mearns, and Flin 2009). Alper and Karsh's (2009) review study identifies six causal categories within this organizational context: (1) individual characteristics, (2) information/education/training, (3) design to support worker needs, (4) safety climate, (5) competing goals and (6) problems with rules. In the present study, the six categories identified by Alper and Karsh are reduced to the three more general characteristics referred to in Figure 1: (1) individual characteristics, (2) organizational characteristics and (3) procedure/rule characteristics. These three broad categories will be presented in more detail in the following sections.

2.1. *Individual characteristics*

According to Neal and Griffin (2004), individual differences in safety-specific behaviour, such as compliance/non-compliance, must be understood on the basis of individual differences in the three determinants of behaviour: knowledge, skills and motivation. These determinants represent factors that are directly related to behaviour. Hence, Neal and Griffin label them proximal drivers of safety behaviour. These drivers are affected by more distal antecedents, which could be related to the individual itself or the organizational context. Organizational and procedure/rule characteristics are therefore always potential distal antecedents, but individual characteristics could be both distal and proximal.

Person-related distal antecedents which are typically examined in studies of safety-compliant behaviour are personality characteristics (Wallace and Chen 2005), job attitudes (Henning et al. 2009) and demographic attributes (Chan et al. 2002). With regard to individual characteristics, the present study focused on the latter by assessing the impact of vessel workers' age and job experience on safety compliance.

According to Alper and Karsh's (2009) review study, evidence in previous studies for the relationship between age and safety compliance is contradictory. Some of the studies to which they refer have found no significant relationship between age and safety compliance (Ji et al. 2005; Naing et al. 2001), others have found a negative impact of age (Ben-David and Gaitini 1997) and still others have found a positive impact of age (Chan et al. 2002; Gershon et al. 1995).

The studies which Alper and Karsh (2009) refer to with respect to age, however, were all carried out within the health sector and deal with compliance with procedures related to biological hazards. These hazards are quite different from the physical ones present in the offshore service vessel sector. Studies of sectors where physical hazards are present point more clearly in one direction, i.e. young employees tend to be more non-compliant than their older colleagues, albeit the amount of variance that age accounts for is quite small (Lu and Yang 2011; Gyekye and Salminen 2009; Siu et al. 2003; Tesluk 2004). In addition, young workers, especially young men, are at greater risk of workplace injuries than their older colleagues (Loughlin and Frone 2004; Salminen 2004). To our knowledge, no universally accepted explanation exists as to why young employees are often found to be more accident-prone and slightly more non-compliant than their older colleagues. Some explanations have, however, been offered. Gyekye and Salminen (2009), for instance, note that it could be caused by an age-related decline in certain personality traits found by Costa and McCrae (1988). Costa and McCrae have noted that activity and excitement seeking decline with age, and that this results in younger individuals being more active and keener to launch into new experiences than older individuals. Additionally, studies of driving behaviour have explained the higher frequency of violation of traffic regulations among young drivers as a result of age differences in risk perception, i.e. young drivers tend to perceive less risk in most driving situations than do older drivers (Boyce and Geller 2002; Jonah and Dawson 1987).

Despite some conflicting findings within the health sector, and in line with previous findings within sectors where physical hazards are present, this study hypothesized that:

> **H1:** Vessel workers' age will be positively related to safety compliance.

Another explanation offered in the literature which attempts to clarify why older workers tend to be more safety-compliant than their younger colleagues is related to job experience and the fact that age is highly correlated with job experience (Gyekye and Salminen 2009; Siu et al. 2003). Older workers have acquired skills, organizational knowledge and knowledge of procedures which should lead to enhanced performance (Gyekye and Salminen 2009); hence, age could be spuriously related to safety compliance when controlled for job experience. This spurious relationship has been found with regard to age and injury risk within the US mining industry. Butani (1988) found that the significant negative relationship between age and injury risk disappeared when controlled for job experience. This might also be the case for safety compliance, but again it should be noted that Alper and Karsh's (2009) review study revealed some conflicting findings. One of the studies which they refer to found a negative relationship between job experience and safety compliance (Rebok et al. 2005) and another found a positive relationship of job experience (Hobbs and Williamson 2002). Both of these studies were performed within the aviation sector, among pilots and mechanics, respectively.

Based on what is described above, and despite some conflicting findings in Alper and Karsh's (2009) review study, this study hypothesized that:

> **H2:** Vessel workers' job experience will be positively related to safety compliance.

2.2. *Organizational characteristics*

Organizational characteristics are by definition distal antecedents of safety-compliant behaviour, i.e. they are considered to affect behaviour by influencing the proximal determinants safety knowledge, safety skills and safety motivation (Neal and Griffin 2004). This division between distal organizational antecedents and proximal individual drivers is clearly illustrated in the article by Wagenaar (1998) entitled 'People Make Accidents But

Organizations Cause Them'. Wagenaar's principal notion is that non-compliant behaviour (or any human behaviour which affects personal and organizational safety) is not a random phenomenon; rather, it is a phenomenon caused by organizational conditions.

Wagenaar's (1998) notion is not unique. Since the 1980s, a string of organizational disasters have indicated that it is beneficial to move the focus away from proximal individual issues to distal organizational issues (Mearns et al. 2003). A considerable amount of research has also been carried out in order to identify the organizational antecedents of non-compliant behaviour. A variety of different organizational issues have been studied, such as leadership (Inness et al. 2010; Lu and Yang 2010), job demands and resources (Hansez and Chmiel 2010; Turner et al. 2012), psychological climate (Larsson et al. 2008) and job autonomy (Parker et al. 2001). The organizational factor which has probably attracted most research interest since the 1980s is, however, safety climate. Safety climate can be defined as the set of perceptions that employees share regarding safety in their work environment (Zohar 1980) and is the preferred term when psychometric questionnaire studies are employed to uncover such perceptions (Flin et al. 2000). According to Neal and Griffin (2004), safety climate studies typically try to reveal perceptions of the organization's policies, procedures and practices associated with safety. Further, these specific perceptions, which in a factor analysis would be labelled first-order factors, should load onto a general second-order factor which constitutes the general safety climate. This factor reflects the extent to which employees perceive safety as valued within the organization (Griffin and Neal 2000; Neal et al. 2000).

According to Clarke (2006), the safety climate of an organization acts as a frame of reference for safety-specific behaviour and attitudes of both individuals and groups of employees. Further, Zohar (2010) assumes that it is within this frame of reference that employees receive, interpret and make sense of signals from a complex web of sources (colleagues, policies, leadership, competing domains, etc.) about what sort of role behaviour is expected, supported and rewarded. Employee behaviour will then tend to align with these perceived expectations.

Clarke's (2006) and Zohar's (2010) theoretical explanations of the role that safety climate plays with respect to workers' safety behaviour are strongly supported in studies of the relationship between safety climate and safety compliance. Several safety climate studies have demonstrated that a positive safety climate promotes safety-compliant behaviour. This finding is relatively consistent across a broad range of industries, such as the manufacturing and mining industries (Griffin and Neal 2000), the construction industry (Zhou et al. 2008), the mechanic, textile and food industries (Cavazza and Serpe 2009), the container shipping industry (Lu and Tsai 2010) and the nuclear power industry (Martínez-Córcoles et al. 2011). The positive relationship between safety climate and safety compliance is also one of the more consistent findings in Alper and Karsh's (2009) review study and in two other in-depth review studies performed by Clarke (2006) and Christian et al. (2009). Hence, this relationship should be considered relatively firmly established.

This study therefore hypothesized that:

H3: Vessel workers' safety climate will be positively related to safety compliance.

As already noted, Neal and Griffin (2004) recommend comprehending and operationalizing the safety climate construct as a second-order (or higher-order) factor. This has been done in the present study, but it should be noted that this is not the case in all safety climate studies.

Several studies put more emphasis on the various sub-dimensions of the construct than on the supreme dimension (Lu and Yang 2011; Lu and Tsai 2010; Olsen 2010). Which sub-dimensions are prioritized varies; but in a review study by Flin et al. (2000), the five most common themes identified were related to employee perceptions of (1) safety management and leadership, (2) the safety system, (3) risk, (4) work pressure and (5) safety competence and training. In the present study, we focused on a second-order factor composed of five first-order factors which did not differ fundamentally from Flin et al. (2000) findings. These were (1) captain's safety leadership, (2) general safety orientation on board, (3) risk, (4) efficiency demands and (5) safety training. This will be elaborated in Section 3.

2.3. *Rule/procedure characteristics*

According to Reason (1998) for the safe running of organizations, it is necessary to formulate safety rules, not only because the rules are important for guiding safe behaviour in relation to identified hazards, but also because the rules constitute a vital record of the organization's learning about the operational risks involved in its activities. Reason (1998) stresses, however, that rules and procedures will never be fully comprehensive or universally applicable. Hence, the body of rules and procedures will never be able to cover all imaginable hazards and accident scenarios within an organization or particular work operation. The appropriateness of rules and procedures is also associated with limitations related to their comprehensibility. In brief, if safety rules and procedures are to work in accordance with their intent, they must be understood by those to whom they are addressed, and they must be perceived as valid for the particular work operation which is in progress. This depends, at least partly, on the degree of clarity within the body of rules and procedures (Battmann and Klumb 1993; Reason 1990; Lawton 1998).

What we have described above might seem self-evident, but studies which emphasize the quality of safety rules and procedures demonstrate that clarity and comprehensibility are a challenge. A study by Elling (1987), referred to in Hale (1990), involving Dutch railway workers' opinion of the rules governing work on and near railway lines is one example. Some 85% of the workers found it hard to find what they were looking for in the rule book, and 70% found the rules too complex and hard to read when they finally found them. A study by Laurence (2005) of Australian mine workers obtained similar findings. When asked to indicate their reasons for not complying with the rules, close to 35% answered that there was some sort of problem with the rules. The workers were then probed more thoroughly about the cause of this problem: some 10% of the workers thought that the content of the rules was poor or contained errors, 12% that the rules were not written in plain language, 16% that the rules were too complex and 18% that there were too many rules to be remembered. Simpson et al. (2009) might therefore have a very relevant argument when they claim that safety rules frequently are far from being appropriate, practical, well-written and well-communicated, and that this is often at the expense of compliance.

Laurence's (2005) study within the mining industry demonstrates that there is a link between rule clarity, comprehensibility and compliance. Alper and Karsh's (2009) review study points in the same direction. Each of the variables in their 'problems with rules' category was positively associated with violations and hence negatively associated with safety compliance. In the present study, however, we did not focus on problems with rules and procedures in general, as Alper and Karsh do. Instead we focused on procedures in terms of clarity and vagueness, and hypothesized that:

H4: Perceived procedure vagueness will be negatively related to safety compliance.

3. Method

3.1. *Survey, data collection and sample*

The present study is based on a survey which was administered as a self-report questionnaire to monitor safety and working environment issues within an offshore service vessel fleet consisting of 85 vessels. Each vessel has two work shifts, so the total number of shifts is 170. All vessels included in this study operate on the NCS and are chartered by one Norwegian oil company. The contracting oil company demands that the crew members speak one of the Scandinavian languages fluently and use one of these as their working language. The great majority of the crew members are of Norwegian nationality, with some representatives from Denmark, Sweden and the Faroe Islands.

The questionnaire was developed and piloted in 2000 and has been employed for data collection within the same population every second year since then and also in other maritime settings (Oltedal and Wadsworth 2010).[2] The questionnaire has also been subject to revisions and adjustments every second year. The data on which the present study is based were collected from August to November 2010. The questionnaires (consisting of 82 items) and an accompanying letter which explained how the questionnaires should be distributed, collected and returned were sent by mail, addressed to the vessels' captains. The crews were asked to return the questionnaires in a sealed envelope within a week of receipt. The questionnaire was given in Norwegian, as most of the crew members were Norwegian. The Norwegian language is also comprehensible for other Scandinavians.

All work shifts (n = 170) were included in the target sample and a total of 2022 questionnaires were distributed. On the work shift level, the response rate was 66%, as 113 work shifts returned the questionnaire. On the individual level, the response rate was 55%, as 1108 vessel workers returned the questionnaire. The individual response rate is a conservative estimate (based on the number of distributed questionnaires), however, as the exact size of each unique work shift was unknown. The estimate is considered conservative due to the fact that the number of questionnaires deemed necessary to distribute was slightly overestimated.

The age distribution in the net sample shows that the majority of respondents (57.5%) were aged 40 years or under and that 38.7% of the respondents were aged between 41 and 60 years (Table 1). A minority of the respondents were aged above 60 years (3.8%).[3] As regards job experience, a majority of the respondents had over 3 years of experience on offshore service vessels (62.5%) and 37.5% of the respondents had three years or fewer of experience.

Sailors (30.1%) constituted the largest occupational group among the respondents, followed by officers (23.7%) and engineers (18.0%). As regards vessel type, the largest group of respondents was employed on supply vessels (46.3%), followed by respondents employed on anchor handling vessels (32.4%) and standby vessels (21.3%).

3.2. *Measures and statistical procedures*

3.2.1. *Independent variables and factor analysis.* In the survey, the respondents were asked nine questions related to demographic characteristics (sex was omitted to preserve confidentiality) and 73 questions related to safety and working environment conditions. The two items were used to measure age and job experience, respectively. No recoding of these items was deemed necessary, and they were consequently implemented in the analyses by means of the same grouping categories as those in Table 1.

Table 1. Respondents' demographics.

Characteristics	Group	Frequency	%
Age	<31	364	33.1
	31–40	268	24.4
	41–50	243	22.1
	51–60	182	16.6
	>60	42	3.8
Job experience on offshoreservice vessels (years)	<1	132	12.0
	1–3	281	25.5
	4–10	445	40.4
	>10	244	22.1
Job title	Captain	87	8.0
	1./2. Officer	259	23.7
	Engineer	196	18.0
	Electrician	58	5.3
	Sailor	328	30.1
	Steward	70	6.4
	Apprentice	91	8.3
Vessel type	Supply	486	46.3
	Anchor handling	340	32.4
	Standby	223	21.3

As regards safety climate and procedure vagueness, 18 items were used to measure these characteristics. The items were selected on face value and on the basis of safety climate literature (Flin et al. 2000). Descriptive statistics for the items are presented in Table 2. Fifteen of the items were presented as statements with which the respondents were asked to specify their level of agreement on a five-point Likert scale. The scale ranged from 'totally disagree' (=1) to 'totally agree' (=5). Further, on two of the items (Q4 and Q5 in Table 2), the response categories ranged from 'very likely' (=1) to 'not likely' (=5), and on one item (Q6 in Table 2) the response categories ranged from 'very unsafe' (=1) to 'very safe' (=5). In addition, a 'don't know' option was included in all items.

In order to uncover the underlying factor structure of the items and to reduce the number of items to a manageable size, exploratory factor analysis (EFA) was conducted. In addition, a second-order EFA was conducted to examine the interrelationship between the safety climate dimensions and to examine whether or not they loaded on one supreme safety climate dimension. The applied EFA (both first and second orders) was principal component analysis with varimax rotation, and factor loadings above 0.40 were considered sufficient to relate the item to the factor (Meyers et al. 2006). The number of factors to be extracted was based on Kaiser's criterion (Field 2005). This meant that only factors with eigenvalues greater than or equal to 1 were retained. Further, internal consistency and reliability were assessed by Cronbach's alpha.

3.2.2. *Dependent variable and binary logistic regression.* The dependent variable, safety compliance, was measured by an item which was formulated as a statement regarding compliance with safety procedures (Table 2). The statement was presented as 'I always follow the procedures'. It was not possible for the respondents to specify their agreement with this statement on a scale. Instead, they either ticked the statement

Table 2. Descriptive statistics for items.

Item	N	Mean	SD
Q1 My captain appreciates that the employees take up safety issues	897	4.74	0.67
Q2 I am sure to get support from my captain if I prioritize safety in all situations	898	4.74	0.67
Q3 My captain sets a good example regarding attention to safety	904	4.68	0.67
Q4 How likely is it that you will be involved in an accident on the vessel where you work?	890	3.64	0.93
Q5 How likely is it that someone in the crew will be involved in an accident on the vessel where you work?	889	3.35	1.00
Q6 To what extent do you feel safe when you think about the risks associated with the work on board?	905	4.53	0.83
Q7 We have sufficient time to train employees on board	890	3.83	1.15
Q8 New employees receive sufficient training to work safely	893	4.12	1.04
Q9 We always perform the emergency exercises which we are ordered to perform	883	4.39	1.00
Q10 On my vessel, we strive to achieve zero harm to people, prevent accidents, and reduce negative effects on the environment	917	4.73	0.69
Q11 Safety has first priority in the shipping company where I work	909	4.63	0.75
Q12 Safety is well taken care of on my vessel	918	4.72	0.68
Q13 Following safety procedures is not rewarded in the shipping co-mpany where I work	812	2.95	1.53
Q14 As long as the work is done, the shipping company do not care about the way we do the work	859	2.06	1.25
Q15 Sometimes I feel forced to continue working, although safety can be threatened	913	2.01	1.31
Q16 In some situations it is necessary to expose oneself to danger to get the job done	910	2.42	1.39
Q17 The procedures are difficult to understand/vaguely formulated	905	2.66	1.26
Q18 I find it difficult to know which procedures are applicable	896	2.45	1.30
Q19 I always follow the procedures	924	0.42	0.49

(demonstrating agreement) or they did not (demonstrating disagreement). This was coded as yes = 1 and no = 0, respectively.

Regression analysis was conducted to test the hypothesized relationship (H1 to H4) between the set of independent variables and the dependent variable. Ordinary least squares (OLS), the basis of linear regression, is not appropriate when the dependent variable is binary or dichotomous. This is because a series of assumptions will then be broken (Meyers et al. 2006). For instance, OLS can produce predicted values greater than one and less than zero, i.e. values that are inadmissible when binary coding is applied. Thus, binary logistic regression (BLR) was chosen to test the hypotheses.

The advantage of applying BLR in cases where the dependent variable is binary is that it allows one to predict group membership (yes or no, one or zero) from a set of independent variables that may be continuous, discrete or dichotomous. More specifically, the BLR model predicts the probability of a case falling into the higher value (i.e. one) on the dependent variable, in our case the probability of a given individual reporting that he/she always follows the procedures on board the vessel.

Similarly to OLS, BLR will also produce a constant (β_0), a regression coefficient ($\beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_n X_n$) for each predictor in the model, and an accompanying

p-value. A positive β_n indicates that there is a positive relationship between the particular independent variable and the dependent variable. A negative β_n indicates a negative relationship. p-Values below 0.05 indicate that this relationship is statistically significant. In addition to the regression coefficients, the BLR will also produce odds ratios (ORs) assigned to each independent variable. An OR of one indicates that there is no relationship between the independent variable and the dependent variable. ORs lower than 1 indicate a negative relationship and, vice versa, ORs greater than 1 indicate a positive relationship.

The general form of the BLR is: $L = (\beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_n X_n)$. The logit ($L$) is not intuitively interpretable, but is used in the antilog function that transforms L to predicted probabilities; $P = 1/[1+ \text{EXP}(-L)]$, that is, the predicted probability of a given case falling into the higher value on the dependent variable. If the predicted probability of a given case is greater than or equal to 0.50, then the case is classified as probably belonging to group 1 (always follow the procedures).

In order to test the hypotheses, the present study assessed the regression coefficients, the ORs and the p-values, but the regression model as a whole was evaluated by Nagelkerke's R^2 and the Hosmer–Lemeshow test. Nagelkerke's R^2 (Field 2005) is an effect size measure which varies between 0 (indicating that the independent variables in the model are useless at predicting the dependent variable) and 1 (indicating that the independent variables in the model predict the dependent variable perfectly). The Hosmer and Lemeshow test is a measure of the match between the predicted values and the observed values, and thus it is often referred to as a goodness-of-fit measure. A non-significant p-value ($p > 0.05$) is preferred in this test, since this indicates no significant difference between predicted values and observed values (Meyers et al. 2006).[4]

4. Results

4.1. *Exploratory factor analysis*

4.1.1. *Factor extraction and factor labelling.* The initial considerations and analysis of the sample verified that the data and the included variables were appropriate for factor analysis. Bartlett's test of sphericity and Kaiser–Meyer–Olkin's measure of sampling adequacy showed satisfactory results (see notes in Table 3). The sample size was reduced to $n = 754$, because respondents with missing values were removed from the factor analysis. However, the common requirement for at least 10–15 respondents per item was still fulfilled (Field 2005).

