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Shipboard safety: exploring organizational and regulatory factors

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ABSTRACT

How vessel crews perceive safety on board (shipboard safety) is a useful indication for the general safety level. In this study a theoretical model was explored, involving factors that could possibly influence shipboard safety. Based on a survey questionnaire (n = 244), safety climate, shipowner efficiency demands and regulatory activities were investigated as influencing factors. Structural equation modelling gave support to the theoretical model and the findings illustrate that simultaneous involvement of various levels of the maritime system (crews, shipowners, regulators) can be effective for safety improvements. The study indicates that shipboard safety is affected by actions and prioritization by external actors through safety climate. It suggests that the maritime industry will profit from monitoring safety climate as part of the ongoing risk considerations, as a supplement to reactive parameters such as accident statistics.

KEYWORDS
safety perceptions; high-speed craft; safety climate; regulation; shipowner

1. Introduction

Passenger transport at sea involves the possibility of major accidents with a large number of fatalities, as well as personal injuries. The industry has a history of several tragic events such as the *Herald of Free Enterprise*, *Scandinavian Star* and *Costa Concordia* disasters. Navigation in severe weather and sea conditions, during night-time, and in narrow waters will always hold the potential hazard of groundings and collisions. Fire and explosion are also dreaded scenarios for captains and crew when carrying passengers in open seawaters far away from rescue personnel. Crew members are also exposed to various occupational hazards in handling dangerous machinery in confined spaces during maintenance, and in conducting heavy lifting and material handling in connection with loading/unloading operations. Adverse weather conditions will further increase the probability of accidents in such situations (Soares and Teixeira 2001).

This article addresses perceptions of shipboard safety among crew members on high-speed crafts (HSC) carrying out passenger transport in Norwegian waters. Such perceptions are found useful as measures of work safety, and might reflect the state of physical and organizational working conditions (Rundmo 1996). More particularly, we will explore whether organizational factors (safety climate, efficiency demands) and regulatory factors (quality of regulatory activities) could influence such perceptions. This should provide new insight into the conditions that influence safety levels. We have not been able to identify previous quantitative research that *simultaneously* considers how external actors and internal conditions influence safety evaluations, even though this could be of great importance when accident preventive measures are to be considered and prioritized.

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According to Rasmussen (1997), control of work safety is influenced by actors on various levels in socio-technical systems, such as politicians, regulators, companies, management and staff. He also emphasizes that most studies only consider *one* level of such socio-technical systems. It is argued that studies that take into account a multilevel perspective are important and can reveal eventual migrations towards the boundaries of acceptable performance. Based on the argument by Rasmussen, the aim of this study is to quantitatively investigate to what extent shipboard safety on HSC is associated with aspects of regulatory, shipowner and crew priorities, thereby including three important levels of the transport system. The empirical foundation of the study is a questionnaire survey, involving personnel from five different HSC shipowners (n = 244).

Safety in maritime passenger transport is influenced by different agencies and actors. The Norwegian Maritime Authority (NMA) is the major regulatory body for the industry in Norway, and international authorities such as the International Maritime Organization (IMO) has considerable influence through standards such as the International Safety Management (ISM) Code. In addition, the industry is characterized by a multitude of different types of vessels, ship owners and operators, insurers and classification companies that together constitute what Ek and Akselsson (2005) denotes 'the maritime system'.

A typical Norwegian HSC is a catamaran design, between 20 and 40 metres and with a cruising speed of 25–35 knots. Most HSC are designed with a passenger capacity of 100–300 passengers. Accident statistics from the Norwegian Maritime Authority (NMA) indicate that the number of HSC accidents (i.e. groundings and collisions) in the period between 2000 and 2010 has increased (NMA 2011). The average number of groundings in the period was five per year. In 2010 nine groundings were registered, where four of the nine recorded groundings occurred while the HSC was en route and at high speed. The MS *Sleipner* shipwreck in 1999 is considered the most severe HSC accident in Norway in recent years, where a total of 16 people tragically lost their lives due to grounding in severe weather conditions. Collisions and groundings are in general considered the most potent hazards for these vessels. This picture is in accordance with an international study of HSC accidents by Antão and Soares (2008) who found HSC to be more liable to collisions, groundings and contact events than other ocean-going commercial vessels.

1.1 *Theoretical model and hypotheses*

The theoretical model that illustrates the relations explored in the study is presented graphically in Figure 1. The rationale behind the model could be described, briefly, as follows: Shipboard safety is influenced by the way individuals and groups act and collaborate during day-to-day activities. How safety is actually prioritized among the crew, and the mindfulness (Weick and Sutcliffe 2007) that they exercise, are important safety climate/cultural traits. Also, such traits do not arise in a vacuum, but are influenced by external actors and their priorities. The shipowners provide important framework conditions for HSCs, including the implicit or explicit signals they convey

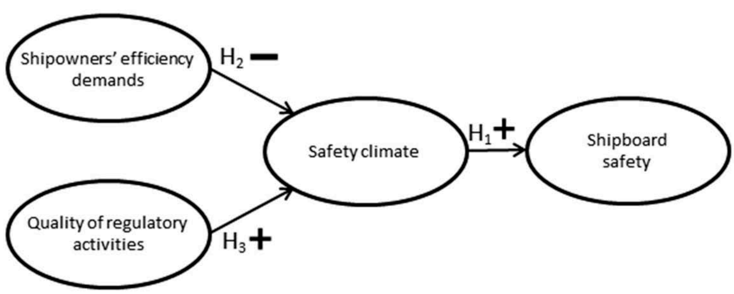

Figure 1. Theoretical model and expected relations between factors.

on how to balance safety and efficiency. The regulatory authorities make use of different means to increase the safety in the industry, including regulations, inspections, safety campaigns etc., which also could have an impact on the actual emphasis that is placed on safety on board HSC. The model is elaborated in the following section.

