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The impact of safety climate on risk perception on Norwegian and Danish production platforms

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ABSTRACT: The study explores the impact of safety climate on subjective risk perception of personal and process accidents on Norwegian and Danish offshore production platforms. The Danish data consists of a survey sent to employees on all productions platform in the Danish sector in 2010. The Norwegian data was also gathered in 2010 and comes from the project "Trends in risk level—Norwegian shelf". The results show that Norwegian offshore employees have more positive perceptions of safety and that the management in the Norwegian sector is more involved in safety compared to our Danish sample. Differences across groups are found for both personal and process risk. The Norwegian offshore employees indicate higher subjective risk perception both with regards to personal injuries and process accidents compared to Danish offshore employees.

1 INTRODUCTION

1.1 *Norwegian and Danish offshore industry*

Since major offshore accidents like the Aleksander Kielland accident in 1980 (123 lost lives) and the Piper Alpha in 1988 (167 lost lives), focus on offshore safety and risk perception has become more intense both in the Danish and the Norwegian offshore sector. In the Norwegian sector discussions in the nineties whether safety on offshore installations had decreased or stagnated, dominated. In Norway, the result of these discussions was the introduction of a new legal framework and a White Paper No.7, 2001–2002 on Health, Environment and Safety in the petroleum industry. Also, the "Trends in Risk Level—Norwegian shelf" (TRL) was introduced by the Petroleum Safety Authorities (PSA). The objective of TRL was to measure: the effect of Health, Safety and Environmental (HSE) work in the industry, identify critical areas for HSE and increase systematic knowledge about working conditions and their significance for risk scenario in the Norwegian sector (Tharaldsen et al. 2008). In the Danish sector, however, national initiatives to improve safety have been less widespread. A new "Offshore regulation" became implemented in 2005 regulating safety, working condition and other health related issues on offshore installations. The "offshore regulation" replaced the former "working environmental act" (www.energistyrelsen.dk/). The offshore sector in Denmark is much smaller than in Norway and this could be one of the reasons why the Danish Energy Agency did not introduce projects on the same scale as TRL in Norway. The operating companies in Denmark have conducted their own surveys about safety climate, but until now no research has been done in the entire Danish petroleum sector population.

1.2 *Previous studies*

Within the field of safety research focus on safety climate and risk perception have been intense, and a large number of studies concerning the offshore industry have been carried out (Fleming et al. 1998; Flin et al. 1996; Flin et al. 2000; Høivik et al. 2009a; Høivik et al. 2009b; Mearns et al. 1998a; Mearns et al. 1998b; Mearns et al. 2001; Mearns et al. 2003; Mearns et al. 2004; Mearns & Flin, 1995; Rundmo, 1992a; Rundmo, 1992b; Rundmo, 1996a; Rundmo, 1996b; Rundmo et al. 1998; Rundmo, 2000; Rundmo & Sjoberg, 1996; Tharaldsen et al. 2008). The results of these studies show that there are different factors influencing risk perception like safety climate, work conditions and management's commitment to safety, but also a negative correlation between safety climate and risk perception have been found, indicating that more positive safety climate results are associated with lower risk perception.

1.3 *Safety climate and risk perception*

The concept of safety climate has been discussed for over 30 years. Still, no agreement exists on a single definition of safety climate. Usually safety climate is measured by questionnaires, which give some implication of the current state of safety (Mearns & Flin, 1999). According to Mearns, safety climate is often used to describe employees' perceptions of how safety is dealt with at the specific workplace. Zohar (2008) means that safety climate refers to shared perceptions regarding safety policies, procedures and practices. According to Cooper and Phillips (2004) the last 20 years of safety climate research can be grouped in the following four areas:

1. The design of measurements instruments and their underlying factor structure
2. Development and testing of theoretical safety climate models
3. The examination of relationships between safety climate perception and actual safety performance; and
4. Exploration of the links between safety climate and organizational climate.

The most common used statistical methods to determinate the dimensional structure of safety climate is factor analysis, but still no agreement exists on which dimensions safety climate consists of. Despite differences the research on safety climate is still useful to ascertain employee's perception about safety.