The application of Kaiser's criterion resulted in a six-factor solution, presented in Table 3. This solution accounted for 65% of the total variance. From Table 3, it is clear that all of the 18 items had sufficient loadings (above 0.40) on a factor to be retained in the final factor solution. At the same time, no items had loadings above 0.40 on more than one factor, indicating a simple factor structure. The six factors were thematically labelled as follows:

Factor 1 – Captain's safety leadership, consisting of three items related to the captain as a role model for safety work and openness towards safety issues.

Factor 2 – Risk, consisting of three items related to how risk is perceived and the perceived probability of being involved in accidents on the vessel.

Factor 3 – Safety training, consisting of three items related to the crew's evaluation of the time and priority given to safety training.

Table 3. Exploratory factor analysis: PCA, varimax with Kaiser normalization.

	Factor loadings						
Items	1	2	3	4	5	6	h^2
Q1	0.857						0.755
Q2	0.844						0.768
Q3	0.814						0.780
Q4		0.892					0.760
Q5		0.874					0.792
Q6		0.487					0.380
Q7			0.852				0.672
Q8			0.804				0.717
Q9			0.530				0.539
Q10				0.791			0.546
Q11				0.769			0.577
Q12				0.684			0.526
Q13					0.687		0.457
Q14					0.650		0.820
Q15					0.632		0.409
Q16					0.543		0.798
Q17						0.822	0.700
Q18						0.795	0.723
Eigenvalue	4.90	1.89	1.44	1.32	1.16	1.00	
% explained variance (after rotation)	13.32	11.12	11.04	10.83	10.18	8.62	65.10

Notes: Bartlett's test of sphericity: $\chi^2 = 4222.75$, $p < 0.001$. Kaiser-Meyer-Olkin = 0.819.
Factor loadings below 0.40 are suppressed.

Factor 4 – General safety orientation on board, consisting of three items related to how safety is taken care of and prioritized on board.

Factor 5 – Efficiency demands, consisting of four items related to the relative priority of safety versus efficiency.

Factor 6 – Procedure vagueness, consisting of two items related to the crew's perception of the procedures with regard to their comprehensibility and user-friendliness.

4.1.2. *Internal consistency, reliability and second-order factor analysis.* Intercorrelations between the measurement constructs and Cronbach's alphas within the constructs are presented in Table 4. According to Nunnally (1978), alpha scores greater than 0.70 are indications of adequate internal consistency and reliability. As Cortina (1993) has noted, however, the alpha score is not only a function of item intercorrelations but also to a large extent a function of the number of items in a scale and '…it must be interpreted with the number of items in mind' (p. 102). Despite the relatively small number of items per construct in the present study, the alpha scores proved satisfactory for four of the six items. For the two remaining items, efficiency demands and procedure vagueness, the alpha scores were 0.61 and 0.65, respectively. According to George and Mallery (2003), alpha scores between 0.70 and 0.60 should be considered questionable, but not poor. Hence, the internal consistency and reliability of the two constructs were

Table 4. Pearson correlation between measurement constructs (Cronbach's alpha in diagonal).

Construct	Number of items	1	2	3	4	5	6
1 Captain's safety leadership	3	(0.856)					
2 Risk	3	0.196*	(0.730)				
3 Safety training	3	0.302*	0.342*	(0.709)			
4 General safety orientation on board	3	0.413*	0.234*	0.343*	(0.712)		
5 Efficiency demands	4	−0.339*	−0.310*	−0.396*	−0.316*	(0.606)	
6 Procedure vagueness	2	−0.208*	−0.219*	−0.318*	−0.208*	0.391*	(0.653)

Note: $*p < 0.01$.

considered questionable, but were still within a tolerable limit when the number of items and the intercorrelations between the items were taken into consideration. The average item intercorrelations for efficiency demands and procedure vagueness were 0.28 and 0.49, respectively.

In order to assess the adequacy of a second-order factor solution for safety climate an EFA which included constructs 1–5 was conducted (efficiency demands items were reversed). This analysis resulted in a one-factor solution (Kaiser's criterion) with factor loadings varying from 0.59 (risk) to 0.72 (safety training). This factor had an eigenvalue of 2.28 and accounted for 45.7% of the total variance. The Cronbach's alpha between the items in this solution was 0.81. According to Milfont and Duckitt (2004), second-order factor solutions derived from EFA should be checked by confirmatory factor analysis (CFA), since the CFA provides indices of goodness of fit. This was done and the CFA supported the one-factor solution for safety climate (RMSEA = 0.053, IFI = 0.945, CFI = 0.945).

4.2. *Logistic regression*

The results from the BLR analysis are presented in Table 5. As shown in the table, the analysis was conducted in four steps (model 1 to model 4). In the first model, age was entered into the regression analysis. In the second model, job experience was entered. In the third model, the second-order factor safety climate was entered, and in the fourth model, procedure vagueness was entered. To investigate multi-collinearity, the tolerance

Table 5. Logistic regression with safety compliance as dependent variable.

Model variable	Model 1		Model 2		Model 3		Model 4	
	β	OR	β	OR	β	OR	β	OR
Constant	−1.227**	0.293	−0.384	0.681	−5.720**	0.003	−3.104*	0.045
Age	0.363**	1.438	0.498**	1.645	0.450**	1.568	0.442**	1.556
Job experience			−0.411**	0.663	−0.333*	0.717	−0.331*	0.718
Safety climate					1.269**	3.558	0.905**	2.471
Procedure vagueness							−0.447**	0.640
Nagelkerke R^2	0.057		0.086		0.189		0.234	
Hosmer & Lemeshow (sig.)	0.332		0.101		0.537		0.442	

Notes: $*p < 0.01$, $**p < 0.001$.

statistic was examined for each variable in all models. The minimum tolerance value was 0.80, which is well above the critical value of 0.20 (Field 2005). To investigate the presence of highly influential cases, Cook's distance (D_i) was examined for each case. The maximum D_j was 0.01, which is well below the cut-off value of 1 (Field 2005).

As shown in model 1, the vessel workers' age is positively and significantly related to safety compliance. Thus, the data gave support to H1. The OR of the age variable indicates that when the age variable increases by 1 (i.e. a 10-year increase in age), the odds of following procedures increases by 1.44. The constant (β_0) and the regression coefficient (β_{age}) result in a logit of –0.86 and 0.59 for the youngest and the oldest workers, respectively. By means of the antilog function, the predicted probability of reporting always following procedures among the youngest workers is estimated to be 29.7%, compared with 64.3% among the oldest workers.

Even though the Hosmer and Lemeshow test indicates that the predicted values in model 1 are not significantly different from the observed values (indicating adequate model fit), the R^2 statistics show that the model only accounts for 5.7% of the variance in safety compliance. The explained variance increases to 8.6% when the vessel workers' job experience is included in model 2. The relationship between job experience and compliance was not in the expected direction, however. That is, the β value is negative and the OR is below one. In addition, the β value is significantly different from 0. This indicates that the vessel workers' job experience is negatively related to safety compliance, the opposite of what we expected from H2.

As shown in model 3, the introduction of safety climate leads to a substantial increase in explained variance (an increase in Nagelkerke's R^2 from 8.6% to 18.9%). The model fit is still adequate and the relationship between safety climate and safety compliance is significant, positive and strong, with an OR of 3.56. This indicates that safety climate has a positive impact on safety compliance, thus supporting H3. By holding age and job experience constant (with minimum values, i.e. 1), the logit for vessel workers who perceive the safety climate as negative (i.e. safety climate = 1) is –4.33, whereas it is 0.74 for vessel workers who perceive the safety climate as positive (i.e. safety climate = 5). By means of the antilog function, the predicted probability of reporting always following procedures among the former group of workers is estimated to be 1.3%, compared with 67.7% among the latter group of workers.

The strong positive effect that safety climate exerts on safety compliance is slightly moderated in model 4, when procedure vagueness is included in the model. The effect of age and job experience is, however, not affected. As expected, the effect that procedure vagueness exerts on safety compliance is significantly negative and the OR is below 1. Thus, the analysis gives support to H4 which postulated that perceived procedure vagueness would be negatively related to safety compliance. At the same time, the explained variance has increased from 18.9% to 23.4%, and the Hosmer and Lemeshow test indicates good model fit. By holding age and job experience constant (with minimum values, i.e. 1) and safety climate constant (with maximum values, i.e. 5), the logit for vessel workers who perceive the safety procedures as vague (i.e. procedure vagueness = 5) is –0.70, whereas it is 1.09 for vessel workers who perceive the safety procedures as clear (i.e. procedure vagueness = 1). By means of the antilog function, the predicted probability of reporting always following procedures among the former group of workers is estimated to be 33.1%, compared with 74.7% among the latter group of workers.

In order to test whether the results obtained in model 4 could be caused by some underlying variables, we controlled model 4 by entering two sets of control variables in a fifth model; job title and vessel type. This resulted in an increase in explained variance (Nagelkerke's R^2 = 25.6%) and still an adequate model fit (Hosmer and Lemeshow = 0.066). None of the new variables entered contributed significantly to the model, however, and they did not moderate the effect of the variables in model 4. Hence, we concluded that the results obtained in model 4 were robust.

5. Discussion and implications

5.1. *Key findings and discussion*

This study was designed to examine the antecedents of safety-compliant behaviour among workers on offshore service vessels operating on the NCS. The principal research model of the study was multi-factorial and measured characteristics related to the individual worker, the organization and the body of procedures on the vessels.

As regards the individual worker, we focused on two demographical attributes, age and job experience, and hypothesized that both would be positively related to safety compliance. The logistic regression analysis gave support to the hypothesized positive relationship between age and safety compliance. This implies that older vessel workers are more compliant than their younger colleagues, but it should be noted that the amount of variance that age accounted for was quite small (5.7% in model 1). This finding is in line with previous findings (Lu and Yang 2011; Gyekye and Salminen 2009; Siu et al. 2003; Tesluk 2004).

The hypothesized positive impact of job experience on safety compliance was, however, not supported. In fact, the analysis demonstrated that job experience was significantly negatively related to safety compliance. This implies that vessel workers with long experience of vessel work tend to be less safety-compliant than those with less experience. This finding also implies that the positive relationship between age and safety compliance is not caused by the fact that older workers are more experienced than their younger colleagues (even though these two attributes correlate positively in the data set, $r = 0.42$). Hence, the positive relationship between the vessel workers' age and safety compliance must be caused by other factors than job experience. As suggested by Jonah and Dawson (1987) and Boyce and Geller (2002), it can be an effect of age differences in risk perception. Costa and McCrae's (1988) findings linked to age-related declines in certain personality traits, like activity and excitement seeking, is also a reasonable explanation.

The significant negative relationship between job experience and safety compliance is in line with Rebok et al. (2005) finding in the aviation sector, among pilots. Although Rebok et al. fail to offer an explanation for this finding, the work of Snook (2000) could shed light on the results related to job experience in the present study. According to Snook, factual and non-compliant work practices within organizations must be understood as a result of a practical drift, a 'slow uncoupling of local practice from written procedure' (Snook 2000, 225), where deviance from established procedures is redefined as acceptable. Snook's main point is that the initial design of the system (with its accompanying rules and procedures) often proves to be unworkable at the local level. Hence, units develop local variations that over time drift away from the original set of established rules and procedures.

Snook's purpose is to explain how and why the collective practices over time turn into routine violations as a result of practical drift. The effect of practical drift that Snook observes with regard to collective practices might also manifest itself on the individual level, however. At least, the results of the present study indicate that vessel workers with long job experience tend to drift further away from the written procedures than their less experienced colleagues.

As regards organizational characteristics, we focused on safety climate. Safety climate was measured by applying 16 items, and the EFA resulted in a reduction into five underlying safety climate dimensions; captain's safety leadership, general safety orientation on board, risk, efficiency demands, and safety training. In order to assess the adequacy of a second-order factor solution for safety climate, an EFA which included these dimensions was conducted. In line with previous research (Neal and Griffin 2004; Griffin and Neal 2000), we found support for a second-order one-factor solution for safety climate. Further, the logistic regression analysis gave support to the hypothesized positive relationship between safety climate and safety compliance. This is in line with previous review studies (Alper and Karsh 2009; Clarke 2006; Christian et al. 2009) and consistent with findings from a broad range of other industries (Cavazza and Serpe 2009; Zhou et al. 2008; Griffin and Neal 2000; Lu and Tsai 2010; Martínez-Córcoles et al. 2011). The findings are also consistent with Clarke (2006) and Zohar (2010) who assert that the safety climate acts as a frame of reference for safety-specific behaviour, and that employee behaviour will tend to align with what employees perceive as expected behaviour. The findings in the present study clearly illustrate that vessel workers who perceive safety as valued on the vessel where they work have a greater probability of reporting always working in accordance with the procedures.

When it came to the rule/procedure characteristics, we focused on procedure vagueness and hypothesized that this would be negatively related to safety compliance. The logistic regression analysis supported this. This implies that workers who perceive the procedures as vague have a lower probability of always adhering to safety procedures. This finding is in line with Alper and Karsh's (2009) review study and Laurence's (2005) study of mine workers.

5.2. *Implications of the key findings*

The empirical findings in the present study have both theoretical and managerial implications. A significant contribution of the study is the empirical testing in a maritime context of findings from previous studies of safety compliance. The empirical testing indicates that the antecedents of safety-compliant behaviour on offshore service vessels are very similar to those identified within other industries. Hence, this industry does not appear to be unique in this context. A possible exception is job experience, however, which proved to be negatively associated with safety compliance.

Another significant contribution of the study is that it points to some important aspects related to safety improvement efforts on offshore service vessels. The results of the present study demonstrate that several factors need to be addressed in order to improve the level of safety compliance.

The first factor is the individual worker. The fact that the vessel worker's age is positively related to safety compliance indicates that shipowners, captains and other stakeholders within the industry should put extra effort into training and attitude formation of young vessel workers. The negative relationship between job experience and safety compliance could indicate that parts of this training need to be formalized and extended beyond on-the-job training. The negative impact of job experience further demonstrates that safety-compliant behaviour is a quality which tends to erode with increased experience. This could indicate that work practices over time are uncoupled from written procedures, and that rule-based logics of action are gradually being replaced with skill-based logics of action. It is management's responsibility to ensure that the balance between these logics of action is within the boundaries of safe practice.

The second factor which needs to be addressed to improve the level of safety compliance is the safety climate of the vessels. In the present study vessel workers who perceived the safety climate as positive reported more frequently that they always followed the procedures. A favourable safety climate was moreover characterized by (1) positive evaluations of the captain as a role model for safety work, (2) low levels of perceived risk, (3) positive evaluations of the time and priority given to safety training, (4) a positive perception of how safety is taken care of and (5) a positive evaluation of the relative priority of safety versus efficiency. In order to improve the safety climate of the vessels in a direction which is favourable for increased safety compliance, it is important to give these areas high priority. High and visible priority of these areas signals to the crew that safety is valued within the company and aboard the individual vessel. According to Zohar (2010) this in turn signals what sort of role behaviour is expected, supported and rewarded.

The third factor of importance for improved safety compliance is related to the quality of the procedures. The findings in the present study clearly imply that creating a body of procedures is not sufficient to ensure compliance. Compliant behaviour turned out to be strongly determined by the quality and clarity of the procedures, but how can quality and clarity be ensured? There is probably no final answer to this question, but Simpson et al.'s (Simpson et al. 2009) basic principles of procedure preparation in the mining industry may well be applicable to the offshore service vessel industry. These basic principles are (1) functional simplicity, (2) tailoring, (3) use of plain, positive language and (4) piloting. The four principles might seem self-evident, but considering the fact that 37% of the vessel workers in the present study found the procedures difficult to understand, these basic principles should be very relevant.

5.3. *Limitations and future research*

The findings and the implications of the present study should be interpreted with some methodological limitations in mind. First, all data were based on self-report measures drawn from the same source and could therefore be vulnerable to both common method bias and responses biased by social desirability. It would therefore be a useful avenue for future research to replicate this study with the use of measures drawn from other sources, e.g. observations of actual work on board vessels. Second, the cross-sectional design makes it difficult to test and establish sequential relationships between the independent variables and safety compliance. Future research should therefore consider a longitudinal design in order to further validate the proposed cause and effect relationships. Third, as we described in Section 2, individual differences in safety-specific behaviour must be understood on the basis of factors that are directly related to safety behaviour: knowledge, skills and motivation, the so-called proximal drivers of safety behaviour (Neal and Griffin 2004). This study, however, focused solely on the proposed distal antecedents of safety behaviour and the direct relationship between these antecedents and safety-compliant behaviour. By omitting the proximal drivers of safety behaviour and the mediating effect that these drivers might have, we miss valuable insight into the mechanisms through which the distal antecedents affect safety compliance. Hence, future research should include measures of knowledge, skills and motivation in order to reach a more profound understanding of how the effect of distal antecedents affects the level of safety-compliant behaviour.

Despite these limitations, the study findings and the implications that we have drawn from them should be relevant and important for safety improvement efforts within the offshore service vessel industry. The findings and the implications should also have relevance for the maritime industry as a whole, where previous research has identified procedure violations as a common causal element in accidents (Macrae 2009). The multi-factorial model applied in the present study points to some important factors that should be addressed in order to deal with such violations. Further, the topics that these factors address are generic and not restricted exclusively to the offshore service vessel industry. An interesting direction for future research would therefore be to examine the explanatory power of these factors within other sub-sectors of the maritime industry and within other operational and cultural contexts.

6. Conclusion

Based on previous research within other sectors, the present study aimed to develop and test a quantitative model which measured the relationship between a set of explanatory factors and safety compliance on offshore service vessels operating on the NCS. The explanatory factors in the model included three relatively broad categories: individual characteristics, organizational characteristics and procedure/rule characteristics. Within these categories the logistic regression analysis revealed that safety compliance was related to safety climate, vessel workers' age, job experience and perceived procedure vagueness. In sum, this implies that shipowners, captains and other stakeholders within the offshore service vessel industry should consider increasing safety compliance from a broad multi-factorial perspective. Due to the fact that procedure violations are an important causal factor for maritime accidents (Macrae 2009), this should also have relevance for the maritime industry as a whole.

Notes

1. A procedure is in general a detailed guide to action, describing the steps to be followed, and in what order in a recurring situation or problem. Standard operating procedures (SOPs) are written procedures aiming at standardizing general activities (Cook 1998).
2. The corresponding author can be contacted in order to receive the complete questionnaire.
3. The relatively low percentage of respondents above 60 years old is because many offshore service vessel workers can retire at the age of 60 years and receive a maritime worker's pension.
4. All analyses were conducted with SPSS 18.0 software.

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Article #2 - Safety compliance on offshore platforms: a multi-sample survey on the role of perceived leadership involvement and work climate

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Safety compliance on offshore platforms: A multi-sample survey on the role of perceived leadership involvement and work climate

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Accident analyses and investigations regularly identify a lack of compliance with rules and procedures as a central contributing factor to workplace accidents. This underlines the importance of identifying the organizational factors that affect the level of safety compliant behavior. The purpose of the present study was to examine how workers' perception of leadership involvement in daily work operations affects the level of safety compliant behavior among workers employed on offshore platforms operating on the Norwegian Continental Shelf. The effect that leadership involvement exerts on safety compliance was measured both directly and indirectly through the intervening variable work climate. Using survey data from six different measure periods ($N = 10003$), exploratory and confirmatory factor analysis identified three dimensions of work climate; (1) workers' competence and involvement, (2) role clarity and (3) follow-up of contractors. The following SEM analyses revealed that leadership involvement in daily work operations has a significant positive influence on the level of safety compliance on offshore platforms. The effect of leadership involvement was found to be both direct and indirect, mediated by the three work climate dimensions selected for this study. Theoretical and managerial implications of the findings are discussed.