1.1.1 *Shipboard safety*

Self-reported safety is, in this article, used as a proxy for shipboard safety. There has been considerable discussion on how well 'subjective' safety evaluations made by lay persons correspond to 'objective' safety estimated by risk analyses experts (Slovic 1987; Kasperson et al. 1988; Rundmo 1996; Bye and Lamvik 2007). Still, self-reports are found to be useful as proactive measures of workplace safety. On the basis of a questionnaire study involving 1,138 offshore workers, Rundmo (1996) concludes that 'when an employee feels at risk, he or she also is at risk'. Subjective assessments might reflect the state of working conditions, and are thus suitable as indicators in safety management and control systems, according to Rundmo.

Pidgeon (1998) also claims that safety perceptions should be an integrated part of risk management and argues that such perceptions could have real consequences for behaviour. How workers view hazards in their daily activities has an impact on how they conduct their work, and should thus be one component on which risk-related decisions are made. When Lu and Yang (2011) review the literature on the issue, they also state that workers' safety perceptions are a most useful indicator of safety performance. Hence, it seems both legitimate and important to include the crews' safety evaluations when shipboard safety is considered.

1.1.2 *Safety climate*

Safety climate is a construct derived from safety culture, where questionnaires are usually applied to measure shared values, attitudes and norms regarding safety in a work community. A general definition of safety climate given by Zohar (2003) is '…the shared perceptions with regard to safety policies, procedures and practices'. Key issues that are embraced by the construct are management support for safety and the overall importance that is assigned to safety in the organization (DeJoy et al. 2004). In relation to the maritime industry, it should be mentioned that a primary goal with the ISM code was to lay the foundation for a new safety culture (Anderson 2003).

The factorial structure of safety climate has been debated in many studies (Guldenmund 2007). Even though there is no full consensus, Flin et al. (2000) point to six organizational themes that are often addressed in safety climate studies: (1) management; (2) safety systems; (3) risk; (4) work pressure; (5) competence; and (6) rules/procedures. Also, Beus et al. (2010) identified seven dimensions within the safety climate domain: (1) management commitment; (2) the priority of safety; (3) general safety policies, procedures, and practices; (4) safety training; (5) safety communication; (6) reporting; and (7) employee safety involvement. According to Griffin and Neal (2000) there is reason to presume that safety climate is a higher order factor comprised of several first-order factors. This higher order factor reflects the extent to which employees perceive safety as valued within their work community.

Previous studies have demonstrated that there is a positive relationship between safety climate and safety performance (Zohar 1980, 2003; Zohar and Luria 2005; Johnson 2007), between safety climate and employees' safety behaviour (Dahl, Fenstad, and Kongsvik 2014; Lu and Yang 2011), and between safety climate and the actual safety level in organizations (Hofmann and Stetzer 1996; Cooper and Phillips 2004; Mullen 2004). The link between safety climate and shipboard safety is examined in a study in the Norwegian maritime industry. The study shows that there are positive associations between key safety climate components, such as local management, working practices and reporting practices, and overall safety evaluation among the crew (Oltedal and Wadsworth 2010). Also, Akhtar and Utne (2015) recently analysed groundings and collisions related to human fatigue. The general picture found for both types of accidents was that many of the factors related to fatigue (e.g. shift work, irregular working hours, excessive demands) were in turn linked to poor safety climate as a generic factor, involving a high tolerance for long working hours. Based on the above, the following hypothesis was investigated:

Hypothesis 1: There is a positive relationship between safety climate on board high-speed crafts and shipboard safety. The more positive the safety climate, the more positive is the perceived shipboard safety that will be observed.

1.1.3 *External actors*

There is less knowledge concerning how external actors can influence the safety climate. Earlier research has focused on internal organizational factors as a determinant for safety climate, such as the organizational climate (Neal, Griffin, and Hart 2000), working environmental conditions (heat, noise etc.), and internal safety policies and programmes (DeJoy et al. 2004).

Still, Rasmussen (1997) considers it important to simultaneously investigate different levels in a socio-technical system like shipping. In a working environment that involves many competing demands (e.g. safety at sea, economy, timetable deadlines and environmental concerns), as is the case for high-speed crafts, this argument could be of special relevance. The safety level on the individual vessel is dependent on the interaction with external actors such as shipowners and regulators, as well as the safety prioritization on board the vessel itself. For example, the introduction of the ISM code and the activities it has instigated by national maritime regulators, has progressed maritime safety in general (Tzannatos and Kokotos 2009), and probably also the safety commitment among shipowners (Lappalainen 2008; IMO 2005). Also, the established relationship between safety climate and safety performance (Johnson 2007; Hetherington, Flin, and Mearns 2006) underlines the significance of the on-board safety prioritization.

The maritime industry is in general increasingly exposed to competition through interconnected, strong trends such as economic developments, globalization and liberalization of markets. Maritime passenger transportation is no exception. The provision of transport services by high-speed craft is a public responsibility at county level in Norway, and competitive tendering is regularly used to acquire the services from private shipowners. The industry is thus highly motivated to reduce costs and improve efficiency in order to be competitive, e.g. by reductions in staffing, optimizing maintenance of equipment and optimizing routes. The shipowners are at the same time required to comply with international and national safety regulations. Although some of the safety requirements are functional, such as many of those provided by the ISM Code, others are quite specific, for example requirements for minimum safe manning, competence demands, and emergency training.

