The influence of interorganizational factors on offshore incidents: challenges and future directions

Vibeke Milch * (Corresponding author)

Department of Psychology

Norwegian University of Science and Technology,

NO-7491 Trondheim, Norway

Telephone: +47 73 59 19 79

Mobile: +47 47 66 01 08

Email address: Vibeke.Milch@ntnu.no

Karin Laumann

Department of Psychology,

Norwegian University of Science and Technology,

NO-7491 Trondheim, Norway

Email address: Karin.Laumann@ntnu.no

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Abstract: In the petroleum industry, incident investigations are an important means to understand and learn from undesired events. Whereas investigations in the petroleum industry typically focus on technical, human and organizational factors, there is a growing tendency towards outsourcing and more complex forms of organizations. Processes occurring at the interfaces between companies represent important influences that should be considered when investigating incidents. The current study aimed to gain a better understanding of the influence of interorganizational factors on offshore incidents on the Norwegian Continental Shelf. Twenty-two investigation reports were analysed to identify interorganizational factors that contribute to incidents. Factors at the interorganizational level contribute to both occupational incidents and major near accidents. Four themes were identified: *Ambiguities in roles and responsibilities between personnel from different companies, inadequate processes to ensure sufficient competence across interfaces, inadequate quality control routines across organizational interfaces* and *communication breakdowns between companies.* The identified factors reflect underlying systemic deficiencies at the interorganizational level that contribute to obscure operational processes and at the same time reduce the effectiveness of existing safety barriers. Broadening the scope and incorporating factors at the interorganizational level when investigating undesired events is important in order to sufficiently learn from incidents.

Keywords: *Incident investigation, interorganizational factors, petroleum industry*

1. Introduction

In the petroleum industry, incident investigation represents an integral part of safety management, and considerable efforts are made to investigate undesired events seeking to learn from them and implement measures to avoid future occurrences. This is important, as seemingly trivial errors in complex socio-technical systems can potentially escalate to cause uncontrolled situations, and, in a worst case scenario, result in major accidents (Perrow, 1984).

Major accidents are complex events that cannot be ascribed to one single cause, but result from intricate interactions between several factors at different levels in the system. This means that everyone involved in work processes both directly, and those that influence work processes more indirectly, can potentially influence an accident scenario (Rasmussen, 1997). Indeed, academics and practitioners have come to realize that, in order to learn from incidents, a broad perspective that takes into account the complexities and intricate relationships that can lead to major accidents, is required. In this regard, the influence of organizational factors such as the role of management, safety culture, communication, division of responsibilities and pressure factors have been accentuated in research literature in recent years (Reason, 1997).

Investigative approaches have experienced a similar shift, evolving from a primary focus on proximal causes of a human and technical nature, to wider approaches that incorporate more remote factors at the organizational level (Katsakiori, Sakellaropoulos, & Manatakis, 2009). This development can be seen in light of recent societal changes and accelerating technological developments that have introduced more complex organizational systems, and subsequently, more complex forms of accidents (Hollnagel, 2012a; Kirwan, 2001; Rasmussen, 1997). This evolution has simultaneously sparked a shift in accident causation thinking, moving from linear models of cause and effect, to more complex models that consider accident causation in terms of complex interrelations in the system as a whole (Rosness et al., 2010).

Despite the fact that incident investigations in the petroleum industry now pay attention, to a larger extent, to the identification of root causes at the organizational level, severe incidents still occur. In Norway, regulators keep asking “why isn’t the industry learning?” One explanation could be that current investigation practices do not sufficiently cover all levels of complexity within the systems that influence risk. As the petroleum industry, like many other high hazard industries, relies extensively on contractor and sub-contractor services, work processes span across a large number of companies with varying degrees of involvement. Emerging evidence from serious incidents in the petroleum industry, including the Deepwater Horizon accident, reveal several problems at the interfaces between companies as contributing to serious incident and accident scenarios (Austnes-Underhaug et al., 2011; Montara Commission of Inquiry, 2010; National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling, 2011; Tinmannsvik et al., 2011). Arguably, looking into inter-organizational factors may add to the understanding of incidents, thereby also increasing the learning potential from incident investigations.

The objective of this paper is to gain a better understanding of how interorganizational factors relate to incidents in the petroleum industry. Through analysing investigation reports issued by the Petroleum Safety Authority (PSA) from 2006–2016, we aim to explore how interorganizational factors are linked to incidents on the Norwegian Continental Shelf (NCS) in order to gain a better understanding of which factors may produce unwanted outcomes. In this respect, our intention is not to account accurately for the prevalence of incidents attributable to interorganizational factors, but rather to identify potential challenges and areas of improvement. The following research questions are explored: *What types of incidents and accidents are related to interorganizational issues? What interorganizational factors can be* *identified in investigation reports contributing to incidents offshore?*

The present study is part of an ongoing research project aiming to develop new knowledge on safety challenges related to interorganizational complexity in petroleum operations, as well as on the connection between interorganizational complexity and risk of major accidents in the petroleum industry.

1. Theoretical background

1.1. Accident and incident analysis

Accident and incident investigation is based on the notion that it is possible, through piecing together information about the sequence of events leading up to unwanted outcomes and exploring factors related to the event, to uncover the cause(s) and thereby prevent similar occurrences in the future. A central objective is to learn and implement means so that future occurrences can be avoided (Cedergren & Petersen, 2011; Jones, Kirchsteiger, & Bjerke, 1999; Reason, 1997). An investigation can take many forms, as there are numerous approaches and methods available. However, in a general sense, an investigation can be regarded as a diagnostic process, typically involving the following steps: collection of evidence and information about the accident, a thorough analysis to establish the cause and contributing factors, the development of recommendations for remedial actions and finally a follow up on remedial actions taken (Kjellén & Albrechtsen, 2017; Sklet, 2004).

The investigation process is shaped by a number of varying factors. The direction and focus of an investigation process is determined by the underlying accident model, embodying assumptions about the casual nature of accidents and how accidents can be prevented (Kjellén & Albrechtsen, 2017). The approach and underlying assumptions of the investigation team will influence what they look for, and therefore inevitably also what they find in the investigation (Lundberg, Rollenhagen, & Hollnagel, 2009). Moreover, the level of scope, the composition of the investigation team in terms of competencies and the investigators' professional background together with the available resources and time frame are all factors that will influence the focus of the investigation which will also determine what is uncovered (Lundberg, Rollenhagen, & Hollnagel, 2010).

Investigations of accident and incidents can be carried out internally, which is often the case for minor incidents and mishaps. However, in the case of more serious incidents and accidents, an external investigation is commenced, often carried out by an independent investigative body. In the Norwegian petroleum industry, external investigations of incidents and accidents are carried out by the PSA. The PSA is the regulating body of the Norwegian petroleum industry, responsible for supervising safety, emergency preparedness and work environment (Petroleum Safety Authority Norway, 2017a). As an element of the tripart regulatory approach in the Norwegian petroleum industry, the main responsibility for regulating petroleum activities on the NCS is left to the operating companies. They are obliged to ensure that operations are in accordance with regulatory requirements, which also means that the operating companies themselves are obliged to supervise their own operational activities. Consequently, the majority of incidents and accidents are investigated internally by the companies. The PSA, however, conducts independent investigations of accidents or incidents that they judge to be particularly severe. These include: major accidents and major near accidents, fatal occupational accidents, serious occupational injuries with a potential to cause death and severe weakening or loss of safety functions and barriers threatening the integrity of the facility (Petroleum Safety Authority Norway, 2017a). On average, the PSA conducts approximately five to ten investigations each year. The reports are made public two to three months later on the PSAs website[1].

[1] All investigation reports issued by the PSA are available online: http://www.ptil.no/investigations/category893.html

The PSA's investigation process is rooted in an MTO (hu(man)- technology-organization) perspective, applying the method MTO-analysis (Tinmannsvik, Sklet, & Jersin, 2004) adapted from the Swedish nuclear industry (Bento, 1992). The MTO-perspective considers accidents to be the result of complex interactions between human, technological and organizational factors (Rollenhagen, 1997) and the MTO-analysis represents a linear hierarchical accident model and aims to map out human, organizational, and technological factors contributing to an event, assuming an equal representation of the factors. However, the method does not specifically include factors at the inter-organizational level. Due to its linear representation of the sequence of events and corresponding causes, some researchers argue that the method insufficiently captures complex interrelationships among factors which can lead to major accidents (Leveson, 2004; Sklet, 2004; Vinnem, 2006). It has also been questioned whether this format of analysis influences the mindset of the investigators to focus on lower levels of analysis, thereby devoting less attention to more abstract higher level factors such as those pertaining to organizational aspects (Rollenhagen, 2011).