1. Introduction

Since the first exploration well was drilled on the Norwegian Continental Shelf (NCS) in 1966, both the authorities and the oil and gas industry have been repeatedly reminded of the high risks involved in offshore petroleum activity. After more than 40 years of production, occupational and major accidents on the shelf have caused the death of 268 offshore workers (Petroleum Safety Authority Norway [PSA], 2011c). The risk level has gradually reduced in the industry over the last years (Kongsvik et al., 2012), but accidents still happen and there is a continuous need for improvement.

Although the standard of the technical equipment on the offshore installations is definitely a critical aspect of safety and accident causation, it is also recognized that the safety level within such complex work systems is highly dependent on human behavior (Adie et al., 2005; Gordon et al., 1996; Johnson, 2007). Hence, the oil and gas industry is now increasing its efforts in developing human risk management systems which aim at enhancing safety behavior (Didla et al., 2009). According to Neal et al. (2000, p. 101), safety behavior consists of two different behavioral dimensions: safety participation and safety compliance. Whereas safety participation refers to voluntary work which aims at supporting and promoting safety in the organization, safety compliance "involves adhering to safety procedures and carrying out work in a safe manner". Human risk management systems within the offshore oil and gas industry pay considerable attention to safety compliance. This is due to the fact that virtually all work operations within this industry are regulated by rules and procedures, and because investigations of offshore accidents repeatedly identify lack of compliance with the regulations as a central contributing factor (e.g., PSA, 2005, 2007, 2011b). This finding is, however, not restricted to offshore accidents, but is a recurring conclusion in accident investigations in general (Hopkins, 2011).

The well-recognized importance of safety compliance as a barrier against workplace accidents has sparked off a considerable amount of research with the aim of identifying the antecedents of non-compliant behavior (e.g., Krause et al., 1999; Lu and Yang, 2010; Matilla et al., 1994; Mearns et al., 2010; Neal et al., 2000; Zohar, 2002; Zohar and Luria, 2003). A common research topic within these studies is that of leadership. Two relatively different, but still complementary perspectives can be identified in leadership studies (Hofmann and Morgeson, 2004). One of them links safety compliance to the safety-specific dimensions of leadership such as monitoring, correction, and reward for safe behavior (e.g. Kapp, 2012; Zohar, 2002). The other focuses more on the general dimensions of leadership

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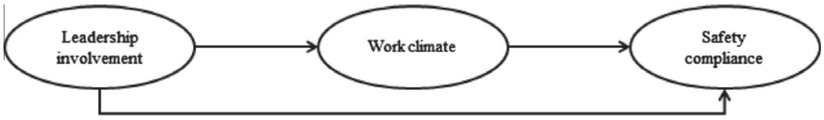

Fig. 1. The principal research model of the present study.

behavior, such as trust, cooperation, and involvement, and how such dimensions are related to safety compliance (e.g. Matilla et al., 1994; O'Dea and Flin, 2001). The vast majority of the leadership studies apply a safety-specific perspective, while considerably less research is undertaken from a more general leadership perspective (Matilla et al., 1994). However, according to Hofmann and Morgeson (2004, p. 170), "it is important, when either reviewing or investigating the relationship between leadership and safety, to move beyond the safety-specific literature to consider the broader leadership literature. This is important because it may yield additional insight into how leadership can impact safety." The present study seeks to explore this relatively untapped area of leadership research. The focus is on leadership's involvement in work operations, which is understood as workers' perceptions of the degree to which leaders participate in the planning and preparation of work, follow up the execution of the work, and contribute to good cooperation among team members, and the significance of such involvement for safety compliance.

In addition to examining the direct relationship between leadership involvement and workers' safety compliance, the present study aims to explicate this relationship by examining the role such involvement plays in establishing a work climate that is favorable to safety compliance. A number of studies have linked safety compliance to both leadership and work climate characteristics such as workers' perceptions of communication, roles, and influence (e.g., DeJoy et al., 2004; Larsson et al., 2008; Matilla et al., 1994), but little research has been done to examine the relationship between these variables (Thompson et al., 1998). The question that is addressed in the present study is therefore how leadership involvement in work operations on offshore platforms directly influences safety compliance, and also how it influences safety compliance indirectly through the work climate. The principal research model is presented in Fig. 1, but it will be further extended by hypotheses which are considered in the following sections of this paper.

This study is based on a multi-sample survey of employees working for a Norwegian oil company on 28 different offshore installations on the NCS. The survey aimed to map the offshore workers' perceptions of their leaders' behavior, the perceived climate of their work group, and the level of safety compliance. The survey was administered six times in the same study population. The advantage of such a study design is that it allows for repeated testing of both the factorial structure and the hypothesized relationships, thus increasing the validity of the study.

1.1. Theoretical background and research hypotheses

Studies which stress the safety-specific dimensions of leadership all indicate that leaders who emphasize, discuss, reward, monitor, and encourage safe performance generate safer performance within their work group (Hofmann and Morgeson, 2004). Within these studies the safety-specific variants of Bass's (1985) concepts of transactional and transformational leadership styles have stimulated great research interest. Safety-specific transactional leadership is characterized by the establishment of appropriate safety goals, by monitoring workers' performance in relation to those goals, and by rewarding or correcting behavior which sustains or improves safety performance (Kapp, 2012; Zohar, 2002). Safety-specific transformational leadership is characterized by leaders who challenge workers to achieve exceptional safety standards, who display concern for the safety and well-being of employees, who challenge the workers to develop improved practices for solving safety-related problems, and who stand out as role models for their staff by working in a safe way themselves (Kapp, 2012; Mullen and Kelloway, 2009).

Both safety-specific transactional and safety-specific transformational leadership styles have been proven to be positively related to workers' safety compliance (Kapp, 2012; Krause et al., 1999; Mullen and Kelloway, 2009; Zohar, 2002; Zohar and Luria, 2003). Studies of offshore platforms also indicate that this is the case in these high risk settings. Mearns and Reader's (2008) study of UK offshore workers is an example of this. In their study they found support for a positive relationship between supervisors' concern for the safety and well-being of employees, and the level of safety behavior of the employees. Further, Bryden's (2002) analysis of a safety behavior program, implemented in an operator company on the UK continental shelf, demonstrated that safety specific transformational leadership is a key element in enhancing safety compliance. Consistent with these findings, Zohar (2002, 2010) recommended that studies of leadership and safety should choose a safety-specific leadership perspective as opposed to a general leadership perspective. Zohar's argument is that safety often conflicts with other aspects of performance and that safe behavior under such conditions will only emerge if safety is given high priority relative to these.

Zohar's argument is plausible, but studies that have investigated the relationship between a broader set of leader actions and safety compliance suggest that good safety management extends beyond the clearly safety-specific characteristics of leadership. Matilla et al.'s (1994) study of safety compliance within the building construction industry is an example of this. The results of their study indicated that supervisors who give feedback on performance, monitor performance, spend time communicating with workers about non-work related topics, and display a participatory style of leadership are the most effective supervisors with respect to both safety compliance and financial performance.

In line with these findings, O'Dea and Flin (2001) argue, in a study of leadership in the offshore oil and gas industry, that good safety leadership is not restricted exclusively to the safety-specific dimensions of leadership. The qualities of good safety leadership which they emphasize can be subsumed under the term "participative management." In addition to high involvement in safety initiatives, a critical activity in participative management is leadership involvement in work operations and frequent communication between workers and leaders (O'Dea and Flin, 2001). Empirical support for this view can be found in an early review of research into successful occupational safety programs, conducted by Cohen (1977). Cohen's study revealed that frequent interaction and daily contact between supervisors and line workers has a positive effect on safety improvement efforts. In a follow-up study which evaluated and compared low versus high accident companies, similar conclusions were drawn (Smith et al., 1978): leaders in companies with low accident rates were more actively involved in supervising, planning, and monitoring the work processes in general; that is to say, they spent more time at the front end of the work operations. A recent study by Yagil and Luria (2010) of 11 manufacturing organizations gives support to Cohen

(1977) and Smith et al.'s (1978) conclusions. This study found that the frequency of interactions and the quality of communication between leaders and subordinates has a direct effect on safety compliance. Similar findings are reported by Simard and Marchand (1997), who found that a cooperative and participative supervisor–employee relationship is among the most important variables for safety compliance. A study by Fleming et al. (1996) of offshore supervisors' role in safety management points in the same direction. The most effective supervisors in their study, with respect to safety, displayed a participative style of management where they discussed jobs with their work group and actively participated in the planning and preparation of work tasks.

The topic which seems to emerge from all of the studies that highlight the broader dimensions of leader behavior is the importance of supervisors who are close to the front end of the work operations and have a cooperative and participative relationship with their subordinates and the work that they perform. This can be referred to as *leadership involvement*. The significance of high leadership involvement in work operations does not only emerge in empirical studies of safety and safety compliance, but it can also be identified in investigations of accidents on offshore platforms on the NCS (e.g., PSA, 2005, 2007, 2011b). An example of this is an accident on a production platform in 2005, where the bottom-hole string was unintentionally loosened from the elevator collar and fell towards the drill floor, seriously injuring the derrickman. The PSA's investigation report concluded that a lack of compliance with procedures was the result of insufficient leadership involvement in the work operations on the drill floor. The supervisors were not taking an active part in the work process, and were thus not aware of the fact that the drill operations were in breach of the relevant procedures (PSA, 2005).

The PSA report indicated that a high level of leadership involvement is important because it enables leaders to reveal unsafe work practices. This effect of leadership involvement is also emphasized in Weick and Sutcliffe's, 2007 literature on high reliability organizations (HROs). According to them, leadership involvement, in terms of demonstrating an ongoing attention to operations and spending time at the front end of the operations, is of significant importance for safety because it "creates a context where surprises are more likely to be surfaced and corrected before they grow into problems" (p. 155). A supplementary effect of high leadership involvement that is emphasized in O'Dea and Flin's (2001, p. 53) study of leadership in the offshore oil and gas industry is that it enables "good interpersonal relationships with subordinates, relationships which are characterized by trust, openness and honesty." Such relationships, they argue, are favorable to safety discussions and getting workers to accept ownership of safety. Consistent with these presumed effects, the present study hypothesized that:

H1. Leadership involvement will positively influence safety compliance.

In addition to the direct effect hypothesized in H1, previous studies of both safety-specific leadership and general leader behavior have indicated that the effect of leadership is indirect as well as direct, and that leadership interventions serve to change behavior via a change in the safety climate of the work group within which worker behaviors occur (Griffin and Neal, 2000; Zohar, 2010). For example, Hofmann et al. (2003) have found that high-quality social exchanges between leaders and employees (known as leader member exchange, or LMX) is positively correlated to safety climate, and that constructive LMX relationships are significantly related to safety behavior when the safety climate is positive. Thus Hofmann et al. conclude that "front-line leaders, and the climates they help create within their work groups, can have a significant impact on the safety performance of their subordinates" (p. 176).

Hofmann et al.'s findings indicate that in order to reach high safety performance, leaders need to have collaborative working relationships with their staff and to create a positive safety climate. Safety climate can be defined as the set of perceptions that employees share regarding safety in their workplace (Zohar, 1980), and is regarded as a significant frame of reference for the safety-specific behavior and attitudes of both individuals and groups of employees (Clarke, 2006). The positive link between safety climate and safety compliance is well documented in previous research (Cavazza and Serpe, 2009; Griffin and Neal, 2000; Lu and Tsai, 2010; Martínez-Córcoles et al., 2011; Zhou et al., 2008). However, studies which have explored the relationship between safety compliance and a broader set of organizational climate perceptions which extend beyond mere safety perceptions, have indicated that such climate characteristics are important as well (DeJoy et al., 2004; Larsson et al., 2008; Parker et al., 2001). For example, Larsson et al.'s (2008) study of construction workers found that climate characteristics, such as clearly defined job descriptions, feedback on work performance, and influence over one's own work, have a significant influence on safety compliance. Hence, Larsson et al. concluded that broad climate factors which extend beyond safety climate constitute important conditions for safety compliance.

In the present study these broader climate characteristics are referred to as *work climate* perceptions. Work climate perceptions are typically related to some general dimensions of the work unit environment such as role clarity, teamwork, and commitment (Anderson and West, 1998; Stringer, 2002), and not to the clearly safety-specific dimensions which are typical of safety climate perceptions (Flin et al., 2000). Further, it is well documented that leadership is of significant importance in the formation and development of the work climate (Koene et al., 2002; Litwin and Stringer, 1968). For example, Stringer (2002) has found that leadership can explain up to 67% of the total variance in the work climate. This makes leadership the single most important antecedent of climate.

According to Tharaldsen et al. (2011), the broad climate characteristics which are considered important in investigations into accidents on offshore petroleum platforms are (1) workers' competence and involvement, (2) role clarity, and (3) follow-up of contractors. Based on research which has found that leadership practices are the most important variable for the prediction of variance in work climate (Stringer, 2002), we can expect that leadership involvement will positively influence these three climate characteristics. The three climate characteristics were therefore examined as possible mediator variables between leadership involvement and safety compliance for the present study. The expected significance of the three climate characteristics as mediator variables between leadership involvement and safety compliance is clarified in more detail in the following discussion.

The first climate characteristic, *competence and involvement*, and its positive link to safety compliance, is highly supported in the empirical literature. Competence and involvement is usually examined in terms of safety-specific training and workers' involvement in the development of safety policies (Griffin and Neal, 2000; Lu and Yang, 2011; Mohamed, 2002). Although important, safety-specific competence and involvement is seldom sufficient for safe operating practices (Cooper, 2001). As Barling et al. (2003) have stressed, safe performance is also highly dependent on general involvement and training that extends beyond the specific confines of safety training. According to Barling et al., increased involvement promotes learning and enables proactive problem-solving and preventive action. Moreover, they argue that competence in general work skills is required for all aspects of a job, including safety. This might be particularly evident within highly complex technical systems such as offshore platforms, where several accident investigations have identified a lack of specific work skills

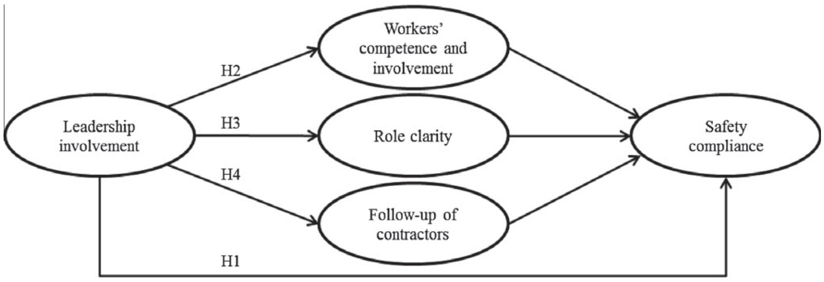

Fig. 2. The hypothetical model of the present study with letters referring to the specified hypotheses.

and competence as underlying contributors to non-compliant actions (e.g., PSA, 2007, 2009a, 2011a). Lack of competence has also been identified as one of the most important underlying causes of the Montara blowout (Hayes, 2012). However, according to Hayes, the lack of competence alone cannot explain the blowout or the unsafe actions carried out by the drilling personnel prior to the blowout. His analysis suggests that active and hands-on supervision of the offshore activities should have revealed whether the personnel had the appropriate competencies and were operating in accordance with standards and procedures. Thus, Hayes draws a line between competence and safety compliance, and also between leadership involvement and competence. Consistent with this, the present study hypothesized that:

H2. Leadership involvement will positively influence safety compliance by means of increased workers' competence and involvement.

The second climate characteristic, *role clarity*, is also highlighted in Hayes' analysis of the Montara blowout, where ambiguity in the roles and responsibilities of senior managers led to several flawed decisions which contributed to the blowout. Whereas Hayes deals with the significance of role clarity and ambiguity at the supervisor level, other investigations of offshore accidents have found this to be of critical importance for compliant behavior at the subordinate level as well (e.g., PSA, 2007, 2009b, 2010). Empirical research points in the same direction. Sneddon et al.'s (2006) study of safety and situational awareness within the offshore oil and gas industry is an example of this. In their study, role ambiguity was seen as a potential source of occupational stress, and such stress was negatively related to safety compliance. Sneddon et al. suggested that the negative relationship between occupational stress and safety compliance is mediated by reduced attention or awareness, such that occupational stress leads to decreased situational awareness and ultimately to short-cuts and rule breaking. The results of Hemingway and Smith's (1999) study of organizational climate in the nursing profession is another example. By applying a six-item role ambiguity scale, which assessed perceived clarity/ambiguity regarding job responsibilities, they found that nurses who experienced high degrees of role ambiguity were more likely to incur a reportable injury at work when compared to nurses who experienced lower degrees of role ambiguity. In addition, they found that role ambiguity was negatively related to support from supervisors. In line with these findings, the present study hypothesized that:

H3. Leadership involvement will positively influence safety compliance by means of increased role clarity.

The third climate characteristic, *follow-up of contractors*, might be particularly important for safe behavior within the Norwegian oil and gas industry, where almost 70% of all offshore personnel are employed by contractors (PSA, 2006). Typically, the contractor workers are involved in some of the most accident-prone work processes, such as drilling, repair work, maintenance, and lifting operations. It is also well documented that contractor workers on the NCS experience occupational injury accidents more frequently than operator workers (Norwegian Government, 2011). Contractors are typically hired on contracts of a limited duration. This means that employees working for a contractor company perform their work under framework conditions similar to so-called contingent workers. In a review study of contingent work, Clarke (2003) found empirical support for the hypothesis that contingent workers have less positive safety attitudes and engage in fewer safety behaviors than core workers. This should imply that the active follow-up of contractors is important for safety compliance, an assumption which is supported in Mearns et al. (2003) study of safety management practices in offshore environments. This concluded that effective operator–contractor coordination is associated with lower incident rates. Consistent with this, the present study hypothesized that:

H4. Leadership involvement will positively influence safety compliance by means of increased follow-up of contractors.

In summary, the four hypotheses of the present study suggest that leadership involvement has both a direct and an indirect influence on safety compliance. This is illustrated graphically in Fig. 2, which is an extended version of the principal research model (Fig. 1).

2. Methodology

2.1. Survey and participants

The present study was based on a survey which was administered as an anonymous self-report questionnaire to monitor effectiveness and safety during the merger process of two Norwegian petroleum companies. A research group consisting of safety advisers and scientists with psychometric competence was established to develop the questionnaire. A review of available survey instruments was also explored in the literature, but none of these fitted the multifaceted needs specified in the project. Thus a new questionnaire was developed and applied. The new instrument was named the *Leadership and Compliance Tool* (LCT). The questionnaire was distributed via e-mail to both onshore and offshore workers, but onshore workers were excluded from our analysis.

All respondents in the study were employed by the operator company; hence contractors were not included in the study. The survey was administered six times in the same study population in the period between January 2009 and October 2010. The target population in each response period incorporated 50% of all offshore workers on 28 different platforms in the integrated company (everyone who was offshore during the response period). This

Table 1
Response rates, demographics and N for all response periods.

Response period		January 2009 (TI) (%)	May 2009 (T2) (%)	October 2009 (T3) (%)	January 2010 (T4) (%)	May 2010 (T5) (%)	October 2010 (T6) (%)	Total (T1–T6) (%)
Response rate		65	55	75	52	62	86	65
Gender (male)		87	85	91	85	85	90	88
Ages	<26	3.2	2.6	1.4	4.1	4.7	1.3	2.7
	26–35	8.1	9.0	8.5	9.3	8.8	9.4	8.9
	36–45	29.5	31.6	31.9	32.2	32.9	31.7	31.7
	46–57	46.6	47.2	49.3	47.7	46.2	49.0	47.9
	>57	12.6	9.5	8.9	6.7	7.4	8.6	8.8
N		1330	1438	2 063	1788	1316	2 068	10 003

means that some of the respondents participated in the survey several times. The response rates, shown in Table 1, varied between 52% (T4) and 86% (T6). The relatively large response rates at T3 and T6 are due to the fact that the response deadline for these periods was six weeks, while it was only 10 days for the other response periods. The total response rate for all six response periods was 65%. This resulted in a total sample size of 10,003 respondents. The number of respondents on each installation varied between 21 and 138, which reflects the fact that the installations vary considerably in size.