Definitions of risk perception are divided in two major directions: objective risk and subjective risk perception. The objective risk relates to the estimations of probabilities of unwanted events to happen and the consequences these event may have (Bye & Lamvik, 2007). Subjective risk relates on the other side to individual feelings of danger or of safety (Mearns & Flin, 1995). Tierney (1999) argues further that risk and risk estimates are socially constructed and focus on two general topics. The first involves the social and cultural factors that influence the selection of "risk" and definition of what is dangerous. The second trend is related to social construction of objective (formal) risk analysis (Tierney, 1999).

In this study we focus on offshore personnel's subjective risk perception and explore whether or not various safety climate dimensions have an influence on risk perception and in what direction. Based on a former study from the UK and Norwegian petroleum sector we assume that there is a negative relationship between safety climate and risk perception; the higher scores on safety climate aspects, the lower perceived risk (Fleming et al. 1998; Flin et al. 1996; Høivik et al. 2009b; Mearns et al. 2001; Tharaldsen et al. 2008).

1.4 *Cross-cultural comparison*

Due to geographical location and history Denmark and Norway always have been closely connected. The same tendency is seen with cooperation in the petroleum industry. Both the Danish and Norwegian Shelves constitute mature oil producing regions. Some of the Norwegian companies have operations on the Danish sector and the same counts for Danish companies in the Norwegian sector. Also, Danish offshore employees work in the Norwegian sector. The common view in the Scandinavian countries is that there is some kind of a common Scandinavian identity. However, in this paper we will look for potential differences. Yet, there has not been done any comparative safety study on Danish and Norwegian offshore employees, but one study in the building and construction sector have compared Danish and Swedish construction employees. This study found differences in safety performance, where the Danes were found to be more accident prone compared to their Swedish colleagues. One of the explanations was better education among Swedish employees and cultural and institutional differences between Sweden and Denmark (Spangenberg et al. 2003).

1.5 *Aim of the study*

The current study explores the impact of the safety climate on the risk perception of personal and process accidents on Norwegian and Danish offshore production platforms. The aim of the article is to compare two populations of Danish and Norwegian offshore employees working on production platforms and explore the impact of the safety climate on risk perception by testing the following hypotheses:

- Due to long experience with the oil industry the Norwegian offshore employees will show more positive safety climate perceptions compared to their Danish colleagues.
- Perceptions of risk will be the same in both sectors.
- Better safety climate will predict lower risk perception.

2 METHODS

2.1 *Data and samples*

Data used in the study comes from two independent questionnaire studies carried out on both shelves. Both of the studies have been conducted in the beginning of 2010, but separately. The Danish and Norwegian data and questionnaires will be described in more details in the following. The present study

includes only some parts of the questionnaire concerning general information, safety climate scales and risk perception, but the description below includes the whole questionnaire.

2.2 *Danish sample*

The design of the Danish questionnaire was based on a translation of the Norwegian survey from the TRL project and a literature review of studies conducted in the offshore industry in Norway and UK (Fleming et al. 1998; Flin et al. 1996; Flin et al. 2000; Mearns et al. 1998b; Mearns & Flin, 1995; Rundmo, 1992a; Rundmo, 1992b; Tharaldsen et al. 2008). The questionnaire was tested at safety meetings in all three operating companies in order to ensure the understanding of the questionnaire and if there were any topics which were not covered. The questionnaire was sent to all production platforms on the Danish sector which involved 2400 employees. The response rate was 32% (N = 771). The questionnaire contained 241 items divided in the following areas:

a. Demographics and job characteristics: gender, age, education, civil status, installation name, shift pattern, rotation, workings area, whether they were employed in operation or contracting company, years of offshore work, years on present installations and the number of installation worked on.
b. Perceived risk: The respondents were asked to evaluate the risk of specific scenarios to happen, like: helicopter accidents, gas leaks, blow-outs etc. on a 6-point scale ranging from 1 = "very little danger" to 6 = "very great danger". The risk perception scale was originally drawn from a study performed by Marek and colleagues (1985) and has later been used by Rundmo (Rundmo, 1992a; Rundmo, 1992b; Rundmo, 1995; Rundmo, 1996b).
c. Safety attitudes, safety climate and accidents and injuries: The safety attitudes and safety climate scales included statements about safety and respondents were asked to indicate whether they agreed or disagreed on a 5-point scale. Safety climate scales used in the Danish sample are based on the Norwegian survey. Also, the respondents were asked about their involvement in accidents/injuries the last 12 months.