Several newer investigative methods have emerged such as Accimap (Rasmussen & Svedung, 2000), FRAM (Hollnagel, 2012b) and STAMP (Leveson, 2004) that take into consideration accident factors in the socio-technical system as a whole, of which interorganizational factors are integral. They seem to be favoured by academics, but not by practitioners, which means that, in practice, these methods are rarely applied in the industry. Underwood and Waterson (2012) argue that this can most likely be explained by issues with usability and user bias, validity and that the models do not identify individual factors at the individual level so that blame can be assigned. Moreover, since these methods target higher-level factors that are more remote from the chain of events, recommendations for improvements can appear more diffuse and less specific, as they are not directed at concrete situations or tasks, but rather highlight dysfunctional systemic properties or interactions.

Preferably, several investigation methods should be combined in order to sufficiently highlight all aspects of a complex accident or incident (Sklet, 2004).

1.2. Interorganizational factors and incidents

The steady increase of outsourcing in the petroleum industry and other high-hazard industries has prompted debate in safety research about the implications for safety management and increased major accident risk (Le Coze, 2017; Oedewald & Gotcheva, 2015). The reality of outsourcing is that operational activities are no longer confined to the operator company, but are performed by a constellation of individual autonomous actors. In petroleum operations, contractor companies are involved in a great variety of safety-critical activities, spanning from design and construction of offshore facilities, maintenance and modification activities, to specific expert services pertaining to drilling and well activities. When activities are distributed across a growing number of contractors and subcontractors, organizational processes become more fragmented and more challenging to manage, and it becomes more difficult to maintain a "big picture" understanding, as no single organization or individual is responsible for the overall result (Albrechtsen & Hovden, 2014; Priemus & Ale, 2010; Quinlan, Mayhew, & Bohle, 2001). Moreover, companies differ, not only in terms of their operational involvement and areas of expertise, but also in terms of cultural and organizational practices, which adds new layers of complexity to the system. For example, Moorkamp and collegues (Moorkamp, 2017; Moorkamp, Kramer, van Gulijk & Ale, 2014) have written about safety issues stemming from dysfunctional social interactions among members from different units collaborating in temporary organizational constellations in military operations.

In their review of the empirical literature addressing interorganizational safety issues within safety-critical industries, Milch and Laumann (2016) identified four broad categories of interorganizational safety issues: issues related to economic pressures between companies, such as safety/production trade-offs (Gomes, Woods, Carvalho, Huber, & Borges, 2009) and blame (Jeffcott, Pidgeon, Weyman, & Walls, 2006); issues related to coordination and organization of activities across companies, such as communication breakdowns between companies (Albrechtsen & Hovden, 2014), cumbersome and complex safety management systems (Kongsvik & Fenstad, 2007) and confusion in roles and responsibilities (Quinlan et al., 2001); issues pertaining to inadequate competence and experience, such as contractor and sub-contractor employees who lack industry-relevant training and experience (Oedewald, Gotcheva, Reiman, Pietikäomem, & Macchi, 2011) or are unfamiliar with the local work environment (Nenonen & Vasara, 2013); and finally issues originating from organizational differences between companies, such as variations in work practices (Cedergren, 2013) and distrust between employees from different companies (Collinson, 1999). The study showed that the complexity of involved companies and the resulting fragmentation of organizational processes lead to increased challenges in terms of supervising and controlling organizational processes as well as maintaining operational oversight. Such issues were in turn associated with elevated major accident risk, as they contribute to produce latent conditions in the system that can go unnoticed, at the same time as hindering important safety management functions (Milch & Laumann, 2016).

In the last decade, there have been several severe incidents in the petroleum industry in which similar issues have been identified as central contributing factors. The most serious recent examples are the Deepwater Horizon accident in 2010 (National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling, 2011; Tinmannsvik et al., 2011) and the Montara oil spill the preceding year. In both these accidents, communication failure, disorganization and confusion regarding roles and responsibilities, inadequate management of competence across companies, and insufficient processes to follow up and check work across involved companies, were found to result in a number of critical errors. The chief counsel's report, following the Deepwater Horizon accident in particular, drew attention to the overarching failure of management, in which central aspects concerned the follow up of contractors in terms of work and competence, and the failed coordination of interfaces between companies. The report also pointed out the highly compartmentalized nature of information within individual companies and organizational units as an important condition hindering the sharing of important information across companies, ultimately resulting in a severely flawed decision making process. Many of the same issues were found in the investigation following the serious well control incident on Gullfaks C in 2010 (Austnes-Underhaug et al., 2011), which has been characterized as one of the most serious near major accidents in Norway the last decade. Arguably, these findings demonstrate that interorganizational factors can contribute to serious safety-critical errors and lead to serious situations in petroleum operations.

1.3.Clarification of terminology

There are many terms found in the literature describing undesirable events: accident, incident, near miss, near accident and so forth. Although extensively applied, there seems to be little consensus in the literature regarding the application and use of these terms. Consequently, the various concepts are used differently and sometimes interchangeably. In order to avoid confusion, we will provide a short description of the terms as applied in this paper.

Following Kjellén and Albrechtsen (2017), *incident* is applied in this paper as an umbrella term for all types of unplanned events resulting in undesired outcomes. Moreover, the paper applies Hollnagel's definition of the term accident: "an unforeseen and unplanned event which leads to some sort of loss or injury" (Hollnagel, 2016). Since incidents vary in terms of magnitude, severity and complexity, a further distinction should be made between occupational accidents and major accidents (Reason, 1997). Occupational accidents tend to be higher in frequency. While they can have severe consequences and result in fatal outcomes, they are often limited in their reach. Major accidents, on the other hand, are rare occurrences, but when they occur, they are system-wide events that have devastating consequences, often resulting in several fatalities and significant damage to assets and surroundings. These events are difficult to control and understand, as they originate from multiple and complex interrelated causes of a human, technical and organizational nature. The PSA defines a major accident as: "An acute incident, such as major discharge/emission or a fire/explosion which immediately or subsequently causes several serious injuries and/or loss of human life, serious harm to the environment and/or loss of substantial material assets" (Petroleum Safety Authority Norway, 2017b)

Near misses also vary greatly in terms of severity and risk. For example, a near accident involving a dropped object has the potential to cause serious damage or injury, but the escalation potential is limited. A well control near miss incident on the other hand involves an escalation potential where the scenario could potentially result in a major accident. Accordingly, it is important to distinguish between the two. In this paper, we apply the definition of *near accident* in similar way that Jones et al. (1999) use the concept near miss, to incidents that represent "a hazardous situation, event or unsafe act where the sequence of events could have caused an accident had the sequence of events not been interrupted" and the term *major near accident* is used to describe occurrences that had the potential to result in a major accident.

2. Method

In order to explore the research questions, a qualitative analysis of investigation reports was performed. Due to the explorative focus of the current study, a qualitative approach was preferable because it allows for obtaining in-depth insight into how interorganizational complexity relates to incidents in the Norwegian petroleum industry. In the following, the methodological aspects of the study are described.

2.1. Investigation reports included in the study

Investigation reports of offshore incidents and accidents on the NCS issued by the PSA in the period 2006–2016 were obtained from the PSA. These are publicly available on the PSA website. In terms of the objectives of this paper, a broad scope of incidents was desirable. Accordingly, all types of incidents and accidents were included. Reports were included in analysis based on the following criteria: interorganizational factors are identifiable in the report, and interorganizational factors identified have contributed to the incident, either directly or indirectly.