The gender distribution in the total net sample (T1–T6) shows that 88% of the respondents were men. This is representative of the gender distribution on the NCS as a whole where approximately 90% of the offshore workers are men (PSA, 2012). As regards age, 56.7% of the respondents were above 45 years, 31.7% were between 36 and 45 years, and 11.6% were below 36 years.

2.2. Measures and statistical procedures

In the survey the respondents were asked to assess their agreement with 39 statements concerning local workplace factors. The level of agreement was assessed on a six-point scale. The scale ranged from *strongly disagree* (1) to *strongly agree* (6). A *not relevant* option was included, but it was not possible to make neutral agreements such as *neither agree nor disagree*. Thus, the applied scale was a so-called forced choice scale.

Sixteen of the 39 items were used to measure leadership involvement, workers' competence and involvement, role clarity, follow-up of contractors, and safety compliance. In order to uncover the underlying factor structure of the items and to reduce the number of items to a manageable size, exploratory factor analysis (EFA) was conducted in the T1 sample. The applied EFA was principal component analysis with varimax rotation. Missing values were replaced with mean scores (an average of 3.0% of missing values on each item). The number of factors to extract was based on Kaiser's criterion (Field, 2009). This means that only factors with eigenvalues greater than or equal to 1 were retained. Internal consistency and reliability were assessed by Cronbach's alpha (Cronbach, 1951). Discriminant validity was assessed by investigating intercorrelations (Pearson's r) between constructs (Pearson, 1896). Factor loadings above .40 were considered sufficient to relate the item to the factor (Meyers et al., 2006). The EFA and its accompanying analyses were conducted using SPSS 18.0.

To evaluate the replicability of the factor structure generated by the EFA, five separate confirmatory factor analyses (CFA) were conducted for samples T2–T6. Since the chi-square value is directly related to sample size and therefore tends to reject models as the sample size increases (Meyers et al., 2006), four other fit indices were examined: RMSEA (root mean square error approximation), NFI (normed fit index), IFI (incremental fit index) and CFI (comparative fit index). The RMSEA was interpreted as follows: values less than .08 indicate good fit; values between .08 and .10 indicate moderate fit; and values greater than .10 indicate poor fit. The three other fit indices were interpreted as follows: values above or equal to .95 indicate good fit; values between .90 and .95 indicate acceptable fit; and values below .90 indicate poor fit (see Meyers et al., 2006).

In order to test the hypotheses included in our research model, structural equation modeling (SEM) was conducted separately for T1–T6 and for the total sample. SEM was preferred since this statistical technique allows the assessment of both direct and indirect effects (Meyers et al., 2006). The model comprised the latent variables which were uncovered in the EFA and tested in the CFA. Maximum likelihood was used to estimate the model's path coefficients. Each path coefficient was then examined to assess significance, effect, and whether or not it showed the expected sign. RMSEA, NFI, IFI, and CFI were examined to assess model fit. The fit indices were interpreted under the same guiding rules as the CFA. Both the CFAs and the structural model assessments were conducted using AMOS 18.0.

3. Results

3.1. Exploratory factor analysis

3.1.1. Factor extraction and factor labeling

The initial considerations and analysis of the T1 sample verified that the data and the included variables were appropriate for factor analysis. Sixteen variables were included in the analysis and the sample size was $N = 1330$. Hence, the common requirement of at least 10–15 respondents per variable was fulfilled (Field, 2009). In addition, Bartlett's test of sphericity and Kaiser–Meyer–Olkin's measure of sampling adequacy showed satisfactory results (see notes to Table 2).

The application of Kaiser's criterion resulted in a five-factor solution, presented in Table 2. This solution accounted for 74% of the total variance. From Table 2 it is clear that all of the 16 variables have sufficient loadings (above .40) on a factor to be retained in the final factor solution. Simultaneously, no variables have loadings above .40 on more than one factor, indicating a simple factor structure. The five factors were labeled as follows:

Factor 1 – leadership involvement. This factor consists of three items concerning workers' perceptions of the degree to which their leader participates in planning and preparing the work, follows up the execution of the work, and contributes to good cooperation. This factor accounted for 41.7% of the total variance. The factor loadings varied from .77 to .88.

Factor 2 – workers' competence and involvement. This factor consists of three items concerning workers' perceptions of the degree to which they are involved in decisions, able to utilize their expertise, and they have received necessary training. This factor accounted

Table 2
Exploratory factor analysis: PCA, Varimax with Kaiser normalization (Tl).

Items	Factor loadings					
	1	2	3	4	5	Communalities
Ql My leader participates actively in planning and preparing the work	**.88**	.11	.18	.16	.14	.86
Q2 My leader systematically follows up the execution of the work	**.87**	.13	.17	.19	.20	.88
Q3 My leader contributes to a good cooperation between units /involved groups	**.77**	.24	.15	.16	.19	.73
Q4 1 am sufficiently involved in/have a say on decisions related to my work situation	.17	**.78**	.16	.14	.12	.70
Q5 1 am able to utilize my expertise and abilities in my present position	.10	**.81**	.08	.10	.11	.70
Q6 1 receive the necessary training to handle new work tasks and responsibilities	.14	**.69**	.25	.16	.14	.61
Q7 The responsibilities of my position are unambiguously documented	.18	.14	**.87**	.12	.17	.86
Q8 The authority of my position is unambiguously documented	.20	.15	**.87**	.09	.17	.86
Q9 The ski II requirements for my present position are clearly documented	.12	.24	**.68**	.22	.20	.62
Q10 In my unit we closely follow up suppliers/contractors we work with	.16	.13	.11	**.83**	.23	.79
Qll In my unit we systematically follow up the feedback we receive from suppliers/contractors	.18	.16	.15	**.79**	.26	.77
Q12 The suppliers/contractors we work with have received the training they need to carry out their tasks in a safe manner	17	15	17	**.70**	25	64
Q13 If we are uncertain about the execution of risk-exposed tasks, we always execute a "safejob analysis" (SJA)	.08	.10	.08	.14	**.76**	.62
Q14 In my unit we live by governing documentation	.15	.12	.16	.25	**.81**	.78
Q15 In my unit we handle non-conformities in conformity with governing documentation	.19	.13	.19	.25	**.76**	.72
Q16 In my unit we systematical ly use governing documentation in planning, preparation and execution of the work	20	12	19	18	**.75**	68
Mean	4.30	4.57	4.51	4.42	4.77	
Standard deviation	1.00	.87	.93	.80	.71	
Eigenvalues	6.68	1.59	1.34	1.22	1.00	
Extraction sums of squared loadings (% of variance)	41.74	9.95	8.36	7.63	6.26	(Total = 73.96)

Bartlett's test of sphericity (approx. chi-square) = 100048 ($p < .001$). Kaiser–Meyer–Olkin measure of sampling adequacy = .89.

for 10.0% of the total variance. The factor loadings varied from .69 to .81.

Factor 3 – role clarity. This factor consists of three items concerning workers' perceptions of the degree to which responsibilities, authority, and skill requirements are unambiguously or clearly documented. This factor accounted for 8.4% of the total variance. The factor loadings varied from .68 to .87.

Factor 4 – follow-up of contractors. This factor consists of three items concerning workers' perceptions of the degree to which contractors are followed up, their feedback is followed up, and they have received necessary training. This factor accounted for 7.6% of the total variance. The factor loadings varied from .70 to .83.

Factor 5 – safety compliance. This factor consists of four items concerning the degree to which safe job analysis is performed before risk-exposed tasks are executed, the degree to which the unit lives by governing documentation, the degree to which non-conformities are handled in conformity with governing documentation, and the degree to which governing documentation is systematically used in the planning, preparation, and execution of the work. This factor accounted for 6.3% of the total variance. The factor loadings varied from .75 to .81. Since most work on offshore installations is performed by teams or units, it was found to be not particularly relevant to the present statements of the respondents that were related to individual safety compliance. A safe job analysis, for example, is and should never be performed by a single worker.[1]

3.1.2. Discriminant validity, internal consistency, and reliability

Intercorrelations between the measurement constructs and Cronbach's alphas within the constructs are presented in Table 3. Measures that correlate too highly with measures from which they are supposed to differ can be considered to show low discriminant validity (Netemeyer et al., 2003). In Table 3 all correlations are moderate. This indicates that the five constructs measure different underlying factors, hence the discriminant validity can be considered to be acceptable.

Alpha scores greater than .70 are indications of adequate internal consistency and reliability (Nunnally, 1978). The alpha scores (diagonal in Table 3) for the five constructs in the T1 sample range from .75 to .89. Hence internal consistency and reliability should be considered adequate.

Table 3
Pearson correlation between measurement constructs, with Cronbach's alpha in diagonal (Tl).

Construct	Number of items	1	2	3	4	5
1. Leadership involvement	3	(.89)				
2. Competence and involv.	3	.42	(.75)			
3. Role clarity	3	.46	.46	(.85)		
4. Follow-up of contractors	3	.47	.42	.43	(.82)	
5. Safety compliance	4	.46	.38	.46	.58	(.85)

All correlations are significant at the $p < .01$ level.

Table 4
Confirmatory factor analysis: maximum likelihood extraction.

Fit indices	T2	T3	T4	T5	T6
RMSEA	.060	.051	.066	.052	.053
NFI	.962	.972	.958	.971	.976
IFI	.968	.977	.963	.977	.979
CFI	.968	.976	.962	.977	.979
X^2	573.19*	594.21*	823.24*	434.28*	635.64*
N	1438	2063	1788	1316	2068

Note: All regression weights between items and constructs are significant at the $p < .001$ level in all measurement periods.
* $p < .001$ (df = 94).

[1] A safe job analysis (SJA) is a safety management/risk assessment tool used prior to the execution of hazardous activities and/or activities which not are covered by existing procedures. All personnel involved in the particular activity shall participate in reviewing the SJA (NORSOK Standard S-012, 2002).

Table 5
Structural equation modeling: maximum likelihood extraction.

Hypothesis and fit indices	Tl	T2	T3	T4	T5	T6	T1–T6
(HI) Lead involv. → compliance	.100*	.148***	.175***	.201***	.070	.109**	.141***
(H2) Lead involv. → competence and involv.	.511***	.577***	.723***	.667***	.776***	.703***	.681***
(H2) Competence and involv. → compliance	.094**	.107***	.132***	.092**	.225***	.152***	.132***
(H3) Lead involv. → role clarity	.495***	.530***	.616***	.594***	.591***	.626***	.592***
(H3) Role clarity → compliance	194***	.206***	.158***	.245***	.202***	.241**	.210***
(H4) Lead involv. → follow-up contractors	.555***	.622***	.637***	.609***	.655***	.640***	.630***
(H4) Follow up contractors → compliance	.511***	.429***	.482***	409***	.457***	.459***	.458***
RMSEA	.066	.074	.070	.081	.077	.076	.072
NFI	.944	.943	.950	.937	.943	.952	.953
IFI	.952	.949	.955	.942	.950	.956	.954
CFI	.952	.949	.954	.942	.949	.956	.954
X^2 (df = 97)	651.86***	864.39***	1064.11***	1226.26***	845.64***	1257.33***	5120.63***
N	1330	1438	2063	1788	1316	2068	10003

* $p < .05$.
** $p < .01$.
*** $p < .001$.

3.2. Confirmatory factor analysis

The CFA with the use of maximum likelihood extraction confirmed that the same factor structure that the EFA uncovered could be replicated in the five succeeding samples. Hence, it was concluded that the measurement model was stable across different time periods. All RMSEA values were within the range of good fit, varying from .051 (T3) to .066 (T4). The NFI, IFI, and CFI values were above .95 in all measurement periods, indicating good fit (Table 4). Further, all regression weights between items and constructs were positive and significant at the $p < .001$ level in all measurement periods.

3.3. Test of the hypothetical model

After having established and confirmed a measurement model (factor structure) with good fit, structural equation modeling (SEM) was conducted to test the hypotheses. The results of the tests of the model are presented in Table 5.

As shown in Table 5, all fit indices were within the range of good fit for the total sample (T1–T6). Further, the RMSEA values for each measurement period were within the range of good fit, except at T4 (RMSEA = .081). The NFI values were above or equal to .95 at T3 and T6, and within the range of acceptable fit for the other periods. The IFI values indicated a slightly better fit with values above or equal to .95 at T1, T3, T5, and T6, and within the range of acceptable fit at T2 and T4. The CFI values were above .95 at T1, T3, and T6, and within the range of acceptable fit in the other periods. In sum, this should indicate that the full model displays adequate fit across different time periods.

The hypotheses in the model appear in the horizontal rows in Table 5. In the SEM analyses the hypotheses were tested seven times, one test for each measurement period and one test for the total sample (T1–T6). The data points in Table 5 are standardized beta coefficients (β values), and significant coefficients ($p < .05$ or better) indicate support for the corresponding hypothesis. A β value of, for example, .50 means that when the independent variable increases or decreases with one standard deviation, the dependent variable increases or decreases with .50 standard deviations.

As shown in Table 5, leadership involvement affected safety compliance positively and significantly in all measurement periods, except at T5. Thus, the data gave support to H1, but with some limitations. Further, the significant β values varied from .10 to .20. This indicates that leadership involvement has only a moderate direct effect on safety compliance. For the full sample (T1–T6) the direct effect was .14.

The test of H2, which hypothesized an indirect effect of leadership involvement by means of workers' competence and involvement, demonstrated (1) a positive effect of leadership involvement on workers' competence and involvement, and (2) a positive effect of workers' competence and involvement on safety compliance. Both paths were significant in all measurement periods; thus, the tests supported H2. The β values in H2's first path varied between .51 and .78, with an average of .68. The β values in H2's second path varied between .09 and .23, with an average of .13. This implies that the indirect effect of leadership involvement through workers' competence and involvement was moderate. In the total sample the indirect effect was .09 (.68 × .13).

The test of H3, which hypothesized an indirect effect of leadership involvement by means of increased role clarity, demonstrated (1) a positive effect of leadership involvement on role clarity, and (2) a positive effect of role clarity on safety compliance. Both paths were significant in all measurement periods; thus, the tests supported H3. The β values in H3's first path varied between .50 and .63, with an average of .59. The β values in H3's second path varied between .16 and .25, with an average of .21. This implies that the indirect effect of leadership involvement through role clarity was also moderate. In the total sample the indirect effect was .12 (.59 × .21).

The test of H4, which hypothesized an indirect effect of leadership involvement by means of increased follow-up of contractors, demonstrated (1) a positive effect of leadership involvement on follow-up of contractors, and (2) a positive effect of follow-up of contractors on safety compliance. Both paths were significant in all measurement periods; thus, the tests supported H4. The β values in H4's first path varied between .56 and .66, with an average of .63. The β values in H4's second path varied between .41 and .51, with an average of .46. This implies that the indirect effect of leadership involvement through follow-up of contractors was strong. In the total sample the indirect effect was .29 (.63 × .46).

The total effect of leadership involvement (for the full sample T1–T6), which includes the sum of the direct effect (.14) and the indirect effects (.09+.12+.29 = .50), was .64.

4. Discussion and conclusion

It has long been realized that leadership practices exert a powerful influence on workers' propensity to act in accordance with safety rules and procedures (e.g., Lu and Yang, 2010; Matilla et al., 1994; Zohar, 2002). Most of the research that forms the basis for this realization has focused on the clearly safety-specific dimensions of leadership such as leaders' reward practices and corrective measures (e.g., Zohar, 2002), their role-modeling behavior, their ability to challenge workers to develop improved practices for solving safety-related problems (e.g., Mullen and Kelloway, 2009), etc. The fact that empirical research has confirmed this relationship is important, and it demonstrates that leaders who place a high priority on safety achieve greater levels of safety compliance from their subordinates than do leaders who place a low priority on safety. However, in order to gain supplementary insight into how leadership can have an influence on safety, it is important to broaden the scope and investigate how the more general dimensions of leadership practices can influence safety compliance (Hofmann and Morgeson, 2004). In the present study this was done by examining how leadership involvement in subordinates' work influences safety compliance on offshore platforms, both directly and indirectly through the work climate.

Leadership involvement and work climate were measured by applying 12 items which mapped workers' perceptions of these conditions. The EFA process resulted in a reduction of these into four underlying dimensions: leadership involvement, workers' competence and involvement, role clarity, and the follow-up of contractors. In addition, the EFA identified safety compliance as a separate dimension (four items). The CFA's conducted on the subsequent five measurement periods showed that this factor structure was stable across different time periods.

The results of the empirical analyses demonstrated that leadership involvement has a significantly positive influence on the level of safety compliance. This implies that the degree to which leaders participate in the planning and preparation of work, follow up the execution of the work, and contribute to good cooperation among team members has a positive effect on safety compliance. The direct effect was, however, moderate and not significant in the fifth measure period. The degree of leadership involvement seemed to have a more powerful indirect effect, by affecting the three work climate dimensions selected for this study. In turn, these three dimensions had a significant influence on safety compliance. Among these three, the degree to which contractors are followed up by the operator company had the most powerful influence, followed by role clarity, and workers' competence and involvement. In sum, the findings indicate that leadership involvement in subordinates' work operations is of vital importance for the level of safety compliance on offshore platforms, and that the work climate (as operationalized in the present study) has a significant mediating effect on the relationship between leadership involvement and safety compliance. These results draw attention to the importance of offshore leaders as providers of a climate which fosters a high level of safety compliance.

4.1. Limitations, future research and implications

The findings of the present study should be interpreted with some methodological limitations in mind. First, all measures were self-reported and drawn from the same source, thus the results could be vulnerable to common method bias. It would therefore be valuable if future research could replicate this study with the use of measures drawn from other sources, for example, by letting leaders report on their subordinates' safety compliance and/or observing actual work or leaders' behavior as it is performed. Second, the cross-sectional multi-sample design makes the sequential relationships between the independent variable, the mediator variables, and the dependent variable difficult to validate fully. Future research should consider an alternative study design to validate further the proposed cause and effect relationships. Third, the study did not differentiate between different leadership levels. Hence, we do not know the hierarchical position of the leaders, who were evaluated by the respondents. The findings of the present study would have been strengthened if the design of the study had made it possible to differentiate between different leadership levels, especially when one considers that previous research has indicated that different leadership behaviors are effective in safety depending on the hierarchical position of the leader (Flin and Yule, 2004). Fourth, the work climate factor structure is made up of items which differ with respect to which level of the work group they refer to. Some items refer to the individual worker, while others refer to perceptions of the work unit. The use of such mixed-level statements represents a potential threat to the conceptual validity of the term *work climate*.

Despite these limitations, the empirical findings of the present study have both theoretical and practical implications. A significant theoretical contribution of the study is that it demonstrates that a broader theoretical perspective on leadership could indeed serve as a useful supplement to the perspectives most commonly applied in safety-specific leadership studies, and yield additional insight into how leadership influences safety compliance. This insight should be viewed as complementary to safety-specific leadership literature, rather than contradictory. Another important theoretical contribution of the study is that it highlights the relationship between leadership, the work climate, and safety compliance. Despite the widespread acceptance of both leadership and the work climate as significant antecedents of safety compliant behavior, few studies have examined the structural relationship between these variables (Thompson et al., 1998). The model applied here underlines that leaders play an important role in promoting safety by influencing the quality of the work climate, which in turn, influences safety compliance.

The most important practical implication of the findings of the present study is that they reveal that good safety leadership extends beyond the clearly safety-specific dimensions of leadership. More specifically, the results demonstrate that safety improvement efforts on offshore platforms should focus on active leadership involvement in work operations in the search for improved safety compliance. The importance of this has also been emphasized in previous empirical research (Cohen, 1977; Fleming et al., 1996; O'Dea and Flin, 2001; Simard and Marchand, 1997; Smith, 1978), management literature (Weick and Sutcliffe, 2007), and in offshore accident analysis and investigations (Hayes, 2012; PSA, 2005, 2007, 2011b). However, the findings of the present study demonstrate that high leadership involvement does not only have a direct effect on safety compliance. A high level of leadership involvement is also an important key to the formation of a work climate that stimulates workers' to act in accordance with safety rules and procedures. Such a climate is characterized by clearly stated roles, active follow-up of contractor workers, and workers who are involved in decisions related to their work situation and receive the training that is necessary to handle their work tasks. Leadership training, according to these findings, is therefore of significance when aiming for improved safety compliance. An important goal of this training should be to increase leaders' awareness of the importance of high involvement in the work of employees. In addition it is necessary to give offshore leaders sufficient time to spend outside their offices and on the frontline of the operations. Previous research of offshore leaders, however, indicates that a recent increase in administrative work and bureaucratic routines represents a significant obstacle to leadership involvement (Lamvik et al., 2008). Hence, operator companies within the offshore petroleum industry should examine the possibility of reducing the administrative responsibilities of offshore leaders, thus enabling high leadership involvement on the frontline.