2.3 *Norwegian sample*

In the TRL project, the PSA carries out a questionnaire study every second year covering the entire offshore population. In this article the offshore sample from 2010 was used. In order to be able to compare across the two shelves only employees working on production platforms were included in our analysis. The response rate for the total sample was estimated to be 30%. (N = 7165). With only production platforms included number of respondents count N = 4304. The questionnaire contained 170 items divided in the following areas:

a. Demographics: Gender, age, installation, and work area and shift arrangement.
b. Safety climate was measured by 46 items. The respondents were asked to rate on a 5-point scale to which degree they agreed with different statements like; "My colleagues are very preoccupied with HSE" or "The safety deputies are doing a good job". Some of the statements were formulated negatively like "My work site is often untidy".
c. Risk perception: The respondents were asked about how they perceived specific risk scenarios. The questions were the same as in the Danish sample.
d. Recreational matters offshore: the respondents were asked about facilities offshore and in which degree they were satisfied with them.
e. Sleep and rest.
f. Working environment.
g. Work, health and sick leave.

2.4 *Statistic procedures*

Principal components analysis with varimax rotation was used to explore the dimensional structure of safety climate in both samples. Afterwards the dimensions were tested by Structural Equation Modeling (SEM) and confirmatory factor analyses. Dimensional solutions were tested on both samples separately. The following fit measures were applied: Comparative Fit Index (CFI), Root Mean Square Error of Approximation (RMSEA) and Goodness of Fit Index (GFI). Internal consistency was tested by Cronbach's Alpha separately for both samples. The associations between safety climate and risk perception were tested by the use of general linear modelling with the country as confounding variable. Perceived risk perception of personal and process accidents were dependent variables. Regressions analyses were used to explore the direction of relation between safety climate and risk perception. Regressions analyses were conducted separately for each sample to explore if there were differences in the direction of association between dependent and independent variables. However, regressions analysis was also conducted for both samples together, but the Norwegian sample was approximately 5 times bigger than the Danish sample which influences the results of the analyses.

Mean scores were calculated for each dimension and t-tests were used to compare both groups. Eta squared was calculated to provide an indication of the magnitude of the differences between groups.

Table 1. Dimensions of safety climate and loadings for each item.

Dimensions and items	Loadings	
	DK	NO
Safety prioritisation (DK α = ,699, NO α = ,636)		
Occasionally I'm required to work in a manner that jeopardizes safety	,720	,664
When it comes to one's career it is a disadvantage to be too concerned with HSE	,713	,693
My lack of knowledge of new technology can sometimes lead to an increased risk of accidents	,655	,580
I find it uncomfortable to call attention to violations of safety rules	,631	,626
The regulatory requirements on HSE are not good enough	,652	,629
Safety management and involvement (DK α = ,791, NO α = ,851)		
The company I work for take HSE seriously	,630	,736
My supervisor is committed to working with HSE on the installation	,620	,733
The safety deputies' suggestions are taken seriously by the management	,724	,729
Risky work operations are always carefully examined before they are commenced	,628	,624
My colleagues are very preoccupied with HSE	,654	,659
I can influence the HSE-conditions at my workplace	,565	,661
Information about undesirable incidents are effectively used to prevent them from recurring	,686	,659
The emergency preparedness is good	,610	,603
The safety deputies are doing a good job	,284	,552
The work permit system is always lived up to	,605	,604
HSE versus production (DK α = ,787, NO α = ,706)		
Lack of maintenance has resulted in reduced safety	,793	,702
In practice concern for production precedes the concern for HSE	,813	,758
Reports on accidents or dangerous situations are often "smartened up"	,821	,766
There are often parallel work operations proceeding that leads to dangerous situations	,692	,691
Safety motivation (individual) (DK α = ,766, NO α = ,587)		
Safety has top priority when I do my job	,841	,745
I ask my colleagues to stop work when I think the task in question is being carried out in a risky manner	,852	,699
I stop working if I think it can be dangerous for me or other to continue	,814	,672
I use personal protective equipment	,529	,567
System perception (DK α = ,660, NO α = ,701)		
I think it's easy to find the right steering document	,711	,755
I always know which person within the organization to report to	,726	,756
The HSE procedures are suitable for my work tasks	,711	,804