In this paper, we define interorganizational factors as conditions, actions or circumstances that contribute to unwanted outcomes, occurring at the interfaces of two or more companies. Reports, in which interorganizational factors could not be identified, either because interorganizational conditions were not discussed, or because sufficient details concerning interorganizational aspects were not available in the report, were excluded. Moreover, reports in which interorganizational factors were identified but could not be linked causally to the incident were also excluded. In total, 50 reports involving incidents offshore in the period 2006–2016 were identified. Among those, 22 reports fit the criteria and were included in the analysis. Note that one of the incidents included (Report 9) was investigated by an independent research company (IRIS). In this particular case, the PSA did not conduct a full investigation. However, the IRIS-report investigates the underlying causes of the incident. Due to the severity and relevance of this particular incident, we chose to include the report in the analysis.

Incidents in which the potential consequences are related to personal injury or asset damage in which escalation potential is limited were categorized as occupational incidents. Major near accidents were defined using PSA's categorization of major accident indicators (DFUs) which reflects known scenarios in which the potential for a major accident is present (Petroleum Safety Authority Norway, 2017c). The PSA lists the following major accident indicators: unignited and ignited hydrocarbon leaks, well control incidents, fire and explosions in other areas, vessels or objects on collision course, damage to facility or stability structure, leaks or damage to subsea production facilities, pipelines or associated equipment, evacuation incidents and finally helicopter incidents. In this paper, we have not included helicopter incidents. By using major accident indicators, we were able to distinguish between incidents in which the potential for a major accident was present, and incidents in which the risk potential was less severe, which is an important distinguishing feature for major near accidents compared to occupational incidents.

Of the included reports, eight were characterized as major near accidents. Of these, there were two well control incidents, two hydrocarbon leaks, two oil spills and two stability incidents. Fourteen of the reports were occupational incidents of which seven were accidents involving fatal or serious injury. The remaining seven involved occupational near accidents. With regard to type of incident, ten of the occupational incidents were related to improper handling of equipment during lifting and winch operations, two involved lifeboat equipment failure during maintenance work (in a non-emergency situation), one involved a person overboard during dismantling of scaffolding, and one involved dropped unsecured equipment. Table 1 provides an overview of the included reports.

Table 1
Investigation reports included in analysis

Number	*Year*	*Type of incident*	*Categorization*
1	2016	Well control incident, sudden uncontrolled release of gas	Major near accident
2	2016	Personal injury, sudden release of wire rope during winch operation	Occupational accident
3	2015	Personal injury, dropped object during coil tubing operation	Occupational accident
4	2015	Hydrocarbon leak, ruptured segment in bypass line	Major near accident
5	2015	Life boat incident, unintentional launch of life boat	Occupational near accident
6	2012	Stability incident, hull damaged by unsecured anchor	Major near accident
7	2012	Stability incident, list due to unintentional filling of ballast tank	Major near accident
8	2010	Lifting incident, dropped object resulting from damage to link blocks in elevator	Occupational near accident
9	2010	Well control incident, rupture in casing and subsequent loss of well control	Major near accident
10	2009	Lifting incident, dropped object due to unintentional elevator release	Occupational near accident
11	2009	Personal injury, person hit by falling riser during lifting operation	Occupational accident
12	2009	Fatal accident, person overboard during dismantling of scaffold	Occupational accident
13	2009	Lifeboat incidents, dysfunctional release mechanism on freefall lifeboats	Occupational near accident
14	2008	Hydrocarbon leak, plug came loose during modification work in utility shaft	Major near accident
15	2008	Oil spill, rupture in loading hose during loading of oil to tanker	Major near accident
16	2008	Personal injury, person hit by steel beam during winch operation	Occupational accident
17	2007	Oil spill, rupture in loading hose during loading of oil to tanker	Major near accident
18	2007	Dropped object, unsecured equipment fell down on drill floor	Occupational near accident
19	2007	Lifting incident, dropped object due to unintentional elevator release	Occupational near accident
20	2007	Fatal accident, person overboard during winch operation	Occupational accident
21	2007	Lifting incident, dropped object, riser and BOP came loose from running tool	Occupational near accident
22	2006	Personal injury, person struck by falling object during winch operation	Occupational accident

2.2. Data analysis

Analysis was performed using Braun and Clarke's version of thematic analysis (2006). The method is particularly appropriate for exploring patterns in textual data, offering a systematic and flexible approach for identifying themes in the data. There are five analytical steps: the first step involves familiarization with the material through repeatedly reading the content. When familiarization is achieved, the material is systematically coded line by line, and descriptive labels are assigned to smaller units of text. This part of the analysis was performed using the software program Nvivo 11. After the first level of coding, the next step involves sorting and grouping initial codes into developing themes and subthemes in which codes with similar content are clustered together. The sorting process is quite rudimentary at this stage, forming a general impression of the most important thematic areas in the material. In the subsequent stage, content of codes and themes are thoroughly reviewed and compared in order to identify deviations or discrepancies. Constantly comparing and refining the codes and themes is a continuous process throughout the entire analytical process. In the final stage, the candidate themes are reviewed and organized into a final set of themes.

Thematic analysis can be performed with varying degrees of interpretation. Braun and Clarke (2006) distinguish between latent and semantic coding. While the former largely focuses on what can be read between the lines, implying a high degree of interpretation, the latter involves remaining close to what is explicitly stated in the text, relying on a less expansive form of interpretation which is much more bound to the content. In this study, the coding process was focused on a sematic level, meaning that the codes closely reflect the content of the reports. Examples of the coding process are given in Table 2.

It has been argued that, due to the different nature of occupational incidents and incidents with major accident potential, greater effort should be made to distinguish between the two (Vinnem, Hestad, Kvaløy, & Skogdalen, 2010). Following this argument, we conducted separate thematic analyses for occupational incidents and major near accidents, in order to identify potential variations in contributing interorganizational factors.

Table 2
Examples illustrating coding process

Text segment	*Initial coding*	*First categorisation*	*Sub-theme*	*Main theme*
No other information documenting either original design or the modified solution with regard to design, manufacturing or load capacity was presented. Drawings that came with the new certificates from [manufacturer] were not up to date/correct and showed original design.	Information lacking about changed design	Changes in design not communicated	Insufficient communication of change	Communication breakdown between companies
The follow up on the part of [contractor] of the work performed by [sub-contractor] personnel on [installation] was largely limited to conversations about plans and progress. [Contractor] follow-up appears in little degree to have focused on risk aspects relating to the job. No activities have been carried out to ensure that [sub-contractor] personnel are familiar with known [operator] requirements relevant for performing the work.	Follow up focused on progress Insufficient activities in follow up	Insufficient follow up	Insufficient follow up of work performed by third-party companies	Inadequate quality control processes across organizational interfaces
As a part of a pattern, the responsibility of other discipline leaders for other disciplines was pointed out when we asked who had a role in the design and in assessing the design of the pipeline	Different perceptions about responsibilities	Ambiguities in roles and responsibilities		Ambiguities in roles and responsibilities between personnel from different companies
It was found that personnel involved in maintenance of lifeboat davits did not possess equipment specific competence. This was found in both operational personnel during the installation and external expert assessment group that carried out the periodical expert control	Lacking equipment-specific competence	Personnel lacking equipment-specific competence	Lack of installation-specific experience and training	Inadequate processes to ensure sufficient competence across interfaces

3. Research findings

Analysis of the reports show that interorganizational factors were most frequently identified as contributing to maintenance and modification incidents and incidents pertaining to lifting operations, but they were also identified as contributing to well control incidents, stability incidents, hydrocarbon leaks and oil spills. Accordingly, interorganizational factors can be ascribed to a wide range of unwanted occurrences, representing both occupational near accidents and accidents and as well as incidents that can be categorized as major near accidents with the potential to escalate into uncontrolled situations.

Thematic analysis resulted in four main themes describing interorganizational factors contributing to incidents offshore: *ambiguities in roles and responsibilities between personnel from different companies, inadequate processes to ensure sufficient competence across interfaces, inadequate quality control routines across organizational interfaces* and finally *communication breakdowns between companies*. Interestingly, there was very little variation in themes identified for occupational incidents and major near accidents as the analyses resulted in the same interorganizational factors. However, there were some variations in terms of how the factors are reflected in the two incident categories. Table 3 gives an overview of the themes (main interorganizational causes) and sub-themes identified in analysis and shows the distribution of themes in the reports. Moreover, the table shows the likely precursors to the interorganizational factors and how the themes appear to be causally related to the incidents.