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Article #3 - Safety compliance in a highly regulated environment: a case study of workers' knowledge of rules and procedures within the petroleum industry

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Safety compliance in a highly regulated environment: A case study of workers' knowledge of rules and procedures within the petroleum industry

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ABSTRACT

Violations of rules and procedures are commonly identified as an important causal factor in workplace accidents. Essentially, there are two different types of violations: intentional and unintentional violations. Whereas the former term refers to deliberate violations of rules and procedures that are known and understood by the actor, the latter refers to violations of rules and procedures that the actor has no awareness or knowledge of and therefore operates without any reference to. The vast majority of previous research has been concerned with intentional rather than unintentional violations. This implies that researchers have put a particular focus on the aspects of work that affect workers' safety motivation and their attitudes towards compliant behavior, and that they have been less concerned with the factors that affect workers' knowledge of rules and procedures. On the basis of semi-structured interviews of 24 contract workers within the Norwegian petroleum industry, this research gap is addressed in the present paper. The objective is to identify, categorize and gain a comprehension of the most significant factors that affect workers' knowledge of rules and procedures. Analysis revealed that eight different factors within the workers' organizational context are important. These are sorted into three paramount categories: the safety management system, work characteristics and social interaction. The theoretical and practical implications of the findings are discussed.

1. Introduction

A recurring conclusion of accident investigations across different industries is that a lack of compliance with rules and procedures is an important contributory factor (Dekker, 2005; Hopkins, 2011). The exact proportion of accidents that such non-compliance accounts for varies between industries, but some writers have claimed that violations of rules and procedures within high-risk industries are a significant contributor to as much as 70% of the total number of accidents (Mason, 1997). This demonstrates that adherence to rules and procedures, usually referred to as *safety compliance*, is of critical importance in maintaining safety at work and, further, that there is a need to identify and explain the reasons why workers violate procedures and to address factors that can improve safety compliance.

According to Battmann and Klumb (1993), a broad range of behaviors that deviate from written rules and procedures can be classified as violations. Thus, they argue that violations should be conceived as actions which belong to a dimension, which can vary from the flexible application of rules and procedures to complete ignorance of them. A useful and relatively clear-cut distinction can be made, however, between *intentional* and *unintentional* violations (Reason, 1990, 1997). The former are deliberate violations of procedures that are known and understood by the actor, such as knowingly breaking procedures to get a job done with less effort or because the procedures are considered impractical in a given situation. The latter are violations of procedures that the actor has no awareness or knowledge of and therefore operates without any reference to (Lawton, 1998), such as operating hazardous machinery in breach of regulations because no operating instructions are available. In such instances, a violation has been committed unknowingly. That is without the actor being aware of the relevant rules or procedures, and not for example because non-compliance has been perceived as an easy pathway towards a goal. In addition to this distinction, both intentional and unintentional violations should be distinguished from malevolent acts, such as sabotage, in which both the act and the damaging consequences are intended. Also, they should be distinguished from acts of human error, such as slips, lapses and mistakes that arise from cognitive and perceptual failures (Reason, 1990) where the plan was good (i.e. to follow the known rules), but the execution failed.

The recognized significance of violations in the aetiology of accidents at work has led researchers to increase their efforts to

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detect the antecedents of such unsafe practices, and to identify factors that can improve safety compliance. Some of this research has focused on characteristics related to the individual worker, such as personality (e.g. Salgado, 2002) and demographic attributes (e.g. Chan et al., 2002). During the last two to three decades, however, researchers have become increasingly aware of the importance of the social and organizational context of work and the role that it plays in reducing the frequency of violations and in achieving a high level of safety compliance (Didla et al., 2009). A variety of different contextual factors have been studied, such as job demands and resources (e.g. Hansez and Chmiel, 2010), ethical work climates (e.g. Parboteeah and Kapp, 2008), cooperative relationships (e.g. Simard and Marchand, 1997), job autonomy (e.g. Parker et al., 2001), safety climate (e.g. Cavazza and Serpe, 2009) and leadership (e.g. Lu and Yang, 2010).

The vast majority of this research has been concerned with intentional rather than unintentional violations (Alper and Karsh, 2009). This implies that researchers have been particularly focused on the aspects of work that affect workers' safety motivation and their attitudes towards compliant behavior, and that they have been less concerned with the factors that affect workers' knowledge of the rules and procedures that govern their work (Barber, 2002). Hence, the accumulated insight into the root causes of intentional violations far exceeds the accumulated insight into the root causes of unintentional violations. If the goal is to grasp the full extent of non-compliant behavior, this research gap should be addressed. This is believed to be important, particularly within highly regulated industries, such as the petroleum, aviation and nuclear power industries, where the body of rules and procedures is extensive and complex and where it could be a challenge for workers to have knowledge of these.

The purpose of the present paper is therefore to shed light on this gap in safety compliance research, based on a qualitative case study of contract workers within one such highly regulated industry, the Norwegian petroleum industry. This is done by examining how the contextual aspects of work affect contract workers' knowledge of the rules and procedures that regulate their work. The overall objective is to identify, categorize and gain understanding of the most significant factors that affect such knowledge. Addressing this objective may yield insights into some of the contextual mechanisms that underlie unintentional violations, which would therefore complement research that focuses on the contextual mechanisms that underlie intentional violations.

Such insights should be particularly relevant to the petroleum industry. First, because virtually all work operations in this industry are highly regulated by a relatively extensive and complex set of rules and procedures. Hence, it would be reasonable to assume that knowledge of these rules and procedures depends on more than just common sense. Second, because investigations of accidents within this industry frequently identify non-compliance with rules and procedures as a central contributory factor (Karish and Siokos, 2004; Thunem et al., 2009). It should also be added that contract workers are of particular interest, because they constitute the group of workers that are most frequently involved in and exposed to accidents within the petroleum industry (Hofmann et al., 1995; PSA, 2012; Walker et al., 2012).

2. Background

As already described, previous research on violations and safety compliance in work settings has focused primarily on the causes of intentional violations and has not been particularly concerned with the causes of unintentional violations (Alper and Karsh, 2009). According to Fogarty and Buikstra (2008), intentional and unintentional violations follow different psychological pathways, whereby the former is associated with workers' safety motivation and safety attitudes and the latter with workers' knowledge of rules and procedures. Previous research has been more concerned with identifying the contextual origins of workers' safety motivation and attitudes than with the contextual origins of their knowledge of rules and procedures.

A number of different social and organizational attributes have proved to be of significance within the research on intentional violations. For example, studies of safety climate, defined as the set of perceptions that employees share regarding safety in their work environment (Zohar, 1980), have demonstrated that workers' perception of safety priorities within their organization positively affects safety motivation and attitudes and, further, that positive motivation and attitudes in turn promote safety-compliant behavior (e.g. Biggs and Banks, 2012; Cavazza and Serpe, 2009; Zhou et al., 2008). Studies of leadership point in the same direction. Several leadership studies have found that leaders who emphasize reward and encourage safe performance generate a lower level of deliberate rule-breaking within their work group by positively affecting workers' attitudes and motivation towards safe conduct (e.g. Lu and Yang, 2010; Tomas et al., 1999). Researchers have also found the balance between job demands and job resources to be important. For example, Hansez and Chmiel's (2010) study of non-compliant behavior within the Belgian energy sector demonstrated that imbalances between job demands and resources affect the frequency of intentional violations negatively because of strain and lack of motivation.

The observation that workers' safety attitudes and motivation are important for reducing the number of intentional violations is not new. Neither is it a new observation that contextual factors are important in the formation of both attitudes and motivation. For example, as early as the 1930s, Heinrich (1931) reported from case studies based on 75,000 accident records that poor attitudes were a major obstacle to safe behavior and that supervisors were highly influential in the formation of such attitudes. Later, Slocombe (1941) argued that ignorance of safety rules at work was the result of poor attitudes and motivation caused by improper safety training. Nearly four decades later, Andriessen (1978) claimed that management's prime task with respect to improved safety performance, which is understood as a reduction in deliberate risk-taking and rule-breaking, is to implement measures that aim to enhance safety motivation.

Despite this long-held proposition, other lines of research have indicated that non-compliant behavior should not be analyzed and understood solely in terms of the interplay between the social and organizational context on the one hand, and workers' safety motivation and attitudes on the other. This research also demonstrates the need to expand the research field beyond the scope of intentional violations. An example of this is a study by Elling (1987), cited in Hale (1990), of railway workers' perceptions of the rules governing work on and near railway lines: 85% of the respondents in Elling's study found it hard to find what they were looking for in the rule book, and when they finally found it 70% found the rules too complex and hard to read. Hence, the eventual gap that emerged between work performance as formally described in the rule book and the way work was actually carried out is not always intentional; thus, it cannot be understood exclusively in terms of the interplay between context, motivation and attitudes. Moreover, Elling's study illustrates that safety compliance within highly regulated industries depends to a large degree on an organization's ability to support workers' knowledge of rules and procedures.

A study by Laurence (2005) of the Australian mining industry draws similar conclusions to those that can be drawn from Elling's study. When asked to indicate their reasons for not complying with the rules, 18% of the mine workers reported that there were too many rules for them to remember, 16% reported that the rules were too complex, 12% reported that the rules were not written in plain language and 10% reported that the content of the rules was poor or that they contained errors. Like the results of Elling's (1987) study, this indicates that confusion relating to the rules or procedures themselves can lead to violations. Further, these types of violations are not primarily provoked by inappropriate safety attitudes or motivation but by a lack of adequate knowledge of the regulations, and thus must be considered as unintentional.

A study which demonstrates this more explicitly is that of Dahl et al. (in press) of the Norwegian offshore service vessel industry. This study revealed that 37% of the vessel workers found the procedures difficult to understand, and that such perceived vagueness about procedures was negatively related to compliant work performance. More precisely, 75% of those who perceived that the procedures were clear reported that they always worked in accordance with the procedures, compared with only 33% of the group of workers who perceived that the procedures were vague. This indicates that workers' knowledge of rules and procedures is highly important for safety-compliant behavior. Further, this indicates that not only should intentional non-compliance be considered but that the unintentional aspects of violations need to be addressed as well.

This last point is even more clearly illustrated in a study by Walker et al. (2012) which mapped the contributory factors in actual incidents within the petroleum industry. This study showed that unintentional violations were a contributory factor in 19% of the 108 analyzed fatalities in 2010 and 2011, whereas intentional violations were a contributory factor in 15%. In addition, Walker et al.'s study showed that unintentional violations were a contributory factor in 24% of the 174 analyzed high potential incidents in 2010 and 2011, whereas intentional violations were a contributory factor in only 9%. This skewed distribution illustrates clearly that there is a need to know more about the organizational factors that hinder or facilitate workers' knowledge of rules and procedures, and that the objective of the present study might be particularly relevant to the petroleum industry.

3. Method

The majority of research on violations and safety compliance has applied a quantitative research methodology, such as linear regression analysis and structural equation modelling, since its purpose is frequently to test hypotheses about cause and effect relationships derived from previous research or theory (e.g. Biggs and Banks, 2012; Cavazza and Serpe, 2009; Dahl and Olsen, 2013; Griffin and Neal, 2000; Lu and Yang, 2010; Martínez-Córcoles et al., 2011). However, the exploratory nature of the present study calls for the qualitative methodology. Thus, semi-structured interviews were conducted with the purpose of gaining a deeper understanding of the factors that hinder or facilitate workers' knowledge of rules and procedures.

3.1. Research respondents

The industry to be studied and the research respondents interviewed in this study were selected by means of purposive sampling (Patton, 2002). This meant that the industry and the respondents were not selected randomly, but by the researcher, according to predefined criteria that fitted with the objective of the study. Four predefined criteria were set: (1) the industry to be studied had to be highly regulated by safety rules and procedures, (2) the industry to be studied had to be a high-risk industry, (3) the respondents selected had to be sharp-end workers who directly interact with some type of hazardous process, and (4) some variation between the respondents with respect to their professional background and experience was required in order to provide a rich array of information. In addition to these four criteria, it was deemed necessary to start with at least 20 respondents, and then to include further cases in the sample until little new information could be added to the analysis, as recommended by Bailey (2007).

The application of these criteria resulted in 24 workers from a maintenance and modification company within the Norwegian petroleum industry being asked to participate in the study (23 men and one woman). None of them refused to participate. All of the interviewees were contract workers. Twelve of them worked offshore on a fixed production platform on the Norwegian Continental Shelf, and the remaining twelve worked onshore on a large gas-receiving terminal (where compressed gas arrives in pipes from the shelf). The production platform and the gas-receiving terminal were owned and operated by a large petroleum company.

Of the offshore workers, eight were electricians/automation workers and four were mechanics/welders. Four of the offshore workers also functioned as regional safety delegates, and two had supervisory responsibilities. Of the onshore workers, six were mechanics/welders, three were scaffolding installers, two were electricians and one was an engineer. Three of the onshore workers also functioned as regional safety delegates/HSE coordinators, and two had supervisory responsibilities (data about age, education and experience were not collected in the interviews).

Within both onshore and offshore contract work, the use of subcontractors (often on short-term contracts) is common practice. This was reflected in the study sample, as 10 of the respondents were employed by subcontractor companies hired by the contractor: five were offshore and five onshore.

3.2. Semi-structured interviews

In order to obtain relevant information about the objective of the study in-depth semi-structured interviews were conducted. This means that the interviews consisted of some predefined open-ended questions and topics from an interview guide, but that the order of questions and topics was modified when appropriate and that questions were added, deleted, probed, modified and so on during each interview in order to elicit relevant and informative answers from the respondents (Cargan, 2007).

The predefined questions and topics in the interview guide (attached in the Appendix A) covered a broader range than the focus of the present paper. However, all of the questions, whether predefined or added during the interview, focused directly or indirectly on safety in general and on safety compliance/violations in particular. All of the predefined questions and topics were developed on the basis of a pre-study which included the following: (1) observation of actual work, both onshore and offshore; (2) informal conversations with senior managers, HSE managers, installation leaders, supervisors, safety delegates, HSE personnel and sharp-end workers from different disciplines; (3) attendance at toolbox meetings, work permit meetings and safety rounds; (4) an examination of relevant documents such as the company's HSE policy, project contracts, work permits and work packages; and (5) a review of previous research and relevant literature.

For practical reasons all interviews, except for two, were conducted with two respondents at a time. The interviews were carried out at the respondents' workplace, and the duration of each interview was approximately 1 h. All interviews were recorded and later transcribed into text. The interviewees were informed that all answers would be treated anonymously and in strict confidence.

3.3. Data analysis

To detect emerging and recurring patterns and themes in the data, content analysis was employed (Patton, 2002). This means that the qualitative material was analyzed with the aim of identifying core consistencies and meanings related to the topic of the study. The type of content analysis that was employed was open coding (Corbin and Strauss, 2008). Open coding is primarily an inductive content analysis, where the findings and the thematic categories emerge out of the data and not from an already existing theoretical framework. In the present study, this implies that the data material was analyzed without explicit reference to previous research or theory. This is a technique which is recommended within the grounded theory approach because it avoids researcher bias arising out of preconceived categories coming from the work of other researchers (Glaser and Strauss, 1967). However, this technique does not restrict the researcher from discussing the research findings and the relevance of the discovered categories in the light of previous research and theory.

By following the guidelines of Corbin and Strauss (2008), the method of open coding in the present study implied a process in which the interviewees' statements were given conceptual labels (statement by statement), based on their content. Then, by comparing similarities and differences between the labels, the statements and their corresponding labels were grouped under more abstract categories. These categories (or factors) were then named according to their core consistencies and meanings.

In contrast to the inductive character of the first part of the analysis, the second part had a more deductive character: the appropriateness and authenticity of the content analysis and the thematic categories that had been developed were tested and affirmed. This included a re-examination of the data that focused particularly on identifying cases that did not fit the developed categories, an approach recommended by Patton (2002).

4. Research findings and analysis

4.1. Brief case description

Maintenance and modification work within the Norwegian petroleum sector is a growing industry, owing to ageing production facilities and a significant decrease in investment in new offshore installations and onshore plants (Sasson and Blomgren, 2011). Such work is labor-intensive and includes a variety of different tasks and operations that differ in complexity and scope. In the case of the company selected for the present study these tasks and operations varied from advanced sub-sea operations and large-scale modification projects to simple routine tasks, such as minor repair and revamp projects. Irrespective of the tasks and operations, virtually all work operations, complex or simple, were regulated by rules and procedures designed to ensure correct and safe operating practices. These rules and procedures are referred to as the 'governing documentation' (a term used interchangeably with 'rules and procedures' in the following) and they are implemented in the operating company's safety management system. This implies that work performed by the contracting company is regulated by rules and procedures owned and formulated by the operating company.

The governing documentation related to a given work task is first and foremost a description of how work should be performed in order for it to be safe, both with regard to the individual worker, the facility, third parties and the environment. Hence, the procedures do not include a description of quality measures, efficiency demands and the like. Moreover, the governing documentation is relatively detailed as regards the description of how people should behave, how the relevant work equipment should be handled, what preparations are necessary, the type of personal protective equipment required and so on. Thus, the governing documentation falls into the category of rules which Hale and Borys (2012a) define as 'action rules'. That is, rules that describe more or less exactly how people should behave (see also Hale and Swuste, 1998).

In order to ensure that all workers have acquired the necessary knowledge of the governing documentation that regulated a given work task, each worker involved in the task had to confirm, by signing the work permit, that the specified set of rules and procedures relating to a given work task were fully known and understood. This signature was a central part of the operating company's work permit system, and no workers were allowed to participate in a given work task without confirming by signature that the relevant governing documentation was known and understood. However, because the governing documentation related to a given work task is frequently revised, corrected and modified, it is not, and should not be, available on paper. Moreover, it was not attached to the work permit form or any other documents associated with the work task. This was the operating company's policy, justified by the fact that the company wanted to avoid outdated procedures being in circulation. The governing documentation related to a given work task was therefore only referred to by paragraph numbers in the work permit, and was only available in full text in the operating company's IT-based safety management system. Hence, all information regarding governing documentation was located in the safety management system, and only there. Up-to-date knowledge of rules and procedures therefore presupposed active use of the safety management system. The IT-based safety management system was accessible on all computers both onshore and offshore. Physical access to computers, however, varied considerably between the onshore and offshore workers. This is discussed in Section 4.3.

4.2. Actual knowledge

Despite the formally defined importance of having an in-depth knowledge of rules and procedures for safe operating practice, it was clear from the interviews that the actual knowledge of these rules and procedures varied considerably. With regard to the level of knowledge, three different groups of workers were identified. The first group of workers reported active use of the safety management system: they knew how to use it, they knew how to locate the relevant governing documentation, they frequently searched for updates and they regularly read through all relevant procedures they did not know well enough or had not understood. Typically, these workers also took their signature on the work permit seriously. As one of the workers expressed it, 'I am familiar with the demands made on me in the work permit, or else I wouldn't have signed it'.

The second group of workers was in many ways similar to the first group, with some notable exceptions. They were relatively active users of the safety management system. They knew how to use it and reported that their knowledge of the relevant governing documentation was, by and large, high. These workers, however, did not regularly check the system for updates, and rarely read through procedures they felt they did not know well enough or had not understood properly: 'Yes, we're supposed to understand the procedures we are working with, we really should know these. But there are updates all the time, and I guess I should have been better at checking these out. I haven't been any good at that at all'.