The relation between efficiency and safety is not always clear cut. As defined by the Oxford English Dictionary, being efficient involves achieving maximum productivity with minimum wasted effort or expense. When this is accompanied by clear lines of responsibility, a competent workforce, and clearly defined procedures, efficiency might not be an opposite pole to safety. However, prominent scholars like Rasmussen (1997) and Hollnagel (2009) point to the possible conflicting driving factors inherent in efficiency and safety. Cost reductions that are introduced to be economically viable in a competitive environment (e.g. reductions in maintenance budgets), might reduce safety margins in the longer run (see Størkersen (2015) for a general discussion on this related to the maritime industry). Also, efficiency demands might introduce time pressure that could go at the expense of thoroughness (Hollnagel 2009). In our survey, we have focused on concrete efficiency measures that might compromise safety (see Table 1, V4–V7).

The balancing between efficiency and safety could vary between shipowners and result in different consequences for the crews. It is reasonable to assume that the efficiency–safety trade-off could influence the amount of work pressure that the crews experience, how the management on board prioritize safety, and the inclination of non-compliance to procedures. In other words, efficiency demands could have a negative impact on the safety climate on board the vessels. Addressing this, the following hypothesis was explored:

Hypothesis 2: There is a negative relationship between shipowners' demands for efficiency at the expense of safety and safety climate. The higher the demands for efficiency, the more negative are the levels of safety climate that will be observed.

Safety is a primary concern for the Norwegian Maritime Authority (NMA), made evident in its main goal (NMA 2012): 'The main goal is for Norway to be an attractive flag state with high standards of safety at sea for crew, vessels and the marine environment.' The NMAs main goal builds on international conventions, in particular SOLAS ('International Convention for the Safety of Life at Sea'), which specifies minimum standards for the construction, equipment, and operation of ships (Celik 2009) and also MARPOL ('International Convention for the Prevention of Pollution from Ships'). The strategies used by the NMA to achieve high standards of safety involve traditional inspections of vessels and the seafarers' working and living conditions, but also measures meant to improve safety attitudes, motivation and behaviour. As an actor with strong sanctions at its disposal, the NMA has the potential to significantly influence the safety and the working conditions on board the vessels, and consequently also the safety climate. The realization of this potential is, however, to some extent dependent on how the NMA's mandate is enacted and the capabilities of the Authority. Reason (1997) has illustrated that regulators in some instances lack the operative competence that is necessary to reveal vulnerabilities, and have increasing workloads and diminishing resources. Related to the maritime industry, Karahalios, Yang, and Wang (2015) claim that many international regulations are not always adequately implemented on the national levels. In short, the quality of regulatory activities can vary, and consequently the extent to which these activities can influence safety climate on board the high-speed craft. We explored the following hypothesis:

Hypothesis 3: There is a positive relationship between the perceived quality of regulatory activities and safety climate. The better the perceived quality of regulatory activities, the higher are the levels of safety climate that will be observed.

2. Method

2.1 *Survey and sample*

The present study is based on a questionnaire survey that was carried out among 244 sailors working on high-speed crafts operating in the Norwegian passenger ferry industry. The survey was initiated by five high-speed craft shipowners and the Norwegian Maritime Authority. All respondents included in the study were employed by these shipowners. We received the crew members' home addresses from the shipowners, and distributed the questionnaire by mail. In the introduction, the anonymity of their responses was stressed. The respondents were asked to return the questionnaires to the research group within one week after receiving them, using an accompanying addressed envelope with postage prepaid. The questionnaire used in the study is largely based on questionnaires that were developed for a safety and work environment study among offshore service vessels working on contract for a large Norwegian oil company (Kongsvik 2000; Bye and Kongsvik 2002; Ramstad, Antonsen, and Norland 2004; Fenstad et al. 2006; Fenstad 2008). The original questionnaire consisted of 77 variables. Among these, 46 variables were related to safety-specific issues: the shipowners' prioritization of safety, the captain's or immediate superior's safety prioritization, safety procedures, safe work practices, safety training, safety reporting, and sleep and rest. In addition there were eight variables related to workers' perceptions of the Norwegian Maritime Authority, and 13 variables regarding safe navigation practices. Ten of the 77 variables addressed background information on each of the participants and their current boat: age, job experience, current position, primary function of vessel, length of vessel, and exposure to accidents and near-accidents during the last 12 months. The questionnaire also included five open-ended questions in order to obtain elaborated comments on: other reasons to not follow procedures, main challenges when navigating HSC, reasons to not report accidents, causes for dissatisfaction with the watch schedule and suggestions on safety measurements.

A total of 261 sailors returned the questionnaires, 17 of these were extracted from the sample due to incomplete responses. Thus, the total sample consisted of 244 respondents, which gives a response rate of 52%. The mean age of the crew members was 45.9 years, with a variation between 21 and 67 years. As regards job experience, 43.9% of the sailors reported that they had more than 10 years' job experience on high-speed crafts, and 3.3% reported less than a year of such experience.

Captains (38.9%) constituted the largest occupational group among the respondents, followed by engineering staff (29.1%), chief officers (14.7%), and seamen (13.6%). The rest had miscellaneous functions like catering, ambulance personnel and combined positions. The majority of the respondents are on boats on ordinary express routes (85%) and have a weekly shift schedule (81%). Of the total number of crew member, 3.3% reported that they had been directly involved in an occupational accident that resulted in sick leave during the last year. In contrast, 26.7% reported that they had been involved in a situation that could have resulted in a serious accident during the last year.