Table 3

Results from thematic analysis

Themes identified in the analysis		Distribution of themes in the reports			Causal relationship	
Likely precursors	**Main interorganizational cause** Sub- themes	Total number of reports (percent)	Occupational incidents	Major near accidents	Type of errors	Likely effect on incident
Vague descriptions of roles and areas of responsibilities between companies Organizational change Complex division of responsibility	**Ambiguities in roles and responsibilities between personnel from different companies**	12 (54, 5 %)	8	4	Omission of safety critical tasks in planning Omission of quality control and follow-up	Important risks remained unidentified which contributed to incident
	Inadequate processes to ensure sufficient competence across interfaces	17 (77, 3%)	11	6		
Unclear criteria for when to involve experts	Personnel with relevant competence not involved in planning	4	0	4	Important risks not identified in planning	Uninformed decisions which contributed to incident
Competence criteria too vague Competence criteria overlooked Content of training program too general Contractor personnel not involved in training program/ received insufficient training	Insufficient installation-specific or equipment specific competence and training	14	10	4	Personnel unaware of important risks in the environment and of the risks involved in operating equipment	Uninformed decisions in planning operations wrong use of equipment which contributed to incident
	Inadequate quality control routines across organizational interfaces	12 (54, 5 %)	9	3		
Lack of coordination between companies in design phase	Lack of integrated quality control of assembled structures	3	1	2	Design errors Existing design errors not discovered	Poor design remained unidentified which contributed to incident
Lacking systematic processes	Insufficient control processes in equipment handover	3	3	0	Errors with equipment not discovered	Unidentified issues with equipment contributed to incident
Lacking routines for following up contractors Trust in other company's competence	Insufficient follow-up of work performed by third-party companies	7	6	1	Insufficient planning and execution of operations	Important risks remaining unidentified which indirectly contributed to incident
	Communication breakdowns between companies	16 (72, 7%)	10	6		
Lacking routines for experience transfer	Insufficient experience transfer	6	3	3	Known risks not communicated	Uninformed decisions which contributed to incident
Lacking routines for communicating changes	Insufficient communication of change	2	0	2	Changes made to design not communicated	Design weakness which contributed to incidents
Insufficient quality control routines	Poor availability and quality of information	12	9	3	Risks remain unidentified	Risks not identified which indirectly contributed to incident

The table presents results from thematic analysis. From left to right: The column to the far left shows likely precursors to identified themes. Next, main themes are presented in **bold** and subthemes are presented below in regular font. The next column includes a distribution of the themes in the reports, showing the total number of reports in which the themes are found, and how many of these are occupational incidents and major near accidents. The next column shows the types of errors associated with the themes, and finally, the last column provides information about likely causal effects of identified themes. Note that the categories are not mutually exclusive, as some incidents involve more than one theme or sub-theme.

3.1.Ambiguities in roles and responsibilities between personnel from different companies

Ambiguities in roles and responsibilities between personnel from different companies were the first factor identified in the analysis of elements contributing to incidents. The theme was identified in 12 of the 22 reports. It was found to contribute to major near accidents as well as to occupational incidents. Analysis suggests that roles and responsibilities tend to be insufficiently defined and perceived differently across collaborating companies and organizational units. Such ambiguities were identified in design, planning of operational activity as well as in the execution phase of operations, implying that this is a widespread issue spanning across several safety-critical phases.

A tendency uncovered in the reports was the assumption that some other company or organizational unit was responsible for ensuring that things were done safely, and that safety critical areas were covered by someone else in the project. The lack of a complete understanding of roles and responsibilities across collaborating companies was linked in the reports to the omissions of safety critical activities such as risk analyses as well as disruptions in the follow-up and quality control of operational processes. For example, in the report following a serious hydrocarbon leak, ambiguities in the division of responsibilities between companies involved was linked to poor design choices when the facility was designed as well as a failure to detect these design weaknesses through quality assurance activities. These conditions indirectly contributed to the incident: *It emerged during the interviews that a lack of clarity prevailed about which specialists in the project, both internally in the various companies and at the interface between them, were responsible for checking that the final design of valves in the pipework was robust. People repeatedly referred to other disciplines, organizational units or companies when asked who was responsible* (Report 4).

Another example can be found in a lifting incident. In this case, the responsibility for ensuring that equipment was in accordance with rules and regulations was not sufficiently clarified between the supplier of the equipment and the operator company, which resulted in a failure to discover issues with the equipment: *It was not specified in the contract between [operator company] and [supplier] how HSE requirements was to be ensured and who was responsible for this. The result was that important issues with the equipment was not uncovered, neither when the order was placed nor when the equipment was shipped to the facility* (Report 19).

In many cases, ambiguities occurred because the division of roles and responsibility between companies were poorly defined, or even conflicting, leaving room for confusion and misunderstandings. In some reports, this was ascribed to inconsistencies in governing documentation, discrepancies in organizational maps and described reporting lines, as well as vague job descriptions and work descriptions. In other cases, ambiguities seem to derive from work practices deviating from what was formally described in governing documentation where established formal interfaces were bypassed or companies were put to perform other tasks than those defined through contract: *"Responsibility and authority was not unequivocally defined on the drill floor (...). Interfaces between the actors on the drill floor on [installation] were unclear. On the drill floor, tasks which [contractor company] had a contract to carry out were in practice distributed between [drilling contractor] and [contractor company] personnel"* (Report 11).

Moreover, the fragmented and complex nature of how responsibilities are distributed between companies, in itself, also appears to be a source of ambiguities and confusion among collaborating units and companies (Reports 4, 15, 13 & 17). Within certain operational domains, the division of responsibility was extremely intricate. Divided across different organizational units and spanning interfaces offshore/onshore as well as professional disciplines, some areas of responsibilities were so complex, that the investigation team in some cases had problems obtaining a complete overview of all involved actors when performing their investigation. *"One of the biggest challenges in this investigation has been to acquire a clear understanding of who has been involved, directly or indirectly, and what responsibility the people involved have had for the work of improving and replacing the lifeboats"* (Report 13).

While ambiguities in roles and responsibilities are found interorganizationally, the analysis suggests that the issue is just as pertinent internally within companies. This was a particularly recurring issue within the largest operator company where several reports revealed ambiguities in roles and responsibilities internally between organizational units, which in turn affected the follow-up and the coordination of contractors. This implies that the issue is not necessarily an interorganizational one alone, but may rather reflect a general tendency that, before activities are commenced, roles and responsibilities are not properly clarified across interfaces in projects.

3.2. Inadequate processes to ensure sufficient competence across interfaces

Insufficient competence was often cited in the reports as a factor contributing to incidents. Analysis suggests that there are inadequate processes to ensure sufficient competence across interfaces. This is evident both with regard to ensuring competence across collaborating companies, as well as internally across organizational units. This theme, which is found in 17 of 22 reports, is the most prevalent of the themes identified. The theme incorporates two subthemes: *Lack of installation-specific experience and training* and *personnel with relevant competence not involved in planning.*

3.2.1. Lack of installation-specific experience and training

Several incidents were attributed to problems with personnel lacking relevant competence and experience, most of which involved contractor personnel from third party companies that were new and inexperienced, had not received sufficient training for the equipment they were operating, and did not have sufficient knowledge about procedures and regulatory requirements. Most incidents attributed to this issue were occupational, relating to lifting, maintenance and modification activities. Several of the reports found that contractor personnel were asked to perform tasks and operate equipment with which they had little prior experience or training. In some cases, personnel had been placed to fill positions different from those they had been hired to occupy: *"The person responsible for installing the exhaust cooler had not received formal training in the use of temporary lifting equipment in accordance with NORSOK R-003 requirements"* (Report 22).

While insufficient competence and training in several reports were identified as an underlying cause contributing to incidents, few of the reports actually address specifically how the issue contributed to the incidents. Consequently, based on the reports, it is difficult to establish the causal contribution of this factor. However, from what is inferred in the reports, insufficient competence and training appear to have contributed to errors resulting from improper use of equipment, maintenance errors as well as poor planning of activities due to lack of awareness of local risk and hazards.