2.5 *Scales*

The scales used in this study were extracted from previous studies done on the Norwegian sample (Høivik et al. 2009b; Hope et al. 2010; Tharaldsen et al. 2008).

By the use of exploratory and confirmatory factor analysis Tharaldsen developed six safety climate dimensions: 1) safety prioritisation 2) safety management and involvement 3) safety versus production 4) individual motivation 5) system comprehension 6) competence.

The safety climate scales used in this study have been validated both in SPSS and LISREL, separately for each sample. Internal consistency of the scales was estimated by Cronbach's Alpha separately for each of the samples. In the final model three out of the originally six dimensions were judged to have a proper fit and consistency: Safety management and involvement, Safety versus production and System perception. The others did not meet normality assumptions. The model has been validated in LISREL. RMSEA was 0,070,

GFI = 0,97 and CFI = 0,95. Table 1 presents the dimensional structures, factor loadings and reliability measures.

The principal component analysis of the risk perception items provided the following 3 dimensions:

1. Risk of process accidents: gas leakages, fire, explosion, blow out, spill poisonous gases/ substances/chemicals and radioactive sources;
2. Risk of major accidents including: helicopter accidents, collisions with ships/vessels/drifting objects and
3. Risk of personal accidents including: serious work accidents and falling objects.

The scales risk of process accident and risk of personal accident met the assumption about normality and were entered in the final model.

3 RESULTS

3.1 *Demographics*

The Danish sample consists of 771 respondents, while the Norwegian consists of 4304 respondents. The majority of offshore employees are men, in the Danish sample 94%, in the Norwegian 90%.

Years of working offshore vary in these two countries. Most of the employees have been working for quite a long time offshore; only 6% worked less than 2 years in both sectors. The Norwegian offshore personnel have higher length of service compared to Danish personnel. 32% worked more than 20 years offshore compared to 20% of the Danes. 27% of the Norwegians worked between 10–20 years compared to 21% of the Danes. On the Danish sector 28% of the offshore employees worked between 2–6 years, compared to 20% on the Norwegian sector.

The distribution between offshore employees working for operating and contracting companies is almost the same in both samples. 50% of the respondents report working in operating and 50% in contracting companies.

86% of the Danish respondents work permanently on the same installations compared to 70% of the Norwegian respondents. Most of the respondents worked in permanent offshore rotation, 87% Norwegians and 90% Danish.

3.2 *Safety climate and risk perception scores on Norwegian and Danish productions installations*

Table 2 shows the results of the t-test analyses and eta squared for both sectors. The Norwegian offshore employees evaluate the risk of both personal and process risk higher than the Danish offshore employees. On the other hand, Norwegian offshore workers show higher scores on the safety management and involvement dimension, safety motivation and safety prioritization. The only dimension with no significant differences is safety versus production.

Table 2. T-test and eta squared for safety climate dimensions and risk perceptions.

Dimensions	DK mean	NO mean	Eta
Safety management and involvement	3, 86	4, 27*	0,079
Safety versus production	3, 40	3, 34	0,000
System perception	3, 79	3, 66*	0,005
Safety motivation	4, 53	4, 70*	0,015
Safety prioritisation	3, 71	3, 92*	0,012
Process risk	2, 29	2, 75*	0,026
Personal risk	2, 67	3, 17*	0,026

Note: *p < 0,000

However, eta values show that the strength of the differences are quite small for safety motivation (Eta = 0,015), safety prioritisation (Eta = 0,012), judgements concerning the risk perception of process incidents (Eta = 0,026) and the risk of being involved in personal work accidents (Eta = 0,026). Differences on the Safety management and involvement dimension, however, have a medium Eta strength value.