2.2 *Measures and statistical procedures*

2.2.1 *Variables*

From the 46 variables related to safety in the original questionnaire, 19 variables were selected in the present study. This selection was done on face value and on the basis of the safety climate literature (Flin et al. 2000; Griffin and Neal 2000; Beus et al. 2010; Oltedal and Wadsworth 2010). Twelve of these variables were used to measure safety climate, four were used to measure shipowners' efficiency demands, two were used to measure perceptions of regulatory authorities' policy instruments, and one variable was used to measure shipboard safety.

For the sailors included in the analysis, a mean average of 6.6% missing values in the items of the scales was observed. The two items regarding perceptions of regulatory authorities' policy instruments had the highest percentage of missing values with an average of 19% missing values. The items that measured safety climate had a mean average of 3.3% missing values. For the four items used to measure shipowners' efficiency demands, the mean average of missing values was 5.7% missing values. To retain a sufficient number of respondents in the sample, we decided to replace missing data by mean substitution for subgroups, assuming a normal distribution for missing data (Acock 2005). Cases with or without missing data were compared. This resulted in a decision to replace missing values with mean values by assigning the corresponding subgroup mean based on belonging to position on board.

All variables, except the dependent variable shipboard safety (V19), were presented as statements where the respondents were supposed to denote the level of agreement on a five-point Likert scale. The scale ranged from 'totally disagree' (value 1) to 'totally agree' (value 5). Shipboard safety was measured on a 10-point Likert scale, varying from 'very good' (value 10) to 'very bad' (value 1). See Table 1 for an overview of the variables, their naming and descriptive statistics.

2.2.2 *Factor analysis and test of hypotheses*

In order to uncover the underlying factor structure of the independent variables and to reduce the number of items to a manageable size, exploratory factor analysis (EFA) was conducted. The applied EFA was principal axis factoring with varimax rotation, and factor loadings above 0.40 were considered sufficient to relate the item to the factor (Meyers, Gamst, and Guarino 2006). The

Table 1. Descriptive statistics for variables used in the study—mean and standard deviation on a scale from 1 ('totally disagree') to 5 ('totally agree') (V1–V18) and from 1 ('very bad') to 10 ('very good') (V19). N = 244.

Variable	Mean	SD
V1: My captain appreciates that the employees take up safety issues	4.26	1.13
V2: I am sure to get support from my captain if I prioritize safety in all situations	4.31	1.13
V3: My captain sets a good example regarding attention to safety	4.18	1.14
V4: The shipowner compromises on safety to cut costs	2.20	1.23
V5: The shipowner compromises on safety in order to keep to the timetable	2.09	1.25
V6: Owing to the shipowners' demand for efficiency, we sometimes have to violate procedures	2.94	1.44
V7: Following the safety procedures is not rewarded in the shipping company where I work	2.94	1.42
V8: On my vessel, we strive to achieve zero harm to people, prevent accidents, and reduce negative effects on the environment	4.56	0.85
V9: Safety is well taken care of on my vessel	4.46	0.96
V10: Captain's judgment of when it is safe to conduct a voyage is respected by the shipowner	4.45	0.96
V11: I find it difficult to know which procedures are applicable	2.09	1.20
V12: The procedures are difficult to understand/vaguely formulated	2.13	1.19
V13: The procedures on board are too general and are not adapted to the vessel I work on	2.23	1.24
V14: We have sufficient time to train employees on board	3.80	1.22
V15: New employees receive sufficient training to work safely	3.91	1.18
V16: We always perform the emergency exercises which we are ordered to perform	4.09	1.05
V17: The Norwegian Maritime Authority's inspection of seafarers' working and living conditions is good	3.19	1.21
V18: The Norwegian Maritime Authority does a good job of motivating the industry to take responsibility for safety themselves	3.30	1.09
V19: Overall, how would you evaluate safety in your work situation?	8.16	1.48

number of factors to be extracted was based on Kaiser's criterion (Field 2005). This implies that only factors with eigenvalues greater than or equal to one were retained. Internal consistency and reliability were assessed by Cronbach's alpha (Cronbach 1951). Whether the data were suited for factor analysis or not was tested by Bartlett's test of sphericity and Kaiser–Meyer–Olkin's (KMO) sampling adequacy (Field 2005). The EFA and its accompanying analyses were conducted using SPSS 18.0.

The factor structure uncovered in the EFA formed the structural basis for the test of the three hypotheses presented in Section 1. Since structural equation modelling (SEM) was employed for the test of hypotheses, a confirmatory factor analysis (CFA) was conducted prior to the SEM. There are some methodological considerations about conducting a CFA on the same sample as the EFA, since the main target of a CFA usually is to test the replicability of a factor structure uncovered by an EFA (Blunch 2008; Hurley et al. 1997). However, without having a sample size that enabled cross-validation or data splitting, we chose to have identical samples on the EFA and the CFA. The CFA was also conducted in order to test whether or not the latent safety climate variables would load onto a higher order safety climate factor, as implied by Neal and Griffin (2004).

To assess the fit of the CFA, we used the fit indices recommended by Hooper, Coughlan, and Mullen (2008): the root mean square error of approximation (RMSEA), the standardized root mean square residual (SRMR) and the comparative fit index (CFI). An RMSEA value of 0.08 or less (Blunch 2008), a CFI value close to 0.95, and an SRMR value close to 0.08 for SRMR are an indication of a good fit (Hu and Bentler 1999).