In some cases, not having adequately trained and experienced personnel performing tasks seemed to be related to a shortage of manpower and low capacity (e.g., Reports 2 & 7). However, the prevalence with which workers are found to operate equipment without formal training can also imply a tendency to disregard competence criteria in the industry. This includes not appreciating the variations of different types of equipment and their user interfaces, the knowledge and skill level required to operate equipment safely and the competence needed to identify significant risk factors in a given environment: *"Use of elevator was not covered in the training matrix on board (...) involved personnel did not have sufficient competence to use the elevator correctly. It was a general misconception among* *involved personnel that the safety pin could be seen as a verification that the elevator was properly closed and locked"* (Report 19).

The reports also point to several shortcomings in systems meant to ensure competency across organizations. Insufficiently specific training manuals and procedures were frequently mentioned in the reports. It was pointed out that the content of training manuals was too general and did not describe all risk aspects of operating specific types of equipment. Several reports also highlighted that the overview of completed training for contractor employees was described too generally, providing insufficient information about the specific type of equipment an individual has been trained to use. Moreover, in many cases, competence criteria were also too general, and did not specifically describe what type of competence would be necessary to perform tasks or use certain types of equipment. For example, in a lifeboat incident ascribed to inadequate maintenance, neither the personnel performing the maintenance work, nor the contractor hired to do periodic expert assessment, were found to possess the equipment-specific competence needed to perform their tasks. The investigation team reported that the maintenance training program was too general and was not optimized to the specific design of this particular piece of equipment: *"A limited description is provided of the content of training manual for the life boat system (...) Generally speaking, knowledge and familiarity with the content of the user manual for life boat davits is lacking. That applies to both MDN operators and management personnel on board who are responsible for using and maintaining davits. Inadequate knowledge of the user manual's content has also been identified at [third party company], the third-party company involved in davit maintenance, and at [third party company] as the enterprise of competence for davits"* (Report 5).

Two of the reports connect insufficient competence and training to insufficient introduction to the installation for new personnel (Reports 11 & 12). Completing an introduction round is mandatory to all personnel who are new to an installation, the purpose of which is to familiarize new personnel to the installation as well as equip them with necessary information pertaining to health, environment and safety, so they are able to perform their tasks safely. In one report, the introduction program was found to be too focused on the social aspects of the work, and as a consequence, the workers were not equipped with the necessary information to understand local risks: *"The [drilling contractor] mentor system has a "social" character where the main focus is to become familiar with the facility. The mentor system is not used to verify competence, including risk perception or special follow up of new scaffolders"* (Report 12).

3.2.2. Personnel with relevant competence not involved in planning

The second sub-theme identified under the current theme concerns the failure to include relevant personnel with expert competence in planning operational activities. Planning of operational activities spans several disciplinary areas of expertise and requires the involvement of personnel that have expert knowledge pertaining to specific processes, technology, equipment or components. In several reports, failing to involve competence existing internally within the operator company, as well as representatives from suppliers or contractors that hold competence pertaining to specific equipment, was linked to the occurrence of incidents. The lack of expert competence in these incidents was found to result in serious planning errors as important risks were not identified nor were they properly understood by those involved.

The issue is identified in both occupational incidents and major near accidents and was found to be a central contributing factor in four major near accidents including two serious well control incidents and two hydrocarbon leakages. A recent well control incident on a mobile drilling unit was, among other things, ascribed to a failure to involve experts from central contractors in planning. In this case, an unconventional well design, in which the actors involved had little experience with the equipment, had been chosen. Specialists from the supplier of a valve serving as a central barrier function had not been invited to participate in the meeting at which risk aspects concerning well design were discussed. The report argues that the presence of expert competence in this case could have prevented the incident, as it would have been more likely that risks connected with the chosen well design would have been discovered: *"According to information received, invitations to the meeting were sent to people in [drilling contractor] and internally in [operator company]. (...) Documentation received shows that neither representatives from the suppliers of subsea systems nor the supplier of FCV/GLV (valves), respectively [supplier] and [supplier], were invited to participate. The well planning group did not identify the risk of using the GLV and FCV (valves) as barrier elements with a vertical X-mas tree (valve assembly device placed on wellhead)."* (Report 1).

Correspondingly, the report following a hydrocarbon leak in the utility shaft of an installation, found that the contractor company failed to include experts from the operator company who had knowledge about the process system and relevant risks: *"The completion of safety run-throughs (Safeop/SJA) lead by [contractor company] was carried out with varying degrees of participation from experts with relevant backgrounds, which is relevant in terms of being able to identify and consider risk for process incidents"* (Report 14).

Few of the reports consider reasons why experts were not included in planning in these incidents. However, from the available content, it appears that one challenge is recognizing when expert competence is necessary. Two of the reports, both relating to serious well control incidents, indicated a perceived control and trust within the group that existing competence was sufficient to properly plan activities and that expert competence would not be necessary (Reports 1 & 9). In these incidents, the involvement of experts could potentially have prevented the situations from spiralling out of control. Hence, this could indicate a challenge, particularly in planning complex operations, to understand when existing competence is sufficient and where the boundary lies for when the utilization of certain equipment or processes requires specialist competence.

3.3. Inadequate quality control processes across organizational interfaces

Inadequate quality control processes was the third factor identified. Analysis suggests that processes to ensure systematic and integrated quality control between companies in design, planning and operation sometimes are ineffective in terms of identifying weaknesses and faults in the system. Identified in 12 of the reports, the theme is consistently found across various types of incidents and across various company constellations. Nine of the incidents were occupational and other three were major near accidents. Three sub-themes were identified within this theme: *lack of integrated quality control of assembled structures, insufficient quality control in equipment handover* and *insufficient follow-up of work performed by third party companies*.

3.3.1. Lack of integrated quality control of assembled structures

In several incidents, design errors in safety critical equipment and structures appear to be linked to the lack of overall assessments of assembled structures as a whole (Reports 4, 6 & 13). Structures on offshore installations comprise of multiple components delivered by different suppliers, intended to function as a coherent whole. This means that, in the design phase, components delivered by one supplier need to be dimensioned in correspondence with other components that go into the structure, which in many cases are delivered by other suppliers. While individual components tend to be thoroughly controlled, there were several examples where quality control of assembled structures as a whole had been omitted, thereby contributing to unwanted situations. For example, in the report following a stability incident on a mobile drilling facility, the incident was connected, among other things, to multiple structural design weaknesses on the vessel. Dimensioning of the anchor bolsters, the hull and the anchor winches had been calculated separately, without an integrated assessment of the component compatibility. Incompatibilities in the components were not identified, ultimately contributing to a breach in the hull which produced a serious list: *"A general deficiency was cooperation between and understanding of the preconditions applied by different players when designing, constructing and operating the facility"* (Report 6). Lack of integrated quality control processes appeared, in many cases, to result from ambiguities in roles and areas of responsibility among companies and complex division of roles and responsibilities.

3.3.2. Insufficient control processes in equipment handover

Insufficient control processes were also frequently observed in the handover of equipment. Generally, the contractual terms pertaining to responsibility and use of drilling equipment are quite complex. A great deal of drilling equipment is hired by the operator from third party companies, but can often be manufactured by a different company. Moreover, the equipment is normally contracted to use by a drilling contractor or a different contractor company. Consequently, quality control processes involve a number of handovers between organizational interfaces. In several reports, it was found that quality control processes in handover had failed, so that errors and faults with equipment had not been discovered and later had contributed to unwanted situations (Reports 2, 8, 10 & 13).*"Initial inspections by [Supplier], [operator company] and [drilling contractor] did not reveal that the elevator had not been modified pursuant to [Safety notice document] or [Production update notification document] from the manufacturer, or that that the operating manual was not delivered, or that the certificates for the elevator were not available on board"* (Report 10).

Few of the reports address the reasons why quality control processes in handover in certain cases fail, but, in two of the reports, it is indicated that such deficiencies can be ascribed to the lack of systematic processes internally in the companies. For example: *"[The operator company] does not have a system to ensure that lifting equipment it owns meets relevant regulatory requirements. [drilling contractor] does not have a management system to ensure that custom-designed lifting gear in the drilling area is checked and certified by a competent body"* (Report 8).