The third group of workers differed considerably from the two other groups. These workers seldom or never used the safety management system, they did not know how to use it and their knowledge of governing documentation was poor. Further, they reported that they had never checked the system for updates or read through rules and procedures that they felt they did not know well enough or had not understood properly. Despite this, most of these workers were well aware of the gap that existed between their confirmatory signature on the work permit and their actual knowledge of governing documentation: 'Personally, I have never used governing documentation. I have been out offshore several times, but I have never been into the safety management system. [...] It's really very daft of me, because I sign my name stating that I have understood governing documentation, without having familiarized myself with it'.

Workers in this last group did not represent extreme or unusual cases in the data material (see Table 1). In fact, of the onshore workers, eight out of twelve interviewees could be placed in this group, and both contractor workers and subcontractor workers were represented. Among the offshore workers, however, this proportion was not as high, five out of twelve, and it was first and foremost comprised of workers employed by subcontractors.

It should be noted here that none of the participants within this last group claimed that it was their own unwillingness that caused them not to use the safety management system in accordance with what was formally expected. Instead, they pointed to factors within their work context that hindered them from being active users of the safety management system, and to factors which made them consider it unnecessary to achieve greater knowledge of the rules and procedures that governed their work. Thus, the interviews and the data analysis focused particularly on these reported contextual factors.

In total, eight different factors were identified in the analysis, some of which were related thematically. They were classified into the following common thematic categories: (1) the safety management system, (2) work characteristics, and (3) social interaction. In the following sections, these categories and their underlying factors are described.

4.3. The safety management system

In the interviews it was evident that certain characteristics of the safety management system itself were deemed very important to having an adequate knowledge of rules and procedures. Three factors within this category emerged from the analysis: access to the safety management system, the user-friendliness of the system and training on how to use it.

4.3.1. Access

Despite the fact that all workers were obliged to confirm by signature that all relevant rules and procedures related to a given work task were fully known and understood, it was frequently stated, particularly by the onshore workers, that such a level of knowledge was difficult to achieve owing to the lack of adequate access to the safety management system. In fact, among the onshore workers ten out of twelve reported that the access not was satisfactory (the remaining two had supervisory responsibilities). This lack of adequate access was, however, not reported by any of the offshore workers. The difference in accessibility might be an important reason why the number of non-active users of the safety management system appeared to be higher among the onshore workers.

Table 1
Number of respondents in each of the three groups, onshore and offshore.

Group	Onshore (N)	Offshore (N)	Total (N)
1. High knowledge	2	5	7
2. Medium knowledge	2	2	4
3. Low knowledge	8	5	13
Total	12	12	24

As explained above, the safety management system was IT-based. The onshore interviewees frequently reported, however, that no computers were located within an appropriate physical distance of where the work was actually carried out or planned. Further, no computers were reserved exclusively for use by ordinary workers who needed access to governing documentation in the safety management system. In fact, all available computers at the gas-receiving terminal were located in supervisors' offices while separate computers, reserved for those who needed access to governing documentation, were located in the offshore workers' break room. Thus, in order to gain access to governing documentation, many of the onshore workers claimed that they had to consult their supervisor and use their supervisor's computer and user profile in order to read through relevant rules and procedures. This process was considered cumbersome, especially if work was carried out far away from the supervisor's office (sometimes up to 2 km), or if the supervisor was absent from the office. The onshore interviewees frequently claimed that this lack of adequate access to the safety management system obstructed active use of the system and that it hindered satisfactory knowledge of relevant rules and procedures. As one of the onshore workers expressed it: '... you have to use the supervisor's access, and he is not always there [...] and then it could be that some don't bother waiting for the supervisor to come back, and just accept what has been said orally. [...] So the ideal thing would be for each of us to have access to a machine, so that we could go in and check it out, we haven't got that so far'.

4.3.2. User-friendliness

Another characteristic related to the IT-based safety management system itself, which was frequently mentioned as important for gaining an appropriate knowledge of rules and procedures, was the user-friendliness of the system. The challenge that some of the interviewees reported was that the relevant governing documentation was often difficult to locate within the comprehensive safety management system, and this increased the effort and time involved in using it. Among the offshore workers it was often stated that this challenge could be overcome if they had access to an easy-to-use service manual:

> The safety management system could have been easier to use if there were instructions by the side of the computer, explaining how to start up the system an how to make a search. [...] They should have made it easier for us, because then we would be better at using it.

This alternative was not mentioned by any of the onshore workers. Presumably owing to lack of adequate access to the system, all of them (except from the supervisors) seemed to be more convinced that regular use of the safety management system would lead to enhanced perceived user-friendliness and increased knowledge of governing documentation:

> The system must be used regularly. If it takes too long between each time it is used, you will forget how to do it. So, more regular use is important to make people check the procedures, to make them check how the job should be done...

4.3.3. Training

The third factor associated with the IT-based safety management system was the importance of training. It might be self-evident that adequate knowledge of rules and procedures presupposes a certain degree of training about how to access the system, how to navigate within it, how to locate the relevant procedures, how different symbols should be interpreted and so on.

Such training also needs to be undertaken in order for workers to be permitted entry to offshore installations on the Norwegian Continental Shelf. Thus, all of the offshore workers interviewed in the present study reported that such training had been undertaken. Of the onshore workers, however, only three interviewees (the two supervisors and one HSE coordinator) reported that they had been offered enough formal training on how to use the safety management system. This, they indicated, had two effects. First, the lack of adequate formal training was interpreted as a signal that active use of the safety management system was not as essential as their signature on the work permit formally indicated. Second, the lack of adequate formal training resulted in a deficiency of the skills needed to access the system effectively. This in turn resulted in a gap between actual and required knowledge of governing documentation:

> Considering that these demands are placed on us, we should obviously have been more familiar with them. Because we are really not familiar with them, none of us are. So you could say it's kind of unfortunate. We should at least have received some training.

4.4. Work characteristics

The second category of factors frequently emphasized by the interviewees as important for knowledge of rules and procedures were the characteristics related to the work itself and the conditions of employment that the workers were bound by. Three factors within this category emerged in the analysis. These were the routinized work, perceived risk level and subcontracting.

4.4.1. Routinized work

The first work characteristic that appeared to be important in seeing the necessity of having a substantial knowledge of rules and procedures was the degree of routine in the work performed. Interviewees who saw their work as being unpredictable and varied often reported that their acquired skills were not sufficient to solve their tasks in a safe way and this increased the need to become familiar with governing documentation. On the other hand, interviewees who saw their work as highly routinized, in particular electricians and scaffolding installers, often reported that the repetitive character of their work led to a reduced need for such familiarization. They frequently claimed that they had successfully performed the same work operations several times before, and in the light of this experience they knew how such operations should be performed. Hence, past success in similar work operations was seen as a guarantee of future safety. One of the offshore subcontractor workers expressed it like this: 'I know what to do, and then I try to do that. [...] and not once have I been into the safety management system to take a look'.

The negative effect that routinized work had on knowledge of governing documentation was particularly evident among the supervisors at the gas-receiving terminal, where the majority of the work tasks were determined by fixed maintenance intervals. In fact, the supervisors interviewed at the terminal claimed that the routinized character of work was the very reason why little or no training was offered in how to use the safety management system. The routinized character of work, they claimed, was also the reason why easy access to the safety management system was not offered. This is illustrated by a supervisor's answer to the question of why easy access and training was not offered, despite the fact that up-to-date knowledge of governing documentation was formally required:

> The thing is that most of our tasks down here are so well-known to us, and we have done them so many times, so we would rather do them the way we are used to, and avoid extra work and stress. Because we know our jobs and do them pretty well, I think.

It should be stressed here that, although routinized work seemed to have a negative effect on the knowledge of rules and procedures, it would be more problematic to claim that routinized work also had a negative effect on safety as such. This is because, as the quotes above illustrate and as has been thoroughly debated in recent safety research (e.g. Besnard and Hollnagel, 2012; Bourrier and Bieder, 2013; Hale and Borys, 2012a,b), working safely is not just a plain and linear function of procedure compliance. There are several reasons for this. One is that procedures cannot cover all the possible challenges a worker faces when performing a task. Hence, as for example Dekker (2006) has argued, experience, adaption and practical skills are always the necessary ingredients of a safe work performance. This is also the point that these interviewees are making.

4.4.2. Perceived risk level

Another work characteristic that was clearly important for seeing the necessity of a good knowledge of rules and procedures concerned the level of risk that workers perceived their work carried. Interviewees who perceived the risk level in their work to be high were usually of the opinion that knowledge of governing documentation was important for safe practice. Interviewees who perceived the risk level in their work to be low were more often of the opposite opinion, and some of them thought that knowledge of governing documentation was only relevant to work that carried greater risks. A comment from one of the offshore workers who never used governing documentation in his work illustrates this quite clearly: 'I am of the opinion that governing documentation is more relevant when you need to enter pressurized systems and the like, when you need to replace a valve or something; that it's more relevant in such cases'.

Ten of the interviewees also indicated that an increased and explicit management focus on risks could encourage more workers to realize the important role that rules and procedures play, and therefore increase workers' effort to improve their knowledge of them. One of the onshore interviewees expressed it this way: 'It is important to make people conscious, conscious about the things that can happen if they don't work by the rules'. Further, he claimed that such consciousness depends on supervisors' and managers' ability to relate governing documentation to the risks that workers commonly face in their work. He claimed that then workers can see the relevance of rules and procedures in relation to the work that they perform more easily.

4.4.3. Subcontracting

As already explained, among the offshore workers, the non-active users of the safety management system and those who reported the lowest level of knowledge of governing documentation were mainly those employed by subcontractors. In the safety literature these workers are often referred to as 'nomads' (e.g. Hovden et al., 2008; Parkes, 2012). Nomads have no regular work/leave schedules, they constantly move between different installations and they carry out specialist tasks for a range of different contractors hired by different operating companies. This was also the case among the offshore subcontractor workers in the present study. The effect of this irregularity, they claimed, was that, in principle, they had to be familiar with different sets of governing documentation and safety management systems, which varied between the installations and between different operating companies. Hence, familiarization with different rules, procedures and safety management systems was seen as a challenge: 'It's different for those who have worked a long time for the same contractor. They are familiar with the system and they know how it works'.

This challenge was strengthened by the fact that they felt their prime duty was to perform the tasks they were hired for, and not to spend time making themselves familiar with a body of rules and procedures that might only be relevant for a limited period of time. Thus, instead of actively searching for answers within the safety management system, and instead of familiarizing themselves with governing documentation, they simply asked supervisors or colleagues with more experience in order to get quick answers. One of the offshore subcontractor workers, who never examined governing documentation before starting a job, expressed it like this: 'When we receive a task we get to work straightaway, and if something is unclear we ask the supervisor for advice, [. . .] but we never consult the safety management system'.

4.5. Social interaction

The third and last theme that was identified as important for workers' knowledge of rules and procedures was the impact of social interaction. Two factors within this category emerged in the analysis: leadership influence and co-worker influence.

4.5.1. Leadership influence

In the interviews it was clear that the interaction between leaders and subordinates was deemed to be important for how the workers prioritized safety in their own work. However, many of the interviewees reported that there appeared to be two sides to this interaction with regard to safety, and that this two-sidedness was significant to how they perceived the importance of up to date knowledge of governing documentation. On the one hand, it was frequently claimed by the interviewees that their leaders repeatedly communicated the importance of safe and attentive work performance, and that this type of communication was seen as having a strong influence on the priority (relative to other domains) that the workers gave to safe performance in their own work. One of the onshore workers expressed it like this: 'You should work safely, it's the first priority. They [the leaders] say it, they let you do it, and they mean it'. In fact, none of the interviewees were in any doubt about what the number one priority was.

On the other hand, however, it was also often claimed (by eight of the onshore workers and seven of the offshore workers), that this type of safety communication from leaders seldom stressed the importance of having up to date knowledge of governing documentation (apart from the fact that they were obliged to confirm by signature that up to date knowledge was obtained). This lack of explicit emphasis on rules and procedures was frequently interpreted by the workers as implying that up to date knowledge was actually not as necessary as it was formally said to be. One offshore subcontractor electrician's description of his leader's lack of emphasis on governing documentation illustrates the effect of this: "Usually, there isn't much focus on it [governing documentation]. So then we'd rather start working and producing instead of sitting down by a computer to look into it". Hence, safe and attentive work performance was often seen as a type of performance that was dependent on experience in how work is usually and actually performed, and not on in-depth knowledge of governing documentation.

4.5.2. Co-worker influence

Co-worker influence is the final factor that was clearly important to how the workers, especially the offshore subcontractor workers, perceived the importance of a high level of knowledge of rules and procedures. All of the offshore subcontractor workers had full access to the safety management system and they had undergone all the necessary training in how to use the system. This formal training, they claimed, also highlighted the importance of a good knowledge of governing documentation and active use of the safety management system. However, in observing their more experienced co-workers' actual use of the safety management system, it was apparent that none of them had the impression that active use of the system was as important as they had been taught during their training. Such observations seemed to affect their own use of the system significantly. A comment by one of the offshore subcontractor workers illustrates this: 'You just follow the crowd. You do like everybody else, and I have never seen anyone else working with the safety management system'. Hence, informal observations of their co-workers' actual practices seemed unintentionally to overrule what they had been taught in their training courses. Another offshore subcontractor worker claimed that this type of unintended influence could be overcome if the focus on governing documentation were more explicit and formalized:

> When someone is newly hired, they should ask: 'Have you used the safety management system before?' 'No, I haven't'. 'You haven't? Then we need to find someone to show you how it works'. In this way, you would get an introduction, some guidance and the opportunity to try it. [. . .] Then we would perhaps be better at using it in our next job.

None of the subcontractor workers reported that they had met with such an explicit focus on how to use the safety management system in their work group. This clearly affected their actual use of the system, their skills in how to use it and their perception of how in-depth knowledge of rules and procedures were valued.

5. Discussion and conclusions

5.1. Key findings

The objective of the present study was to identify, categorize and gain an understanding of the most significant factors that affect the workers' knowledge of the rules and procedures that regulate their work, on the basis of a qualitative case study of contractor workers within the Norwegian petroleum industry. The actual knowledge the 24 workers interviewed had about rules and procedures varied considerably, despite the fact that in-depth knowledge was a strict requirement of the formal work permit system. Use of content analysis and open coding to uncover recurring patterns and themes in the interview data showed that eight factors (summarized in Fig. 1) within the workers' organizational context contributed to this variation.

The first three of the identified factors were related to the IT-based safety management system, wherein the body of rules and procedures was assembled. The three factors were (1) *access* to the safety management system, (2) the *user-friendliness* of the system, and (3) *training* in how to use it. As regards access and training, the lack of sufficient training and adequate access to the safety management system affected the onshore workers' knowledge of rules and procedures negatively. This effect was negative, not only because these conditions were disadvantageous to the workers' practical skills in terms of how to use the safety management system, but also because it signalled to the workers that an in-depth knowledge of rules and procedures was not as necessary as had been stated formally.

Hence, it can be argued that there was a perceived misalignment between what is usually referred to in the organizational science literature as the 'espoused values' and the 'enacted values' (Argyris and Schön, 1996), since the priorities as enacted (i.e. involving lack of sufficient training and adequate access) were clearly in conflict with the espoused priorities (i.e. necessity for in-depth knowledge of rules and procedures). The present study

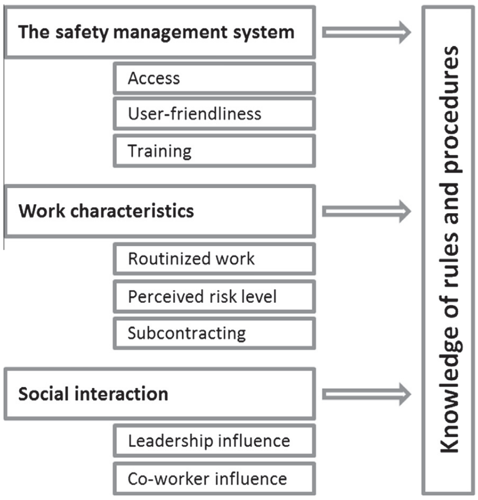

Fig. 1. The most significant factors affecting workers' knowledge of rules and procedures.

complements previous safety literature, which has argued that misalignment between espoused and enacted values is detrimental to fostering a high priority for safety in a work unit (Leroy et al., 2012; Zohar, 2003), as it also finds such a misalignment to be disadvantageous to the workers' knowledge of rules and procedures. According to Zohar (2010) such misalignment is detrimental to safety because it is the enacted values, not the espoused values that provide employees with reliable information regarding what sort of behavior is expected and supported.

The lack of satisfactory user-friendliness of the IT-based safety management system also negatively affected the workers' chances of gaining appropriate knowledge of rules and procedures. The offshore workers particularly emphasized that it was difficult to locate the relevant governing documentation within the system, and that this reduced their actual use of the system. This finding is consistent with Elling's (1987) previously described study of railway workers, which found that characteristics related to the regulations themselves, such as complexity and size, had a negative impact on the workers' knowledge of rules and procedures and on whether the regulations were actively used. This finding is also consistent with Antonsen et al.'s (2008) conclusions in a study of safety compliance on an offshore supply base, which identified procedural simplicity as a key condition for achieving increased use of procedures.

The next three factors that were identified in the data material were related to the characteristics of the work itself and to the conditions of employment that the workers were bound by. These three factors were (4) *routinized work*, (5) *perceived risk level* and (6) *subcontracting*. As regards subcontracting, the negative effect of this was primarily visible among the offshore subcontractor workers who frequently moved between different installations and worked for different operating companies. This nomadic existence seemed to have a negative effect because it led to a shortage of time spent at each installation. This reduced the offshore opportunity for the subcontractor workers to become familiar with the operator-specific safety management system and the installation-specific body of rules and procedures. Related effects of the nomadic characteristics of subcontracting have also been found in other studies. For example, Biggs et al.'s (2013) study of safety culture within the construction industry found that subcontracting was the most significant barrier to improvements in the safety culture because of the transient characteristics of this type of employment. It should, however, be noted that the findings related to subcontracting in the present study are restricted to knowledge of specific rules and procedures, and not to safety in any wider sense, as is the case in Biggs et al.'s study. It should also be noted that the subcontractor workers' varied practice at different installations and their experience of other safety management systems, rules and procedures might make an in-depth knowledge of the installation-specific body of rules and procedures less essential.

The workers' perception of the risks involved in their work appeared to be positively related to their comprehension of how important knowledge of rules and procedures was and, consequently, how much effort they put into becoming familiar with governing documentation. This implies that those who perceived their own work to be hazardous were more often of the opinion that in-depth knowledge of rules and procedures was necessary, which was in contrast to those who perceived that their own work contained little risk. This finding complements those of previous studies of safety in work organizations which have argued that there is a positive link between risk perception and safe behavior (e.g. Arezes and Miguel, 2008; Ji et al., 2011; Mearns and Flin, 1995). However, none of these studies has explored the link between risk perception and workers' knowledge of safety rules and procedures. The findings in the present study might indicate that such knowledge is an important mediating variable in the causal relationship between risk perception and safety behavior.

As regards routinized work, the effect of this appeared to be negative. That is, workers who experienced little variation in their work were of the opinion that in-depth knowledge of rules and procedures was not necessary because, on the basis of experience and past success with similar tasks, they knew how their tasks should be performed. In turn, this led to little active use of the safety management system and a low level of knowledge of governing documentation. This negative effect of routinized work has not received much attention in previous studies, but it is well demonstrated that unsafe behavior, such as the failure to use protective gear and the ignorance of known safety procedures, is strongly provoked by routine work, partly because past success in using unsafe practices in similar tasks serves as a reinforcement to continue with unsafe practices (e.g. Snook, 2000; Zohar and Erev, 2007). Hence, while routinized work is recognized in previous studies as a significant antecedent of intentional violations, its effect on knowledge of rules and procedures is under-investigated. It should, however, be stressed that the interviewees in the present study considered the routinized characteristics of their work to be a positive aspect with respect to safety, in spite of its negative effect on knowledge of rules and procedures. Hence, the findings do not give any direct support to the notion that routinized work has a negative effect on safety in a wider sense.