3.3 *Impact of safety climate on risk perception*

General Linear Modeling was used to explore the relation between safety climate and risk perception. For the Danish sample, only the Safety versus production dimension exerts an impact on employees' perceived risk of personal and process accidents (p < 0,000; Wilks' Lambda = 0,848). However the impact is small. 10,2% of the variance in employees' perceived risk of process accidents and 9,6% of the variance in perceived risk of personal accidents can be explained by the safety versus production dimension.

In the Norwegian sample all three dimensions: safety management and involvement (p < 0,000; Wilkis' Lambda = 0,861); safety versus production (p < 0,000; Wilkis' Lambda = 0,893) and system perception (p < 0,000; Wilkis' Lambda = 0,976) has an impact on employees' risk perception. However, the statistical impact is, as we have seen in the Danish sample, weak. Safety management and involvement explains 6,6% of the variance in the perceived risk of process accidents and 7,6% of the variance in perceived risk of personal accidents. The numbers are approximately the same for the Safety versus production dimension. The third dimension System perception only explains 1,8%

of the variance in perceived risk of process accidents and 1,4% of variance in the perceived risk of personal accidents.

Multivariate regressions analysis has been done separately for each of the samples and shows a negative relation between Safety management and involvement and both of the risk perception scales, indicating that the higher safety management involvement, the lower perceptions of process and personal accident risk. The same tendency appears for the dimension safety versus production and system perception.

4 DISCUSSION

The result of the current study shows, as expected, that the Norwegian offshore employees have more positive safety climate perceptions compared to their Danish colleagues. The t-test shows that evaluations of safety prioritisation and safety management and involvement were higher among the Norwegian offshore employees than between their Danish colleagues.

However, our expectation that risk perception will be the same on both sectors did not appear. The t-test showed that Norwegian offshore employees reported higher perceived risk of both personal injuries and process accident. The differences are small, but nevertheless it is an interesting result; seen in the light of the fact that the Norwegian employees had more positive scores on the management commitment to safety dimension. One of the explanations may be related to years of work experience offshore. The Norwegian offshore employees have more offshore work experience compared to Danish workers. Some of them may have experienced large safety improvement during their work time, where earlier phases were more dominated by workers getting injured or even have been involved in accidents themselves, and such experiences may alter one's risk perception. Rundmo (1995) found a positive association between experience of an accident and risk perception; i.e. employees who had suffered an accident themselves felt less safe compared to those who had not experienced an accident (Rundmo, 1995). More offshore work experience also gives a higher probability of being involved in an accident yourself or of experiencing colleagues having accidents. Hence, such phenomena may influence one's risk perception. Following Tierney (1999) and Bye & Lamvik (2007) in their understanding of risk perception as socially constructed, longer work experience may influence perception of risk.

The general linear model showed differences between our Danish and Norwegian samples with regards to the impact of our measured safety climate dimensions on both kinds of risk perception. In Norway all safety climate dimensions showed a significant impact on both risk perception scales, while in Denmark only the safety versus production dimension exerted such an influence.

As expected, better safety climate scores predicted lower risk perception. The study carried out in the Norwegian sector indicated the same tendency (Tharaldsen et al. 2008).

5 CONCLUSION

The study shows that risk is perceived differently in the Danish and the Norwegian sectors. The impact of our safety climate scales on perceived risk of personal and process risk varies between the two sectors, and so does the perceived risk level. Scores on our safety climate dimensions are higher among Norwegian respondents, while perceived risk of personnel and process accidents are higher on the Norwegian compared to the Danish shelf. The higher perceived risk among Norwegian personnel does not necessarily mean that Norwegian production platforms are more dangerous than Danish platforms, but may also be related to longer work experience and having experienced either yourself or your colleagues being injured or involved in different types of accidents. Conclusions are not obvious and more comparative research is needed to investigate what the differences between Norwegian and Danish respondents actually mean.

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