3.3.3. *Insufficient Follow-up of work performed by third party companies*

Another tendency identified in the analysis is that work or services provided by third-party companies in many cases is not verified or followed up sufficiently (Reports 5, 11, 12, 13, 14, 16 & 20). There were several incidents in which work performed by third-party companies had not been properly followed-up, where faults and errors had gone unnoticed: *"Separate analyses or assessments have not been conducted by [operator company] for risk, individual faults, barriers, functionality and the performance of safety-critical components and systems related to the new life boats on [offshore facilities]. Nor has [operator company] pursued any activities to assess and verify that other parties involved have implemented the necessary analyses and assessments of the lifeboats"* (Report 13). Some reports found that operators sometimes failed to check whether contractors actually had sufficient competence to perform the services they had been hired to perform: *"We would also like to point out that [operator company] should have registered [contractor]'s lack of crane and lifting competence at an earlier stage and thus made sure that a formal organization and competent personnel were present at the planning of the lifting operation"* (Report 16).

In addition, few of the reports discuss reasons why verifications and follow up of third party services are omitted. In one report, the issue is connected to lack of systematic processes to control and provide feedback on third party services: *"Conversations both on the facility and on land indicated that no systematic approach is taken to assess or provide feedback on work carried out by third-party contractors on the facility"* (Report 5).

However, there are indications that this issue to some extent may also be rooted in a high degree of trust in the work delivered by other companies. Due to the level of specialization and the fragmented nature of expertise, the operator or the drilling contractor is dependent on hiring companies that hold specialist competence they do not possess themselves. As such, they have to rely on the competence and expertise of others, which potentially can affect efforts made to verify and follow up the work. For example, in one report it was found that a contractor company, based on previous experience, trusted that the subcontractor would have the necessary competence to plan and complete the work. The contractor company did not possess the specific competence in its own organization, and relied on the subcontractor's competence, consequently not taking the necessary steps to follow up the work: *"[Contractor company] states that it understood that this was a critical job, but did not dedicate responsible technical personnel to the delivery (package responsible) in accordance with normal follow-up. The reason given is that hot tapping is a special expertise that [contractor company] does not possess and that [contractor company] had confidence in and good experience with [subcontractor company]'s competence and work from previous jobs."* (Report 14).

3.4.Communication breakdowns between companies

The fourth and final factor identified as contributing to incidents in analysis concerns communication breakdowns between companies. The issue is identified in 16 of the reports, six of which were major near accidents and nine of which were occupational incidents. Maintaining sufficient information flow across collaborating companies as well as transferring experience and lessons learned appear to be central challenges. Three sub-themes were identified within this theme: *insufficient experience transfer*, *insufficient communication of change* and *poor availability and quality of information*

3.4.1. *Insufficient experience transfer*

Failure of efficient experience transfer and lessons learned between companies was identified in several reports as a factor contributing to a number of incidents, both occupational and major near accidents (Reports 4, 9, 10, 13, 14, 15, 17 & 19). Deficient experience transfer was particularly related to known issues with equipment, local risks and lessons learned from previous incidents. The failure of experience transfer in these cases contributed to the fact that hazardous conditions went undetected and remained uncorrected which later created undesired situations. For example, in the previously mentioned hydrocarbon leak, similar vibration issues in various parts of the process plant had been encountered and resolved on another facilities a few years before. These experiences, although known in the operator company and in the company supplying valves, were never communicated to the contractor in charge of design and construction. Consequently, the problem was never corrected, ultimately resulting in a rupture of the process line: *"The fact that similar control valves had been "reversed" to improve handling of the operating conditions was known both at the [valve supplier] workshop in Bergen and within several of the [operator company]'s operations units and it's expert centre [organizational unit]. This information was not passed on to the [contractor company] or the engineering department of [valve supplier].* (Report 4).

In another example following an occupational incident, it was found that known issues with the elevator equipment were not communicated to the end-users: *"Available safety notifications informing of important experiences with the equipment were not delivered* *with the rental equipment or communicated to the users in other ways. Several safety notices from [manufacturer] and from the supplier, [Supplier], that notified about similar incidents and described different types of compensating measures were not followed up"* (Report 10).

Again, the reports do not consider in detail what causes failure of experience transfer. It seems that although information about past experiences and lessons learned exists within individual companies, good systems are lacking to ensure experiences are systematically collected and shared within and between collaborating companies. In one report, it was mentioned that sharing of relevant prior experiences depended on what was specified in contracts. In this case, operational issues were only communicated back to the building contractor in case of warranty issues: *"Representatives from [contractor company] say that when a facility is taken over by [operator company] and brought on stream, they are not informed about operational experiences and equipment problems unless guarantee issues are involved"* (Report 4).

3.4.2. Insufficient communication of change

The second sub-theme within the current theme concerns issues pertaining to documentation of change. Changes or modifications made to components or equipment are not always communicated between organizations. In two of the reports, changes had been made to the design of a component in a coupler unit where the manufacturer had not documented the change. It turned out that the change made contributed to a design weakness that resulted in unwanted incidents. This was identified as a contributing factor both in (Report 15) and (Report 17). There are other examples, such as (Reports 2 & 3) where changes to equipment were made without being risk assessed or documented, but, in these examples, documentation of change is not linked causally to the incident.

3.4.3. Poor availability and quality of information

The third sub-theme identified within this theme reflects issues related to the availability and quality of information that should be available to operators to perform their tasks, such as user manuals and procedures. There were several examples in the reports where components or equipment had been delivered from the manufacturer without a user manual (Reports 2, 8, 10, 18 & 19)*: "The user manual was not delivered with the equipment and was not available to operating personnel"* (Report 10). In other cases, the information delivered with components or pieces of equipment was of poor quality and did not address relevant operational aspects and important risks: *"The instructions were unclear, illustrations and descriptions of the [equipment] securing device were wrong where eye bolts were used. The supplier had developed an illustration of the securing device, but this documentation was not available on board."* (Report 18). *"Among other things, information about what the alarms meant, a figure showing what had to be greased regularly in the winch, and information about what spring loads the winch should have when the anchors were fastened to the bolsters was missing"* (Report 6).

Over-general and unspecific information was also found to be an issue with internal procedures and guidelines: (Reports 2, 5 & 12). *[Operator company], [contractor company] and [subcontractor company] procedures are of a general nature and are limited when it comes to describing risk aspects for the installer* (Report 12*)*. Sometimes, operational procedures and relevant governing documents were simply unavailable or difficult for contractors to locate (Reports 2, 14 & 21). *"Instruction for work in the offloading area was not available to [contractor company]'s personnel doing the work, but were included in the work instructions for [operator company]'s operations personnel"* (Report 2)

From the conclusions drawn in the reports, the specific influence of this subtheme is difficult to determine as most of the reports list problems with availability and quality of information as deviations without specifically discussing how these issues contributed to the occurrence of incidents. In light of the fact that many of these incident appear to be induced by erroneous actions of contractor personnel who were inexperienced and lacked sufficient information, it is not unlikely that unavailable and poor procedures and guidelines have, without doubt, contributed to these occurrences.

4. Discussion

In this study, we sought to gain deeper insight into how interorganizational factors are related to incidents in the petroleum industry through analysing investigation reports. The following research questions were explored: *What types of incidents and accidents are related to interorganizational issues? What interorganizational factors can be identified in investigation reports contributing to incidents offshore?*

4.1.Factors identified in the study

Addressing the last question first, the analysis revealed several areas in which interorganizational factors have contributed to incidents in the industry. The main issues were related to *ambiguities in roles and responsibilities between personnel from different companies*, *inadequate processes to ensure sufficient competence across interfaces*, *inadequate quality control routines across organizational interfaces* and *communication breakdowns between companies*. This is consistent with previous research on interorganizational safety issues in other high-risk industries where similar factors were identified (Milch & Laumann, 2016), and with findings from the investigations of accidents Montara (Montara Commission of Inquiry, 2010) and Deepwater Horizon (National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling, 2011).