The last two factors which emerged in the analysis were related to the impact of social interaction. These were (7) *leadership influence* and (8) *co-worker influence*. The emergence of these two factors was not unexpected. The relationship between leadership behavior and the safety behavior of subordinates is well recognized in the safety literature (Hofmann and Morgeson, 2004), and has been so for a long time (e.g. Heinrich, 1931). Previous studies have also recognized the important role of co-workers, in particular the influence that experienced workers have on newcomers (e.g. Choudhry and Fang, 2008; Mullen, 2004). In the present study these two factors were important for the workers' perception of the true priority of knowledge of rules and procedures in the organization, which is similar to the effect of the lack of sufficient training and inadequate access to the safety management system. For example, the strong focus on safe and attentive work performance, combined with the lack of an explicit leadership focus on the governing documentation per se, was frequently interpreted by the offshore subcontractor workers as implying that an in-depth knowledge of rules and procedures was in practice not so important, notwithstanding its formal expression through the work permit. The misalignment between the espoused and enacted values is therefore relevant for understanding the impact of these factors as well.

5.2. Implications, limitations and further research

A significant contribution of the present study is the insight it provides into some of the factors that affect workers' knowledge of rules and procedures. This is an under-researched area of safety compliance research. The factors identified are to a certain degree also related to motivation and attitudes. However, these types of motivation and attitudes are not connected to the propensity to act in accordance with the prevailing regulations during the execution of work; instead, they are associated with gaining knowledge of rules and procedures prior to the execution of work. Thus, the factors identified in the present study fill a serious research gap within safety compliance research, and shed light on factors that it is important to take into consideration in order to understand some of the organizational origins of unintentional violations. In combination with previous research, the findings of the present study therefore offer a more comprehensive framework for understanding non-compliant behavior.

In addition to these theoretical contributions, the findings of the present study have some important practical implications. While these are particularly relevant to the petroleum industry, they are also relevant to other industries characterized by extensive and complex safety regulations, such as the aviation, mining, shipping and nuclear power industries. Most importantly, the findings clearly imply that bureaucratic routines, such as requiring workers to confirm by signature that a specified set of rules and procedures is fully known and understood, are not at all sufficient to ensure adequate knowledge. If such bureaucratic routines are expected to have a significant impact, several other aspects of the work context should also be addressed.

First, all workers should be offered adequate access to relevant rules and procedures and receive the necessary training to enable them to locate and interpret the regulations. This is not only important because access and training are essential practical tools, but also because it signals that knowledge of rules and procedures is a real priority for the organization. In addition, the body of rules and procedures should be characterized by simplicity and user-friendliness. Second, the characteristics of the work itself and the workers' conditions of employment should be taken into consideration. In particular, the findings indicate that it is important to make sharp-end workers aware of the link between rules and procedures and the risks that such administrative barriers are meant to reduce. Further, it is important for managers, leaders and other stakeholders to pay particular attention to routinized work, and to ensure that the balance between the practical acquired know-how and knowledge of rules and procedures is within the boundaries of safe practice. In addition, the findings clearly indicate that it is important to pay specific attention to nomadic subcontractor workers, and to recognize that this group of workers needs to be offered extra time and resources. Third, the signals that leaders send to their subordinates and the impact that experienced workers have on newcomers should be given particular attention. If knowledge of rules and procedures is given a high and visible priority, this signals to the crew that it is of real importance and not just a bureaucratic necessity.

In sum, these three aspects point to one common theme: the importance of sending clear and unambiguous messages to workers about the level of understanding that is actually expected of them with regard to knowledge of rules and procedures. Such an unambiguous approach cannot be delivered simply by issuing a clear formal demand (the demand for signing the work permit to confirm adequate knowledge) while, at the same time, displaying a passive attitude when it comes to the organization's responsibility to support this demand. Clearly, employees could interpret such passivity as indicating that up to date knowledge is not as necessary as the formal statement implies. Moreover, this could also result in the impression that the signature and the rules are necessary only to protect the back of management if something goes wrong. According to Chunlin and Chengyu (1999), this is actually the widespread impression of petroleum workers. In their study, 48% of the workers on the UK Continental Shelf were of the opinion that some rules only are there to cover management's back.

Despite the theoretical and practical implications of this study, the findings should be interpreted in the light of certain methodological limitations. First, owing to the study design and the sample size, the findings are not generalizable in the traditional statistical sense of the word. Irrespective of this, it is believed that the particular empirical setting of the study, a highly regulated work environment, fits the explorative objective of the study well, and that it therefore sheds relevant empirical light on an under-investigated area of safety compliance research that is transferable to other industries. It would, however, be useful for future research to examine and test the findings of this study with a quantitative study design, across different settings. Second, like any other interview study, the data limitations of the present study include the possibility of inaccurate and distorted responses owing to personal bias, bias introduced by social desirability, recall errors and so on (Patton, 2002). Hence, the findings of the present study would have been strengthened if the interviews had been underpinned by observations. Observation studies should therefore be considered in future research on this topic. Such a study design could also be well suited to identifying relevant factors that might have been overlooked in the present study. Third, and more fundamentally, the study does not shed empirical light on the actual relationship between knowledge of rules and procedures, compliance and safety. That is, the findings do not necessarily imply that more knowledge automatically leads to more compliance, or that more compliance automatically leads to safer operations. This last relationship is for example problematized by Reason (1997), Besnard and Hollnagel (2012) and Dekker (2006), who emphasized that rigid compliance with procedures is not a guarantee for safe operations and that departures from procedures sometimes are necessary to preserve safety. This is not a topic which has been dealt with explicitly here, owing to the research objective of the study. Hence, the findings of this study should be understood within the limits of its research objective.

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Appendix A. Interview guide

Question: Can you please tell me a little about yourself, including your professional background and the work that you perform here?

Examples of follow-up questions: How long have you been working offshore/onshore and on the current installation/plant? Are you working for a contractor company or a subcontractor company? Do you have any leadership

(*continued on next page*)

responsibilities/HSE duties? Can you please tell me more about that?
Question: The HSE statistics indicate that there are relatively few accidents and injuries among the workers here, what do you think is the reason for that?
Examples of follow-up questions: Is it your opinion that safety is taken seriously here? What does it mean in practice to take safety seriously? Can you please give an example? Compared to where you have worked before, how is safety prioritized here?
Question: Have you ever been involved in or witnessed an accident/incident here? Can you please tell me more about that?
Examples of follow-up questions: From your perspective, what was it that caused the accident/incident? Could it have been prevented?
Question: How do you plan your work with regard to safety?
Examples of follow-up questions: Can you give a step by step description? In what way are you involved in the pre-planning? Is such involvement important? Why?/Why not?
Question: When planning and performing a job, how relevant are rules and procedures?
Examples of follow-up questions: Are rules and procedures an integrated part of the planning? How do you locate the relevant rules and procedures? Are you familiar with the rules and procedures? Are you familiar with the IT-based safety management system? Why?/Why not? Is knowledge of rules and procedures/active use of governing documentation emphasized in your department? Please explain.
Question: Do you encounter unexpected situations that make it necessary to ignore rules and procedures?
Examples of follow-up questions: Can you give an example? In what way does this affect safety?
Question: Are you offered enough time to perform your work safely and to make yourself familiar with rules and procedures?
Examples of follow-up questions: Does this affect your work performance in any way? How?
Question: How do you make yourself familiar with rules and procedures?
Examples of follow-up questions: Is knowledge of rules and procedures important for safe performance? How? What gives you that impression? Have you been offered any formal training in rules and procedures and the IT-based safety management system? In what way is such training important?
Question: In what way is leadership important to how you perform your work with regard to safety matters?
Examples of follow-up questions: What characterizes a leader who works proactively with safety? How does your leader compare with such a description? How does your leader prioritize safety? Are knowledge of rules and procedures a part of this priority? How? In what way is your leader involved in the work that you perform? In what way does your leader follow up newcomers and subcontractor workers?
Question: Are safe working practices a common topic at meetings? How?
Examples of follow-up questions: How is knowledge of rules and procedures emphasized in these meetings? Are rules and procedures explicitly discussed? How is safety performance in completed work tasks/safe job analyses evaluated at these meetings?
Question: In what way is the operator company important for how you perform your work with regard to safety matters?
Examples of follow-up questions: How does the operator company prioritize safety? Are knowledge to rules and procedures a part of this priority? How? How is accident reporting followed up by the operator company?

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Article #4 - Labour inspection and its impact on enterprises' compliance with safety regulations

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Article 3

LABOUR INSPECTION AND ITS IMPACT ON ENTERPRISES' COMPLIANCE WITH SAFETY REGULATIONS

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ABSTRACT

A recurring conclusion in accident investigations and analyses, across a range of different industries, is that non-compliance with safety regulations is a significant contributory factor to accidents. Such non-compliance can take place both at the individual level and the organisational level. In recent years, safety researchers have mostly focused on individual non-compliance, its contextual origins, and the relevant measures that can be taken to improve safety compliance among frontline workers. However, few studies have paid attention to organizational compliance or non-compliance with safety regulations and the measures that can be taken to improve compliance at the organizational level. In Norway it is first and foremost the Norwegian Labour Inspection Authority which is responsible for ensuring that enterprises comply with the national safety regulations, such as the Working Environment Act and its accompanying regulations. This is done primarily by on-site inspections of the enterprises. On basis of two field experiments (N=291), which compare inspected versus previously uninspected enterprises, the present paper examines the impact that such control activity has on the enterprises' compliance with national safety regulations. The results of the comparative analyses show that enterprises which have been subject to inspections by the labour inspection authorities exhibit a significantly higher level of compliance with safety regulations compared to enterprises which not have been subject to inspections. These findings are of great importance considering the fact that non-compliance is a common triggering factor of accidents at work. The implications of the findings are discussed here.

1. INTRODUCTION

Accident investigations and analyses across a range of different industries regularly identify non-compliance with safety regulations as a significant contributory factor (Hopkins, 2011). This is not only the case in investigations of occupational accidents with a relatively limited extent of loss, but is also a recurring finding in investigations of major accidents and catastrophes (Hudson et al., 1998). One of the best known examples of this is the Chernobyl catastrophe in 1986, where five of the seven human actions that led directly to the accident were deviations from written procedures (Reason, 1987), and the Piper Alpha disaster two years later where platform managers' safety practices were found to be contributory to the disaster and significantly diverging from written procedures (Wright, 1994). Another well-known example is the BP Texas City refinery explosion in 2005, where an important finding, among others, was that a casual attitude to compliance with safety procedures contributed to the explosion at the refinery (Hopkins, 2009).

As regards occupational and organizational safety, non-compliant acts can be defined as 'deviations from safe operating procedures, standards or rules' (Reason, 1997: 72). Such deviations can take place both at the individual level, in relation to company internal safety procedures, and at the organisational level, in relation to the national occupational health and safety regulations. In recent years, safety researchers have paid most attention to individual non-compliance among frontline workers, and a considerable amount of research has been conducted with the aim of identifying the antecedents of such unsafe acts and suggesting measures which can be taken in order to improve individual safety compliance (e.g. Antonsen et al., 2008; Clarke, 2006; Dahl and Olsen, 2013; Griffin and Neal, 2000; Kapp, 2012; Kongsvik et al., 2012; Lawton, 1998; Lu and Yang, 2011; Martínez-Córcoles et al., 2011; Mearns et al., 2010; Pedersen and Kines, 2011; Torp and Grøgaard, 2009; Zohar, 2002). A recurring finding in these studies is that non-compliant behaviour not is a random phenomenon (Wagenaar, 1998) that evolves in a vacuum, but is triggered to a large degree by different inadequate organizational conditions, often created by management itself (Alper and Karsh, 2009).

In spite of the substantial amount of research that has been conducted with the aim of identifying the origins of non-compliance at the individual level and effective measures which can be taken to improve individual safety compliance, few studies have paid attention to the organizational level. Thus, few studies have examined why some organizations follow national safety regulations while others do not and few studies have aimed at identifying effective compliance-enhancing measures at the organizational level.

There are, however, some exceptions. For example, Saksvik et al.'s (2003) study of Norwegian companies and Baldock et al.'s (2006) study of British small enterprises, found that poor compliance with safety regulations at the organisational level is a consequence of a limited access to health and safety resources. Hence, factors such as enterprise size, public sector, management training and experience and membership of trade or business associations were found to be positively associated with rule compliance at the organizational level in these studies.

As regards effective compliance-enhancing measures, Baldock et al. (2006) found that enterprises inspected by regulatory authorities (labour inspections) were far more likely to comply with safety regulations, compared to enterprises which not had experienced such inspections. In fact, in their study, inspections on the part of regulatory officials were found to be the variable with the most positive influence on organizational safety compliance. In addition, the study revealed that enterprises which had been controlled by the regulatory authorities' labour inspectorates were more likely to use external assistance in order to improve compliance with health and safety regulations. Hence, the positive impact of labour inspections was found to be indirect as well as direct. On the basis of these findings, Baldock et al. (2006: 844) therefore concluded that an appropriate strategy with regard to enhanced compliance at the enterprise level "would be to provide the resources needed to increase substantially the number of inspections undertaken".

Baldock et al.'s findings in relation to the impact of labour inspections are important because they indicate that public resources spent on control and enforcement within this area actually serve one of its intended key-purposes, namely to improve enterprises' compliance with health and safety requirements. This finding is also supported by some other studies which have looked at a broader set of regulatory instruments (Andersen et al., 2009; Wright et al., 2000).

A limitation of these studies, however (including Baldock et al.'s (2006) own study), is that compliance is measured by the use of self-reported data. This can result in an unintended positive bias. Another limitation is that the cross-sectional design of these studies makes it difficult to establish a sequential cause and effect relationship between the measures imposed by the labour inspectorates and improved compliance. The internal validity of these studies, related to their interpretations of cause and effect, can therefore be discussed. In order to further examine the impact of regulatory authorities' control activity on enterprises' compliance with safety regulations it is therefore necessary for additional investigations which make use of research methods which not are vulnerable to the biases associated with self-reported data. This is what the present study aims to do.

The methodological limitations related to interpretations of causality that are associated with the studies described above are characteristic of social research in general, and there is no widely acknowledged solution to the causality problem in the social sciences (Vedung, 1997). The experimental research design is, however, often pointed out as the research method that is most suitable for producing systematic and robust evidence when examining the effects of different public actions or services in general (Clarke and Dawson, 1999), and has been recommended as an appropriate research methodology for examining the effects of safety interventions (Robson et al., 2001) and labour inspections in particular (Hillage et al., 2001). In order to further examine the effect that labour inspections have on enterprises' compliance with safety regulations, the present study was therefore designed as a field experiment, where compliance was measured by more objective criteria than self-reports and where the researchers fully controlled the independent variable (i.e. labour inspections).

To date, 130 countries have ratified the international Labour Inspection Convention (ILO, 2013). This implies that the majority of countries across the world have implemented a system of labour inspection, under the control of a central authority, which aims to secure the enforcement of legal provisions relating to health and safety at work. The purpose of the present paper is not to address the multitude of different labour inspection systems, but to focus on one of them; the Norwegian Labour Inspection Authority (NLIA). The control activity which is examined here is on-site inspections of enterprises related to workplace safety (not health or employment conditions), carried out by the NLIA, and the objective of this paper is to examine whether labour inspections carried out by the NLIA have an impact on enterprises' compliance with safety regulations.

The methodological design of the current study allow for a comparative analysis of the level of compliance between inspected versus previously uninspected enterprises. The applied method and specific research hypotheses will be described in detail in section three of this paper, after a section that gives a brief description of the case of NLIA. Section four of the paper presents the empirical results of the study and is followed by a discussion and a conclusion in sections five and six, respectively.

2. BRIEF CASE DESCRIPTION

In general, the overall mission of most labour inspectorates, regardless of country, is to ensure safe and healthy work environments and secure employment conditions, by making sure that the enterprises comply with existing legislation. Within the Norwegian context it is intended to achieve this mission via the application of different instruments, such as inspections, verifications, guidance, information, campaigns and through collaboration with other public authorities like the police, the tax authorities and the environmental authorities. The main instrument, however, is the one that is the focus of this study, namely inspections of enterprises which aim to control and enforce compliance with the national working environment regulations.

The NLIA performs approximately 15.000 workplace inspections per year, and at this activity level the inspectorate covers roughly 7% of all land-based enterprises annually. Some guidance and information is usually offered by the inspectors during an inspection, but when dealing with enterprises that do not comply with the requirements of the Working Environment Act and its accompanying regulations, the NLIA has four different coercive measures available: formal orders, coercive fines (which can be imposed if formal orders are not followed), shutdown of operations and reports to the police. Formal orders, which are written orders to correct eventual violations within a limited time period, represent the most widely applied coercive measure. In 2011 formal orders were given in approximately 60% of all inspections (NLIA, 2012).

The inspections are divided among different priority areas such as work-related musculoskeletal disorders, work-related psychological disorders, social dumping, young workers, chemical hazards and technical safety. In this study, which deals with safety rather than health-related issues or employment conditions, it is important to underline that the effect of inspections was evaluated by addressing the two priority areas that are most clearly related to safety, namely *chemical hazards* and *technical safety*. Hence, priority areas related exclusively to health and employment conditions (such as wages, contracts and working hours) were excluded from this study.[1]

In 2011 roughly 20% of all inspections were performed within the priority area of technical safety, and 17% within the priority area of chemical hazards (NLIA, 2012). Within both of these priority areas the NLIA's focus is on control of some paramount statutory demands, such as appointment of safety representatives, establishment of safety objectives, risk identification, risk analysis and plans of action, but also on some specific statutory demands, such as proper access to personal protective equipment, safe storage of hazardous substances and the technical condition of production facilities. The legal basis for these demands is the *Working Environment Act* and its accompanying regulations such as the *Internal Control Regulations* and the *Regulations concerning Safety Representatives*.

3. METHOD

3.1. The experimental research design

As already described, the present paper is based on a study that applied an experimental research design. Basically, an experiment is a form of research methodology which examines the effect that an independent variable has on a dependent variable, by means of comparing two groups; an experimental group and a control group. Under ideal experimental conditions, assignment to the two groups should be random to assure that they are equal, except that the members of the experimental group are exposed to the independent variable, and the

[1] Separate studies (within other priority areas) related to the impact that labour inspections performed by the NLIA has on enterprises' compliance with health regulations and employment conditions has also been conducted, but is not reported in this paper.

members of the control group are not. Further, both groups should be pre-tested. The independent variable is usually dichotomous (i.e. present or absent, e.g. treatment or no treatment) and is typically under the control of the experimenter. In this model, the experimenter measures observations of changes in the dependent variable when the independent variable is present compared to observations of when it is absent (Clarke and Dawson, 1999).

The upside of the experimental research design is that it provides a high level of causal inference and internal validity. That is, it enables relatively firm conclusions to be drawn with regard to the effect of the independent variable (Babbie, 2010). Within the social sciences, including safety science, true experimental conditions are often difficult to achieve unless the experimental situation is moved to a laboratory or another artificial context. Such a context is, however, normally not desirable because it is necessary for the external validity to study the subjects in their naturally occurring environments (Clarke and Dawson, 1999). Thus, when experimental designs are applied in safety research the pure experimental design is usually replaced with different types of quasi-experimental designs, where some of the characteristics of the true experimental design are altered (Shannon et al., 1999).

In the present study, two experiments were conducted; one for the priority area of chemical hazards and one for the priority area of technical safety. A particular type of quasi-experimental design was employed for both experiments; the so called *post-test-only control group design* (Campbell and Stanley, 1963), also referred to as *after-only measures and a control group* (Robson et al., 2001). This implies that there were no pre-tests of the experimental groups and the control groups. Instead the experimental groups and the control groups were compared simply by assuring equality between the two groups through the use of matching pairs. Also, the context of the two experiments was natural. Such experiments are usually referred to as field experiments, and are frequently used within all types of evaluation research (Clarke and Dawson, 1999).

3.2. Experimental groups and control groups

The assignment of enterprises to the experimental groups in the present study was done primarily by means of randomization. This implied the existence of two lists of all enterprises that had been subject to inspections which either focused on (1) chemical hazards or (2) technical safety during the previous calendar year was created (at least 6 months and maximum 18 months before inclusion in the study), and then enterprises were selected at random from these lists. In total 100 enterprises were selected randomly from the list of enterprises that had been subject to inspections which focused on chemical hazards.