In order to test the three hypotheses in our research model, SEM was conducted. SEM was preferred since this statistical technique allows the assessment of both direct and indirect effects (Meyers, Gamst, and Guarino 2006). The model comprised the latent variables which were uncovered in the EFA and later tested in the CFA. Maximum likelihood was used to estimate the model's path coefficients. Each path coefficient was then examined to assess significance, effect, and whether or not it was in the expected direction. RMSEA, CFI, and SRMR were examined to assess model fit. The fit indices were interpreted under the same guiding rules as the CFA (Hu and Bentler 1999). Both the CFA and the structural model assessment were conducted using AMOS 18.0.

3. Results

3.1 *Factor extraction and factor labelling*

The initial considerations and analysis of the sample and the independent variables demonstrated that the data were appropriate for factor analysis. Both Bartlett's test of sphericity and KMO measure of sampling adequacy indicated this. Bartlett's test of sphericity demonstrated that the correlation matrix was not an identity matrix and that the correlation between the variables was sufficient (χ^2 = 2140.77, p < 0.001). The KMO sampling adequacy was 0.81, which is well above the recommended 0.60, and all values along the anti-image correlation matrix were above 0.7 (between 0.717 and 0.889).

The application of Kaiser's criterion resulted in a six-factor solution, presented in Table 2. This solution accounted for 63.4% of the total variance. From Table 2 it is clear that all of the 18 variables have sufficient loadings (above 0.40) on a factor to be retained in the final factor solution. Simultaneously, no variables have loadings above 0.40 on more than one factor. This indicates a simple factor structure.

From Table 2 it is clear that the variables V1–V3 load on factor 1, that V4–V7 load on factor 2, that V8–V10 load on factor 3, that V11–V13 load on factor 4, that V14–V16 load on factor 5, and that V17–V18 load on factor 6. Based on wording and meaning in the statements, the six factors were thematically labelled as follows: (Factor 1) *Captain's safety orientation*; (Factor 2) *Shipowners efficiency demands*; (Factor 3) *General safety orientation*; (Factor 4) *Procedure vagueness*; (Factor 5) *Safety training*; and (Factor 6) *Quality of regulatory activities*.

3.2 *Discriminant validity, internal consistency, and reliability*

Factors that correlate too highly with factors that they are supposed to differ from can be a sign of low discriminant validity (Netemeyer, Bearden, and Sharma 2003). Intercorrelations between factors (discriminant validity) are presented in Table 3. All correlations are moderate, suggesting that the discriminant validity is acceptable. This indicates that the six constructs measure different underlying factors. The internal consistency and reliability of the factors was evaluated by

Table 2. Rotated factor matrix after extraction, principal axis factoring with varimax rotation (N = 244).

	Factor loadings						
Variables	1	2	3	4	5	6	h^2
V1	**0.892**	−0.079	0.160	−0.061	0.111	0.008	0.84
V2	**0.851**	−0.106	0.142	−0.017	0.118	0.057	0.77
V3	**0.847**	−0.064	0.157	−0.059	0.107	0.122	0.78
V4	−0.006	**0.709**	−0.074	0.224	−0.108	−0.102	0.58
V5	−0.064	**0.697**	−0.110	0.190	−0.203	0.008	0.58
V6	−0.149	**0.614**	−0.086	0.181	−0.199	−0.170	0.51
V7	−0.091	**0.590**	0.005	0.196	−0.102	−0.251	0.47
V8	0.218	−0.011	**0.877**	−0.021	0.042	0.055	0.82
V9	0.135	−0.071	**0.757**	−0.104	0.084	0.037	0.62
V10	0.078	−0.119	**0.694**	−0.051	0.140	0.051	0.53
V11	−0.067	0.243	−0.128	**0.916**	−0.083	0.031	0.93
V12	−0.062	0.250	−0.014	**0.717**	−0.163	0.021	0.61
V13	−0.007	0.226	−0.066	**0.533**	−0.145	−0.181	0.39
V14	0.132	−0.258	0.065	−0.141	**0.824**	0.223	0.84
V15	0.109	−0.217	0.149	−0.226	**0.738**	0.038	0.68
V16	0.176	−0.136	0.147	−0.079	**0.447**	0.273	0.35
V17	0.074	−0.234	0.075	−0.049	0.203	**0.728**	0.64
V18	0.051	−0.086	0.035	−0.021	0.090	**0.679**	0.48
Eigenvalue after rotation	2.42	2.12	2.00	1.90	1.70	1.28	
Percentage of variance explained after rotation	13.44	11.79	11.08	10.53	9.42	7.10	
Sum of explained variance	63.38						

Table 3. Pearson correlation between measurement constructs, with Cronbach's alpha in diagonal (N = 244).

Factor name	1	2	3	4	5	6
Factor 1: Captain's safety orientation	(0.92)					
Factor 2: Shipowners efficiency demands	−0.23	(0.80)				
Factor 3: General safety orientation	0.32	−0.20	(0.84)			
Factor 4: Procedure vagueness	−0.15	0.49	−0.18	(0.81)		
Factor 5: Safety training	0.32	−0.47	0.28	−0.38	(0.79)	
Factor 6: Quality of regulatory activities	0.17	−0.34	0.15	−0.17	0.38	(0.70)

Cronbach's alpha (the diagonal in Table 3). All alpha-values were equal to or above 0.7, indicating adequate internal consistency and reliability (Field 2005).