Ambiguities in roles and responsibilities between personnel from different companies emerged as a central challenge in the analysis. While roles and responsibilities are established formally in contracts and in governing documents, analysis suggest that they are often not equivocally understood by representatives involved and that this is an area in which confusion and misunderstandings occur. In several incidents, such confusion was found to result in omissions of safety critical tasks and neglected quality control, such as verification activities to ensure robust design (Report 4), risk analyses (Report 2), and handover inspection (Report 16). This suggests that the disorganization of roles and responsibilities can severely deteriorate existing processes and functions that are in place to ensure safety. This is in line with several studies where confusions in roles and responsibilities between companies have been found to cause safety problems by the deterioration of operational oversight (Mayhew, Quinlan, & Ferris, 1997; Priemus & Ale, 2010). The current findings correspond with findings from both the Montara and the Deepwater Horizon accidents. In the case of Montara, the report pointed at ambiguities in roles and responsibilities regarding well control between the operator and the drilling contractor as one of the most significant indirect causes of the blowout (National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling, 2011). Confusion in roles and responsibilities was also discussed in the chief counsel's report following the Deepwater Horizon accident. Here, questions arise as to whether internal confusion in the operator company about responsibilities for ensuring compliance with the operator company standards, and, for quality control of the cement design delivered by the cement contractor, contributed to the critical omissions in these areas (National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling, 2011).

Another issue *concerns inadequate processes to ensure sufficient competence across interfaces*. The level of specialization and technological complexity inherent in petroleum activities requires that employees have equipment-specific training and experience. However, it could be questioned whether necessary competence requirements are fully appreciated in the industry. Contractor employees were often found to operate equipment without necessary skills. This is in line with findings from other safety-critical industries that have shown contractor-employees often lack installation-specific training and experience (Albrechtsen & Hovden, 2014; Oedewald et al., 2011) and can be unfamiliar with the installation and its specific hazards (Nenonen & Vasara, 2013). While operational failures at the sharp-end, due to wrongful use of equipment, were mostly found to contribute to occupational incidents, the inability to ensure sufficient competence can have far more severe consequences in other operational areas, such as operational planning. Failure to include experts from different domains in operational planning was identified as a contributing factor in several major near accidents, found both between companies as well as internally across organizational units. As important safety-critical processes such as cementing and drilling fluids are delivered by contractor companies, the involvement of contractor specialists is important in order to achieve a comprehensive understanding of all risk aspects. Moreover, internal experts from the operator company also play an important role in terms of checking the work of contractors. In the Deepwater Horizon accident, crucial decisions concerning the cement were made without the consultation of internal experts in the operator company, the involvement of whom could potentially have revealed weaknesses with the cement (National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling, 2011). To some extent, the failure to include experts in the current findings, appears to reflect structural challenges such as lacking sufficient knowledge of expertise in co-workers from other companies and organizational units as well as challenges with coordinating meetings. However, there were also indications of a tendency to trust that available competence was sufficient and that involving experts was unnecessary, which again raises the question of whether competence needs are sufficiently understood.

Another tendency found in the analysis is *inadequate quality control routines across organizational interfaces* with regard to identifying errors in design, planning or problems with equipment. The level of complexity in these projects, where numerous companies are operating independent of each other, requires that good quality control processes are in place so that potential errors can be detected before they are allowed to escalate into uncontrolled situations. It still appears that routines often are lacking to ensure quality control of equipment and processes across companies. One problem in this regard seemed to be that work or services provided by third-party companies is rarely checked. The lack of follow-up of the cement contractor was also a main issue identified in the investigation of the Deepwater Horizon accident. As the cement contractor was a highly regarded, global supplier, the operator management did little to follow up and check the quality of the cement (National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling, 2011). In the reports, as well as in the case of the Deepwater Horizon accident, there seems to be a high degree of trust in the quality of the services provided by known contractors. Of course, the fact that contractors and subcontractors possess specialist expertise implies that a certain level of trust is essential. However, too much trust can induce complacency, potentially causing crucial signals to be missed (Sætren & Laumann, 2015). In this respect, the importance of a questioning culture for safety management in complex systems has been accentuated in safety writings (Weick, Sutcliffe, & Obstfeld, 2008).

With regard to *communication breakdowns between companies*, findings not only suggest that there are great variations in the quality and availability of information but imply several challenges related to the processes by which information is shared across companies. In particular, the failure in communicating changes to equipment and design, and experience transfer, were found to be prevalent issues contributing to undesired events. It appears that good systems are lacking to ensure efficient sharing of information and lessons learned across the companies involved. The findings corresponds with findings from both the Montara and the Deepwater Horizon accidents, in which the failure of the companies involved to share important information and relevant experience across interfaces emerged as an important contributing factor (Montara Commission of Inquiry, 2010; National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling, 2011). In the Deepwater Horizon accident, the drilling contractor had been involved in a similar major near accident four months previously, but failed to communicate the lessons learned. While communication breakdowns between companies can be, to a large extent, ascribed to structural challenges of fragmented work processes across a number of individual companies (Quinlan et al., 2001), there may also be barriers embedded in the contractual relationships between companies that hinder information sharing and experience transfer. For example, some studies suggest that the perceived customer/client aspect of the contractor/operator relationship may hinder contractors from enclosing information about faulty equipment or known challenges (Collinson, 1999; Priemus & Ale, 2010).

While this study targeted interorganizational factors, the issues identified in analysis do not appear to be confined to interorganizational processes alone. It should be noted that similar issues are also found between organizational units within the same company. As the largest operator company on the NCS, the specific operator company in which similar issues were found can almost be considered a complex socio-technical system in itself, with many individual organizational units that are geographically distributed. In this sense, the findings suggest that organizational complexity, whether internally or between companies, implies similar structural challenges.

Another observation is that factors in the current study largely concern structural aspects pertaining to the coordination and management of processes between companies. In Milch and Laumann’s study (2016) challenges pertaining to organizational differences and economical aspects were additionally identified as sources of interorganizational safety issues. In their study, issues such as distrust between employees from various companies and trade-offs due to economic pressures between companies were identified as constraints that negatively influenced processes such as the coordination and sharing of information across companies. In the current study, however, such factors were not identified. This could suggest that interorganizational issues that contribute to produce incidents in the Norwegian petroleum industry largely relate to structural aspects. One the other hand, it could also indicate that issues originating from organizational differences and economic pressures are present, but have not been uncovered in investigations, since these might be factors that are more difficult to get information about in interviews.

4.2.Incidents related to interorganizational factors

With regard to type of incidents, interorganizational factors appear to contribute to both small-scale and more serious incidents, including incidents that can be categorized as occupational incidents such as dropped objects and personal injuries at the sharp-end, as well as incidents with major accident potential, such as well control incidents and serious hydrocarbon leaks. The fact that interorganizational factors are found to contribute to occupational as well as major near accidents, suggests that both appear to stem from the same systemic deficiencies pertaining to the coordination and management of activities across organizations.

Overall, interorganizational issues were most frequently identified as contributing to sharp-end incidents in connection with modification, maintenance and lifting operations, and were less frequently found in hydrocarbon leaks and well-control incidents. Of course, this is not entirely surprising, as occupational incidents pertaining to lifting and modification work are far more frequent than major near accidents such as hydrocarbon leaks and well-control incidents (Vinnem, 2014). Due to this asymmetrical relationship, the prevalence of interorganizational issues in occupational incidents should not necessarily be taken as an indication that interorganizational problems occur more frequently in these incidents compared to the latter category. While it should not be ruled out that such differences could also reflect variations in the degree of influence of interorganizational factors in incidents, a plausible explanation could be that the influence of interorganizational factors is more visible in lifting and maintenance work compared to hydrocarbon leaks and well control incidents in which interorganizational influences may be more remote.

The differences may also potentially reflect variations in the investigation processes in the extent to which interorganizational factors are focused on. For example, several incident reports following well control incidents were found to be quite technical in their focus, and did not always go into detail on organizational aspects. Of course, these incidents often involve more technically complex failures compared to, for example, lifting incidents, which naturally will imply a strong focus on the technical aspects as well as require investigators with thorough technical knowledge of the physical processes. However, human and organizational factors are equally relevant, and should be equally weighted in an MTO-analysis (Rollenhagen, 1997). As these reports are found to be quite technical, and the focus of investigation reports in general tend to reflect investigators' competencies and areas of expertise (Cedergren & Petersen, 2011; Svenson, Lekberg, & Johansson, 1999), one may question whether the composition of investigation teams in these cases was diverse enough to cover all relevant MTO-areas.