The list of enterprises that had been subject to inspections which focused on technical safety was subdivided into two different lists. These lists mirrored two different types of inspections within this priority area: accident inspections and preventive inspections. The first list consisted of enterprises which had been subject to an inspection due to an accident (accident inspections). The second list of enterprises consisted of enterprises that had been subject to preventive inspections. In total 40 enterprises from the first list were selected randomly. The 40 enterprises from the second list, however, were selected by matching. This implies that each enterprise from this second list was matched with another enterprise selected from the first list (matched pairs). The enterprises were matched on the following variables: branch of industry, geographical localization and number of employees.

In order to assure that the three experimental groups were comparable to the control groups, the assignment of enterprises to the control groups was done by using matching pairs. Firstly, a complete list of enterprises that had never previously been subject to inspections by the NLIA was created. Then, enterprises were selected from this list so that they matched those in the experimental groups. In total, 100 enterprises were selected to match those from the experimental chemical hazard group, and 40 enterprises were selected to match those selected from the two (40+40) experimental technical safety groups. Branch of industry, geographical localization and number of employees were used as criteria for matching. This ensured that the matched pairs were within the same branch of industry, that they were located within the same province and that they had approximately the same number of employees.

3.3. Measures, hypotheses and statistical procedures

In order to compare the level of compliance with safety regulations between the experimental groups and the control groups, follow-up inspections were conducted. These inspections were performed by regular inspectors from the NLIA. Due to practical reasons, however, some of the enterprises and some of the inspectors were not available for follow-up inspections. The net sample was therefore reduced accordingly, see table 1.

Table 1
Gross sample, net sample and net sample rate

	Chemical hazards		Technical safety		
	Exp. group	Contr. group	Exp. group 1[a]	Exp. group 2[b]	Contr. group
Gross sample	100	100	40	40	40
Net sample	96	96	33	33	33
Net sample rate (%)	96.0%	96.0%	82.5%	82.5%	82.5%

[a] Preventive inspections, [b]accident inspections

During the follow-up inspections, the inspectors applied a check list to measure the level of compliance with safety regulations within the enterprises. The check list consisted of eight variables and was developed by the researchers, prior to the inspections, in collaboration with chief inspectors and experts from the NLIA within the given priority area. Unlike for example Levine et al.'s (2012) study of labour inspection effects in the U.S., safety performance data such as occupational injury records was not applied. This was a conscious choice based on the aim (*compliance* and not *safety performance*) of the study, and because objective and comparable safety performance data are notoriously hard to obtain (e.g. Brown et al., 2000, Choudhry et al., 2007).

To assure reliability, validity and to avoid potential positive bias, all the inspectors were given written instructions with regard to how the inspections should be performed and with regard to how the check list should be applied. All eight variables were dichotomous, and were either assigned a 'yes' (value 1), indicating compliance, or a 'no' (value 0), indicating non-compliance. All the variables typically represented compliance with a specific relevant statutory demand, see table 2. Thus, if an enterprise was assigned a 'no' on a given variable, this would also trigger a formal order. Hence, the potential for systematic errors, positive bias and reduced validity were reduced by the fact that a 'yes' or a 'no' would trigger a real juridical consequence.

Table 2
Dichotomous variables included in the check-lists

Chemical hazards (CH)	CH1: Can the enterprise ensure that a written risk assessment of chemical hazards, which take all relevant risk factors into account, has been conducted?
	CH2: Can the enterprise ensure that measures have been implemented to reduce the potential risks of identified chemical hazards and/or has the enterprise prepared a relevant and scheduled plan of action?
	CH3: Can the employer ensure that he/she has undergone training in health, environment and safety work?
	CH4: Can the enterprise ensure that safety representatives have been elected (or have the parties agreed in writing upon a different arrangement/not to have a safety representative, which is allowed for enterprises with less than ten employees)?
	CH5: Can the enterprise present an up to date record of substances and products?
	CH6: Can the enterprise ensure that written procedures regarding use, storage and maintenance of personal protective equipment are available?
	CH7: Can the enterprise ensure that the employees have received information regarding risks revealed by a risk assessment?
	CH8: Can the enterprise ensure that that it has prepared periodic plans and reports regarding the work that the occupational health service carries out? [a]
Technical safety (TS)	TS1: Can the enterprise ensure that hazards are identified and that risks are assessed against this background?
	TS2: Can the enterprise ensure that measures have been implemented to reduce the risks of identified hazards and/or has the enterprise prepared a relevant and scheduled plan of action?
	TS3: Can the employer ensure that he/she has undergone training in health, environment and safety work?
	TS4: Can the enterprise ensure that safety representatives have been elected (or have the parties agreed in writing upon a different arrangement/not to have a safety representative, which is allowed for enterprises with less than ten employees)?
	TS5: Can the enterprise ensure that it registers all personal injuries/illnesses which occur as a result of work performed in the enterprise?
	TS6: Can the enterprise ensure that the employees have received information regarding risks revealed by a risk assessment?
	TS7: Can the enterprise ensure that it has prepared periodic plans and reports regarding the work that the

occupational health service carries out? [a]

TS8: Can the enterprise ensure that it has implemented routines to uncover, rectify and prevent non-compliance with national safety regulations?

[a] Enterprises which not are obliged to provide occupational health services were given the value 1 on this variable.

On basis of the check lists, all enterprises were assigned an index-score of between 0 and 8 following an inspection, by summing up the score on each individual variable (no missing values were registered). This index-score was treated as a measure of compliance with safety regulations on the enterprise level (dependent variable), and was used to test the following two hypotheses:

Hypothesis 1: Enterprises that have been subject to labour inspections which focus on chemical hazards will display a higher level of compliance with safety regulations relevant to this priority area, compared to enterprises that have never been subject to labour inspections.

Hypothesis 2: Enterprises that have been subject to labour inspections which focus on technical safety will display a higher level of compliance with safety regulations relevant to this priority area, compared to enterprises that have never been subject to labour inspections.

In order to test hypothesis 1, a one-tailed independent samples t-test was performed (Field, 2005). A one-tailed test, not a two-tailed, was considered appropriate owing to the fact that the hypothesis was directional. The t-test tested whether the mean index-scores in the experimental group were significantly higher from those in the control group. The alpha level was set to .05. This implies that if the t-test yields probability values below .05 this indicates that the hypothesis is supported by the data, whereas the existence of probability values greater than .05 indicates that the hypothesis is not supported by the data. The effect size was estimated by Pearson's r (Field, 2005).In order to test hypothesis 2, a t-test was not appropriate since the data consisted of three groups (two experimental groups and one control group). For this reason, a one-way ANOVA was conducted (Field, 2005).[2] The advantage of the ANOVA is that it can test whether or not the means of three or more groups are all equal. The ANOVA, however, does not provide information on which means are significantly different from each other. To test this, a Least Significant Difference (LSD) post-hoc test was applied (Ott and Longnecker, 2010), and, in line with hypothesis 2, it was expected that the two experimental groups would have a mean index-score greater than the control group, but that they would not differ significantly from each other. As for the t-test, the alpha level was set to .05 for both the ANOVA and the LSD-test.[3]

4. RESULTS

4.1. Internal consistency and reliability

Prior to the test of the two hypotheses the internal consistency and reliability of the applied indexes were evaluated by Cronbach's alpha coefficient of reliability (Cronbach, 1951). According to Nunnally (1978) alpha scores (α) greater than .70 are indications of adequate internal consistency and reliability. The alpha scores (see table 3) for the two indexes vary from .78 to .82. Hence the internal consistency and reliability were considered adequate.

Table 3

Descriptive statistics for indexes

Index	Variables	Mean	SD	N	α
Chemical hazards	8	5.78	2.20	192	.78
Technical safety	8	5.63	2.44	99	.82

4.2. Test of hypothesis 1

After having confirmed that the index had adequate internal consistency and reliability, the one-tailed t-test was conducted to test hypothesis 1. The results of the test, including a comparison between the experimental group and the control group for each individual variable in the index are presented in table 4.

[2] Hypothesis 2 is directional. However, the ANOVA is a non-specific test which means that it just tells us whether there is a difference or not. Thus it is not possible to run a one-tailed ANOVA (Field, 2005).

[3] All statistical tests, including randomization, were conducted with SPSS 18.0.

As shown in table 4, the experimental group scored higher on all of the eight individual variables in the index. The greatest difference between the two groups was to be found in variable CH1, where 84% of the enterprises within the experimental group were given the value 1 (=yes) compared to only 42% of those within the control group. This implies that whereas 84% of enterprises which had been subject to a labour inspection that focused on chemical hazards could document that a written risk assessment of chemical hazards has been conducted, this could only be documented by 42% of the enterprises which had not been subject to a labour inspection. The smallest difference between the two groups is to be found in variable CH4, which concerns the election of safety representatives, where 89% of the enterprises within the experimental group were given the value 1 (=yes) compared to 82% within the control group.

The t-test of hypothesis 1, which concerns the overall safety compliance index, demonstrated that enterprises which have been subject to a labour inspection (M=6.70, SD=1.61) display a significantly higher level of compliance with safety regulations relevant to the priority area of chemical hazards, compared to enterprises that had never been subject to labour inspections (M=4.85, SD=2.32), t(190)=6.40, p<.001. Thus, the data gave support to hypothesis 1. This implies that labour inspections performed by the NLIA have a positive effect on enterprises' compliance with safety regulations relevant to the priority area of chemical hazards. The calculated effect size was r=.42, p<.001, and the difference between the experimental group and the control group on the safety compliance index represents a 38.1% difference.

Table 4
Scores on variables and index in the experimental group (N=96) and the control group (N=96), including t-test of mean index difference (hypothesis 1)

	Exp. group		Contr. group		Difference
Variables/index	Mean	SD	Mean	SD	Mean difference
CH1	.84	.37	.42	.50	.42
CH2	.76	.43	.42	.50	.34
CH3	.89	.32	.78	.42	.11
CH4	.89	.32	.82	.38	.07
CH5	.86	.34	.78	.42	.08
CH6	.83	.38	.66	.48	.17
CH7	.76	.43	.48	.50	.28
CH8	.86	.34	.50	.50	.36
Index (chemical hazards)	6.70	1.61	4.85	2.32	1.85[a]

[a] T-test: df=190, t=6.40, p<.001 (effect size: r=.42, p<.001)

4.3. Test of hypothesis 2

The results of the ANOVA, including a comparison between the two experimental groups and the control group for each individual variable in the index are presented in table 5. As shown in the table, the two experimental groups scored higher than the control group on all of the eight individual variables in the index. The greatest difference between the two experimental groups and the control group was to be found in variable TS7, where 82% and 67% (mean for both groups =75%) of the enterprises within the experimental group 1 and 2 were given the value 1 (=yes) respectively, compared to only 33% within the control group. This implies that whereas 75% of enterprises which had been subject to a labour inspection which focuses on technical safety could document that they had prepared periodic plans and reports regarding the work that the occupational health service carries out, and this could only be documented among the 33% of enterprises which had not been subject to a labour inspection. The smallest difference between the two experimental groups and the control group was to be found in the variables TS2 and TS8, which concern implementation of risk-reducing measures and routines to uncover, rectify and prevent non-compliance with national safety regulations.

As regards the test of hypothesis 2, which concerns the overall safety compliance index, the ANOVA demonstrated that there was a statistically significant difference between the groups, F(2, 96)=4.47, p=.041. The LSD post-hoc test revealed that enterprises which had been subject to a preventive inspection (M=6.10, SD=2.18) scored significantly higher on the safety compliance than did enterprises which not had been subject to an inspection (M=4.76, SD=2.70), p=.025. This difference in the safety compliance index represented a percentual difference of 28.2%. Also, the LSD-test revealed that enterprises which had been subject to an accident inspection (M=6.03, SD=2.23) scored significantly higher on the safety compliance index than enterprises which not had been subject to an inspection, p=.033. This difference in the safety compliance index represents a percentual difference of 26.7%. In addition, the LSD post-hoc test (not reported in table 5) revealed that there was, as expected, no statistically significant difference between the two experiment groups, p=.918. In sum, the results from the ANOVA and the LSD supported hypothesis 2. This implies that labour inspections performed by the NLIA have a positive effect on enterprises' compliance with safety regulations relevant to the priority area of technical safety.

Table 5

Scores on variables and index in experimental group 1 (N=33), experimental group 2 (N=33) and the control group (N=33), including ANOVA-test of mean index difference and LSD-tests (hypothesis 2)

	Exp. group 1[a]		Exp. group 2[b]		Contr. group		Difference	
Variables/index	Mean	SD	Mean	SD	Mean	SD	Mean diff gr. 1	Mean diff gr. 2
TS1	.76	.44	.73	.45	.67	.48	.09	.06
TS2	.70	.47	.64	.49	.61	.50	.09	.03
TS3	.76	.44	.82	.39	.70	.47	.06	.12
TS4	.88	.33	.85	.36	.55	.51	.33	.30
TS5	.73	.45	.76	.44	.61	.50	.12	.15
TS6	.79	.42	.85	.36	.67	.48	.12	.18
TS7	.82	.39	.67	.48	.33	.48	.49	.34
TS8	.67	.48	.73	.45	.64	.49	.03	.09
Index (techn. saf.)[c]	6.10	2.18	6.03	2.23	4.76	2.70	1.34[d]	1.27[e]

[a] Preventive inspections, [b]accident inspections

[c] ANOVA: df=2, 96, F=3.29, p=.041, [d] LSD-test: p=.025, [e] LSD-test: p=.033

5. SUMMARY AND DISCUSSION

To ensure that enterprises comply with national health and safety regulations, most countries across the world have implemented a system of labour inspection (ILO, 2013). However, few studies have attempted to examine the effect that labour inspections actually have on enterprises' compliance with safety regulations. Some exceptions exist, but the methodological design of these studies (self-reports/cross-sectional) has some limitations in regard to interpretations of causality (e.g. Baldock et al., 2006). Thus, by applying an experimental research design and focusing on two priority areas (chemical hazards and technical safety) within the Norwegian Labour Inspection Authority (NLIA), the objective of the present study was to examine whether labour inspections carried out by the NLIA have an impact on enterprises' compliance with national safety regulations.

By comparing inspected versus previously uninspected enterprises, via follow-up inspections conducted by inspectors from the NLIA, the results of the empirical analyses demonstrated that enterprises which had previously been subject to inspections by the NLIA exhibit a significantly higher level of compliance with safety regulations compared to enterprises which not have been subject to inspections. Within the priority area of chemical hazards, the experimental group (previously inspected enterprises) scored 38.1% higher than the control group (previously uninspected enterprises) on the safety compliance index. The t-test confirmed that the mean score within the experimental group was significantly higher than the mean score of the control group, thus supporting hypothesis 1. Within the priority area of technical safety, the two experimental groups (preventive inspections and accident inspections) on average scored 26.7% higher than the control group on the safety compliance index. The ANOVA and the LSD post-hoc test confirmed that the mean score within both experimental groups was significantly higher than the mean score of the control group, but that there was no significant difference between the two experimental groups, thus supporting hypothesis 2.

Owing to the fact that comparability between the experimental groups and the control groups was assured (at least on three variables) through matching pairs, it would be reasonable to conclude that the variation between the two groups' level of compliance was caused by variation in the independent variable; labour inspection. These findings are consistent with previous studies of the impact that labour inspections have on enterprises' compliance with safety regulations (Andersen et al., 2009; Baldock et al., 2006), but the methodological design of the present study provides higher internal validity with regard to inferences about the causal relationship.

The findings have important theoretical implications. As already described, safety researchers have traditionally been concerned with identifying the origins of non-compliance among frontline workers and to suggest effective measures which can be taken to improve individual safety compliance. Simultaneously, few studies have paid attention to compliance at the enterprise level and even fewer have examined the impact that labour inspections have on enterprises' propensity to act in accordance with prevailing safety regulations. The findings of the present study should therefore fill a research gap within safety research and add new knowledge to our understanding of the impact of labour inspections.

In a broader sense, the findings should also shed light on another under-researched topic within safety research, namely the causal relationship between company external factors and safety critical internal factors. As Kongsvik et al. (2012) previously have highlighted, there is a need to include external factors in order to more fully understand the state of safety within organizations. The findings of this study are an example of this, and they clearly illustrate a classical point made by Rasmussen (1997); that the socio-technical system which actually is involved in the creation of organizational safety extends far beyond a company's internal conditions and, moreover, that it is the result of the interplay between actors operating on different societal levels.

In addition to these theoretical implications, the findings of the present study also have some important practical implications. As described in the introduction, non-compliance with safety rules and procedures is a common triggering factor of accidents at work. Hence, it needs to be dealt with. The findings of the present study indicate that labour inspections have a positive effect with regard to this. This is important. Because, as has been stressed by for example Levine et al. (2012), occupational health and safety regulators are surrounded by controversies, with some observers claiming that workplace inspections have no effect on workplace safety and others arguing that inspections improve workplace safety. The findings of the present study, including Levine et al.'s own study which focused on injury rates and inspections conducted by OSHA[4], clearly support the latter group of observers. The findings should thus be a well-founded argument for the necessity of labour inspections in a period where (1) deregulation has been debated for a long time (Walters et al., 2011), (2) where a reduction in the frequency of labour inspections is a fact in many countries (e.g. Larsson, 1997; Tombs and Whyte, 2010; 2012), and (3) where economic recession has led to funding cuts which in turn have forced regulatory authorities across several countries to limit their activities (Johnson, 2012).

However, the findings of the present study should be interpreted with some methodological limitations in mind. Firstly, the study deals only with short-term effects. All enterprises in the experimental groups that were included in the study had been subject to an inspection in the previous calendar year (at least 6 months and maximum 18 months before inclusion in the study). Thus, the findings do not offer information on long-term effects. It would therefore be useful for future research to replicate the present study over a longer time span.

Secondly, the study was performed within the Norwegian context. Hence, the validity of the findings is, strictly speaking, restricted to inspections conducted by the NLIA. The conclusions that can be drawn from the study are thus not automatically generalizable to other regulatory regimes. The methodology which is developed in this study, however, should be applicable, with some adjustments to national variations, when assessing the effect of labour inspections within other regulatory regimes.

Thirdly, the findings do not illuminate the causal mechanism between labour inspections and improved compliance. Thus, the study indicates that labour inspections performed by the NLIA have a positive impact on enterprises' compliance with safety regulations, but it says less about why. It would be tempting to interpret the findings as a result of enforcement actions, and to conclude that compliance at the enterprise level can be improved by more enforcement and more use of coercive measures. However, as Wright and Marsden (2005) and Wright et al. (2005) have previously noted, non-compliance at the enterprise level is not only associated with deliberate attempts to ignore regulations, but more with a lack of knowledge and understanding of the regulations. If this is true, it is likely that the positive impact that labour inspections were found to have in the present study was caused more by guidance and information given during inspection than by formal orders or other coercive measures. The present study, however, does not provide sufficient information for robust conclusions to be drawn on this subject. It would therefore be valuable if future research could test and compare the impact of enforcement-only inspections versus guidance-only inspections.

6. CONCLUSION

The present study has demonstrated that enterprises which have been subject to inspections by the Norwegian Labour Inspection Authorities exhibit a significantly higher level of compliance with safety regulations compared to enterprises which not have been subject to such inspections. The methodological basis of the study was two field experiments which applied a post-test-only control group design that compared inspected versus previously uninspected enterprises. Comparability between the two groups of enterprises was assured through matching pairs. It is thus highly likely that the variation between the two groups' level of compliance was caused by the fact that the one group of enterprises previously had been subject to inspection while the other had not. These findings are important considering the fact that non-compliance is a common triggering factor of accidents at work. The findings should also contribute with significant knowledge of the impact of labour

[4] OSHA: U.S. Occupational Safety and Health Administration

inspections and about the causal relationship between company external factors and safety critical internal factors. Also, the findings should be important in a time where deregulation, economic recession, funding cuts, and a reduction in the frequency of labour inspections are affecting many countries.

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