3.3 *Confirmatory factor analysis (CFA)*

The CFA with the use of maximum likelihood extraction demonstrated that the factor structure discovered in the EFA was confirmed by the CFA. The CFA also demonstrated that the four latent safety climate factors (factors 1, 3, 4 and 5) loaded onto a higher order factor, which was named *safety climate* (see Table 4). Further, the CFA demonstrated that all the regression weights between variables and constructs were in the expected direction and significant at the $p < 0.001$ level. In addition, all fit indices (RMSEA, SRMR and CFI) demonstrated adequate fit between the model and the observed data.

3.4 *Test of the theoretical model*

After having established and confirmed a factor structure with good fit (comprised by six first-order factors and one higher order factor: *safety climate*), SEM was conducted to test the hypotheses in the theoretical model. The expectation in the theoretical model is that the latent

Table 4. Confirmatory factor analysis: maximum likelihood extraction (N = 244).

			B	SD	p	β
Factor 1	<—	S Climate	1.512	0.421	<0.001	0.40
Factor 3	<—	S Climate	1	–	–	0.37
Factor 4	<—	S Climate	−2.342	0.567	<0.001	−0.58
Factor 5	<—	S Climate	2.977	0.685	<0.001	0.74
V1	<—	Factor 1	1	–	–	0.92
V2	<—	Factor 1	0.969	0.048	<0.001	0.89
V3	<—	Factor 1	0.953	0.049	<0.001	0.87
V4	<—	Factor 2	1	–	–	0.73
V5	<—	Factor 2	1.027	0.102	<0.001	0.73
V6	<—	Factor 2	1.182	0.118	<0.001	0.73
V7	<—	Factor 2	1.063	0.115	<0.001	0.67
V8	<—	Factor 3	1	–	–	0.88
V9	<—	Factor 3	1.027	0.083	<0.001	0.80
V10	<—	Factor 3	0.932	0.081	<0.001	0.72
V11	<—	Factor 4	1	–	–	0.92
V12	<—	Factor 4	0.868	0.069	<0.001	0.80
V13	<—	Factor 4	0.688	0.071	<0.001	0.61
V14	<—	Factor 5	1	–	–	0.90
V15	<—	Factor 5	0.862	0.068	<0.001	0.80
V16	<—	Factor 5	0.545	0.061	<0.001	0.57
V17	<—	Factor 6	1	–	–	0.98
V18	<—	Factor 6	0.512	0.117	<0.001	0.55
Factor 2	<–>	Factor 6	−0.439	0.086	<0.001	−0.42
Factor 2	<–>	S Climate	−0.193	0.048	<0.001	−0.80
Factor 6	<–>	S Climate	0.155	0.043	<0.001	0.48
df		χ^2	RMSEA	SRMR	CFI	
128		220.13	0.054	0.067	0.955	

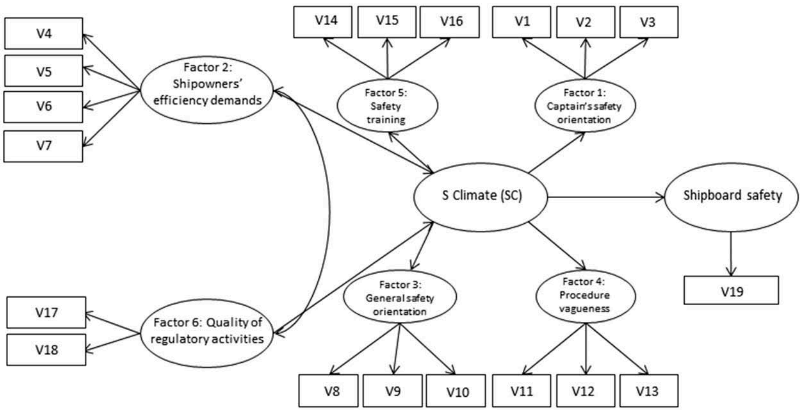

Figure 2. Hypothesized structural equation model.

factors, *shipowners' efficiency demands* and *quality of regulatory activities*, influence the higher order latent factor *safety climate*, which in turn is expected to influence *shipboard safety*. More precisely, we have hypothesized that *quality of regulatory activities* positively influences *safety climate*, that the *shipowners' efficiency demands* negatively influence *safety climate*, and that *safety climate* positively influences *shipboard safety*. The complete structural model is presented in Figure 2, and the results of the SEM analysis are presented in Table 5.

As shown in Table 5, all fit indices were within the range of good fit, indicating adequate fit between the structural model and the observed data. The RMSEA and the SRMR values are below 0.08 and the CFI value is close to 0.95. The tests of each of the three hypotheses in the theoretical model appear in the three first horizontal rows in the same table.

Table 5. Structural equation modelling: parameter estimates and goodness of fit indices (N = 244).