Regarding how interorganizational factors are addressed in the reports, few of the reports actually consider such aspects directly. In most cases, underlying factors at the interorganizational level were implied "between the lines", often categorized either as organizational or operational issues. Only four reports were identified that directly list interorganizational aspects as contributing causes. This implies that, despite the fact that causes at the interorganizational level are identifiable, interorganizational aspects tend to be given less focus in investigations. Whereas the composition of the investigation team is one influential factor in this regard, the approach underlying the investigation is another aspect that influences the scope of factors that are included. As previously mentioned, it has been questioned whether the MTO-approach sufficiently captures all aspects that can lead to accidents in complex socio-technical systems (Leveson, 2004; Rollenhagen, 2011; Sklet, 2004). The fact that the method does not directly include factors at the interorganizational level could potentially divert the investigation from interorganizational influences.

Moreover, the extent to which interorganizational aspects are pursued in an investigation process will also depend on factors such as ease of access and availability (Lundberg et al., 2010). In this regard, there could be several conditions that complicate or hinder investigating factors at this level. For one, as PSA investigations is concerned with identifying nonconformities from regulatory requirements, problems at the interorganizational level will inevitably touch upon the question of blame, which generally complicates the process of obtaining unbiased information (Kletz, 2001). Taking into account that the investigation process primarily relies on interviews as the primary source of data collection, obtaining information about such aspects through interviews could prove challenging, particularly with regard to contractor or third party employees who may fear negative sanctions for their company.

4.3.Quality of study and limitations

There are a few limitations to the current study that should be addressed. One aspect concerns the number of reports that could be included in analysis. Of the available reports in the period 2006–2016, less than half of the reports were included in analysis. Many of the reports did not contain sufficient information about interorganizational aspects to inform analysis. There were several reports, with indications that interorganizational factors had had an influence on the incident, which could not be included in analysis. Accordingly, the empirical material on which the analysis is based is restricted to those cases in which sufficient information was available.

Moreover, the quality of the current analysis is very much tied to the content of investigation reports. There was great variation in the reports in terms of scope, length and focus, and the extent to which the reports addressed inter-organizational aspects varied considerably. Of course, as incidents differ widely in terms of severity, context, causal patterns and complexity, what is focused on in an investigation will naturally depend on the specifics of the individual incident and the mandate and therefore, the reports will differ in terms of what causes are found and what aspects are focused on. However, as the PSA investigation process is guided by a standard approach, one would expect that the reports would be more similar in format and content. On the contrary, the PSA reports were noticeably diverse. For example, some reports were quite detailed in the description of organizational context, the interaction between various companies, and what role individual companies had in relation to the incident. Other reports did not contain any information about specific companies at all, and could not be included in analysis. Moreover, while the examination of underlying factors in some reports was quite extensive, evenly addressing human, technical and organizational factors, many of the reports focused exclusively on the technical or human causes, barely discussing organizational aspects.

Such large variabilities did not only introduce certain constraints to the analysis in terms of what reports could be included and what information could be retrieved, but also posed analytical restrictions in terms of how thoroughly each case could be analyzed. In addition, with such variability, it is also difficult to obtain an accurate picture of the representation of identified factors across the various incident categories.

There were also large variations in terms of how underlying factors were discussed in relation to the incidents in the reports. In several reports, contributing factors were merely listed as nonconformities without addressing specifically how identified factors contributed to the incident. Consequently, the extent to which we were able to make inferences about the causal relationships between the factors we identified and the incidents also varied considerably in analysis.

4.4. Implications of study

Despite the above-mentioned shortcomings, the current study has several implications for both research and practice. The study contributes to existing literature and provides new insight about interorganizational challenges in the petroleum industry through the identification of factors that negatively influence safety and contribute to incidents. As such, the study can be regarded as a valuable contribution to an area in safety research in which knowledge is currently limited. Moreover, through the identification of specific factors, the study provides a sound foundation for future research, giving clear direction for areas that should be targeted. More research is needed to better understand the effect of identified factors on safety functions and how such factors develop. Increased knowledge in these areas will be important in order to understand how negative safety effects of interorganizational complexity can be counteracted. As there are great variations in how petroleum operations are governed and regulated across countries, other national contexts should also be explored in order to identify potential national differences.

As the current study utilized a qualitative approach with an in-depth exploration of a limited segment of empirical data, the concept of generalizability is not applicable in the same manner as with quantitative results. Instead, there is a consensus among qualitative researchers that applying the concept of transferability, which concerns to what extent the findings may be transferable in other contexts, is more appropriate in qualitative inquiry (Lincoln & Guba, 2000; Malterud, 2001). The fact that the findings from the current study are in line with previous findings in other safety-critical industries (Milch & Laumann, 2016) suggest that factors identified in this study are not unique to the petroleum industry, but reflect systemic organizational mechanisms that stem from organizational complexities inherent in these systems. It is therefore reasonable to assume that the findings are relevant to other safety-critical contexts with similar interorganizational structures.

The study also has several practical implications for the petroleum industry. The insights from this study provide clear indications for specific challenges that arise between companies and how these challenges can contribute to increased risk of occupational as well as major accident risk. As such, the findings point towards several areas of improvement, and may be utilized to increase awareness in the industry as well as to develop safety measures aimed at ameliorating these issues and strengthening collaboration and organization of work across organizational interfaces. In particular, effort should be made in the industry to improve the coordination of roles and responsibilities across organizational interfaces, as this represents a great source of misunderstandings and safety-critical errors.

Moreover, there is a need for greater awareness concerning the competence requirements embedded in increasingly specialized technological and operational conditions. In this regard, there is also a need to develop better systems for ensuring sufficient levels of competence. The ever-expanding complexity of petroleum operations places greater significance on personnel that have sufficient competence and training, not to mention the role of experts. As expertise is fragmented across many specialized companies and organizational units, safe operations depend on the involvement of the right people in planning and decision-making. Yet, the increased involvement of contractors and third-party companies makes it increasingly challenging to manage and keep track of existing competence in the system. Therefore, sufficient understanding of modern competence requirements and how to meet them is paramount.

The insights from the current study also provide valuable contributions to the field of accident investigation. By demonstrating the relevance of looking into interorganizational factors and their influence on incidents, the current study suggests that there is a need to broaden the scope in accident and incident investigations in order to better capture the organizational mechanisms that are underlying incidents in the petroleum industry. The inclusion of factors identified in this study may enhance the learning potential from investigations and thereby contribute to a more comprehensive understanding of what causes incidents and accidents. In this regard, it could be questioned whether an approach that is purely based on an MTO-perspective is sufficient to address the complexities of modern petroleum operations or if existing approaches should be combined with newer investigation methods that better address complex relationships in socio-technical systems.

5. Conclusion

The current study sought to gain a better understanding of the influence of interorganizational factors on petroleum incidents by exploring investigation reports. Findings suggest that issues at the interorganizational level contribute to both occupational incidents and major near accidents. Mechanisms occurring at the interfaces between companies represent important influences that should be given more attention in investigations. This is in line with recent safety writings contending that investigating incidents and accidents in complex socio-technical systems requires better and more comprehensive approaches that address contributing factors in the system as a whole (Hollnagel, 2012b; Leveson, 2004; Rasmussen & Svedung, 2000).

The findings from this study contribute knowledge that has a practical application value by identifying specific challenges occurring between collaborating petroleum companies that contribute to incidents. From a preventative perspective, the knowledge from this study can be used to develop more comprehensive investigative approaches in the petroleum industry, thereby increasing the learning potential from investigations. Moreover, from a proactive perspective, the current knowledge can be used to inform the development of initiatives in the industry to enhance cooperation and organization of work among collaborating companies, to ameliorate identified challenges and to reduce negative safety effects.

Empirically, the findings from the current study add to existing literature addressing the safety effects of interorganizational factors in complex safety-critical systems, supporting previous findings. In this respect, the findings are not only relevant to the petroleum industry, but offer new insight into what appears to be generic interorganizational challenges that arise from broader organizational mechanisms in complex socio-technical systems. Through the identification of specific challenges, the study also contributes to highlight specific areas in which more research is needed. Future research should aim to develop better understanding concerning how these challenges develop within complex safety-critical systems and explore in more detail how such challenges influence safety. Moreover, research is also needed to better understand how such challenges can be mitigated, so that negative safety effects can be reduced.

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