Hypotheses				B	SD	p	β
H_1	Shipboard safety	<—	S Climate	3.938	0.863	*	0.71
H_2	S Climate	<—	Factor 2	–.225	0.052	*	–0.75
H_3	S Climate	<—	Factor 6	0.058	0.023	0.010	0.26
	Factor 1	<—	S Climate	1.46	0.404	*	0.38
	Factor 3	<—	S Climate	1			0.36
	Factor 4	<—	S Climate	–2.199	0.531	*	–0.54
	Factor 5	<—	S Climate	2.857	0.642	*	0.69
	V1	<—	Factor 1	1			0.91
	V2	<—	Factor 1	0.974	0.048	*	0.89
	V3	<—	Factor 1	0.956	0.050	*	0.87
	V4	<—	Factor 2	1			0.73
	V5	<—	Factor 2	1.028	0.101	*	0.73
	V6	<—	Factor 2	1.183	0.116	*	0.73
	V7	<—	Factor 2	1.06	0.113	*	0.67
	V8	<—	Factor 3	1			0.88
	V9	<—	Factor 3	1.027	0.083	*	0.80
	V10	<—	Factor 3	0.93	0.081	*	0.72
	V11	<—	Factor 4	1			0.91
	V12	<—	Factor 4	0.874	0.070	*	0.80
	V13	<—	Factor 4	0.696	0.072	*	0.62
	V14	<—	Factor 5	1			0.91
	V15	<—	Factor 5	0.844	0.067	*	0.79
	V16	<—	Factor 5	0.54	0.060	*	0.57
	V17	<—	Factor 6	1			0.97
	V18	<—	Factor 6	0.519	0.103	*	0.56
	Factor 6	<->	Factor 2	–0.44	0.086	*	–0.42
df		χ^2	RMSEA		SRMR	CFI	
145		258.26*	0.057		0.069	0.948	

*p < .001

Hypothesis 1, which assumed a positive relationship between safety climate on board the high-speed crafts and shipboard safety, is supported on the basis of the data. The beta value (β) shows the expected positive direction (0.71) with a p-value below 0.001, indicating a significant positive relationship. This implies that the more positive the safety climate, the more positive is the shipboard safety that is observed. More precisely, if *safety climate* increases by 1 standard deviation, *shipboard safety* increases by 0.71 standard deviations.

Hypothesis 2, which assumed a negative relationship between shipowners' demands for efficiency and safety climate, is supported on the basis of the data. The beta value (β) shows the expected negative direction (−0.75) with a p-value below 0.001, indicating a significant negative relationship. This implies that the higher the demands are for efficiency, the more negative is the safety climate that is observed. More precisely, if *shipowners' efficiency demands* increases by 1 standard deviation, *safety climate* decreases by 0.75 standard deviation. Further, the indirect effect between *shipowners' efficiency demands* and *shipboard safety* is −0.53 (this follows from $-0.75 \times 0.71 = -0.53$).

Hypothesis 3, which assumed a positive relationship between the perceived quality of regulatory activities and safety climate, is supported on the basis of the data. The beta value (β) shows the expected positive direction (0.26) with a p-value below 0.010, indicating a significant positive relationship. This implies that the better the perceived quality of regulatory activities, the more positive the safety climate that is observed. More precisely, if perceived *quality of regulatory activities* increases by 1 standard deviation, *safety climate* increases by 0.26 standard deviation. Further, the indirect effect between *quality of regulatory activities* and *shipboard safety* is 0.18 (this follows from $0.26 \times 0.71 = 0.18$).

4. Discussion and implications

Overall, the analysis supports that the theoretical model illustrated in Figure 1 is a plausible way of representing the survey data. Shipboard safety seems to be influenced by the safety climate on board, but also indirectly by the shipowners' efficiency demands and the quality of regulatory activities. All three hypotheses were confirmed. The different relationships in the model will be discussed in the following.

4.1 *Safety climate and shipboard safety*

The model presupposes that shipboard safety is influenced by the safety climate. More specifically, it was hypothesized that a more positive safety climate was associated with a more positive shipboard safety. Our higher order safety climate factor was strongly and significantly associated with shipboard safety considerations, thus confirming the first hypothesis. This strong relationship also makes sense. If the captain and the crew as a whole prioritize safety and regard safety as important, then it should follow that the safety is perceived as good on board.

Moreover, the confirmation of the first hypothesis is in line with previous research on the relationship between safety climate and safety performance. On a general level, Oltedal and Wadsworth (2010) found various safety cultural factors to contribute to better shipboard safety. The first-order safety climate factors that constituted our second-order factor were the Captain's safety orientation, General safety orientation, Procedure vagueness, and Safety training. How *first-line management*—in this case the captain—values safety in various decisions and is involved in safety activities, is known to have a safety impact (Flin et al. 2000; Lu and Tsai 2010). Further, a common response towards shipping accidents is the introduction of more *formal procedures* in order to prevent similar accidents occurring (Lu and Tsai 2010), such as the ISM code's requirement of establishing an effective safety management system (Akyuz and Celik 2014). If these procedures and systems should contribute to better shipboard safety, they need to be simple, both in language and complexity, and accessible for the crews. This is also in line with the recommendations after the assessment of the impact and effectiveness of implementation of the ISM code (IMO 2005), where more user friendly guidelines etc. was one suggested measure. The process of implementation of the procedures is also known to be important for later compliance with the procedures (Antonsen, Almklov, and Fenstad 2008; Håvold and Nesset 2009; Knudsen 2009).

One implication of these findings is that external actors should be sober-minded when implementing new procedures, and also take great care in formulating procedures, issues that are also thoroughly discussed by authors like Hale and Swuste (1998) and Bieder and Bourrier (2013). A thorough and inclusive implementation process would also increase the crew's attention and attitude towards the procedures and contribute to a positive safety climate. Also, *safety training* is considered to be a prerequisite for shipboard safety. In addition to technical and navigational skills, crew members need non-technical skills in order to perform their job in a safe manner (Flin, O'Connor, and Crichton 2008). These skills would typically be bridge and deck communication, teamwork, leadership, situation awareness, handling and management in emergency crises, and priority-setting of workload (Hetherington, Flin, and Mearns 2006). Technical and navigational skills are well covered through the standardized international maritime education and training system and shipowners monitor each sailor in terms of fulfilling the mandatory courses and certifications. In addition, emergency preparedness drills are routine work on-board ships. There are attempts in the shipping industry to strengthen non-technical skills through crew resource management (CRM) courses influenced by the work done in the commercial aircraft industry. Nevertheless, little is known of the effect these non-technical training activities might have on safety records in the shipping industry.

4.2 *Efficiency demands*

The model in Figure 1 also illustrates an expected relationship between the shipowners' efficiency demands and the safety climate. It was hypothesized that higher demands for efficiency from the shipowner were associated with more negative levels of safety climate on board. The hypothesis was confirmed: there was a strong association in the expected direction between the two factors.

As previously mentioned, the maritime passenger industry in Norway is exposed to efficiency demands that have led to staff cutting, route optimization and cost cuts regarding maintenance and equipment. Fierce competition is one of the several hallmarks of a modern market economy and decision-makers constantly need to make short-term decisions in order to fulfil demands related to profitability. These decisions are usually made to optimize performance in one part of a system without reference to how they collectively will influence long-term goals regarding safety (Rasmussen 1997).

Efficiency demands from shipowners are a major contributor to negative safety climate in this study. In particular, our respondents perceive compliance with procedures for safety as challenging when shipowners also want efficient operations. A plausible explanation of this could be that procedures are often quite specific regarding requirements for safety manning, competence and emergency training, and violations of these requirements are easily noticeable and associated with the shipowners' decisions.

Decision-makers could mediate mixed signals when emphasizing efficiency and safety compliance simultaneously (Zohar 2010; Hollnagel 2009). The compromising of safety to cut costs or to keep to a timetable is in essence procedure short-cutting, which is one important starting point for accidents. There is, however, a possibility that shipowners are not always aware of when efficiency efforts compromise safety. In such cases, efforts to monitor the efficiency–safety trade-off—for example, by means of regular surveys—can contribute to better informed decisions, a positive safety climate and ultimately good safety results.

Studies also show that an increased administrative workload could represent a barrier to participation and visibility from managers in safety work (Flin et al. 2000; Lamvik, Bye, and

Torvatn 2008; Lu and Tsai 2010). We suggest that both shipowners and regulatory authorities need to consider the extent of such activities, and ensure that captains on HSC have adequate time to be involved in activities vital for shipboard safety. This could also contribute to the maintenance of a good safety climate on board.

4.3 Regulatory activities

The last association explored in the study was between the quality of regulatory activities, in our case activities performed by the Maritime Authority, and safety climate. A positive relationship was hypothesized; we expected that the better the perceived quality of the regulatory activities, the more positive the levels of safety climate would be observed. This hypothesis was also confirmed; there was an association between the two factors in the expected direction, although somewhat weaker than the other two associations explored.

Safety is at the very core of the NMA's concern (see NMA 2012). It must be regarded positive that the NMA's activities (inspections of seafarers' working and living conditions, safety motivational work) seem to influence the safety climate on board. Nevertheless, when we investigate the mean scores for the items that constitute the factor (see V17 and V18 in Table 1), we see that the seafarers' evaluation of the NMA's activities is quite average.

According to Poortinga and Pidgeon (2003), trust in institutions (like the NMA) can be crucial for risk perception. They suggest that trust in governments' risk policies can be summarized in two basic underlying dimensions: general trust and scepticism. Their conclusion is that in a well-functioning society a high degree of scepticism combined with a general trust in institutions (labelled 'critical trust') could be favourable to a situation with full acceptance. In accordance with this view, the scepticism towards NMA in this study can be understood as critical trust, where an active and competent workforce will question the value of information and initiatives from government agencies. This is also argued by Antonsen (2009), where conflicting views on safety are seen as a safety resource that can facilitate learning among individuals and organizations. In such a situation, rather than measures aimed to increase trust in government institutions, institutions like the NMA need to find ways and create structures so that they can gain access to the constructive criticism raised from practitioners in the industry. This could strengthen the positive influence of the NMA on the safety climate and perceived shipboard safety found in this study.

4.4 Limitations and further research

Common method bias could possibly be an issue in this study, which means that some of the revealed relations between the constructs could be spurious and caused by using the same method and data source. In our case, the same questionnaire was used for measuring all the factors in our theoretical model (see Figure 1). Also, all the factors in our model are based on self-reported considerations of statements. A typical remedy would be to at least introduce an 'objective' measure of safety, like, for example, actual injury or accident rate as a substitute for shipboard safety. Since our data are cross-sectional, we also lack the possibility to actually test the causality in our data. Even though the results from the SEM analyses are in accordance with the theoretical causal relationship, a longitudinal study would have provided us with more statistical power and thus been better in providing evidence for a causal relationship between our factors.

Captains represented the largest group among the respondents (39%). Being company representatives, it is possible that their responses could be biased in favour of the shipowners, for example regarding the items considering the shipowners' efficiency demands. By emphasizing that the anonymity of the respondents was assured, we tried to limit this potential bias as much as possible. It is also likely that the captains will be influenced by loyalty towards their crew.

Generally, and also based on the actual results of the study, we do not think that bias in the empirical material is a significant problem.

Further research should thus involve the use of alternative and independent data sources to investigate whether the relations found in this study can be validated. It will also be fruitful to apply qualitative approaches to explore the lines of causality that are suggested in the theoretical model and investigated by the SEM analysis. This analysis does not validate causal relationships, only illustrating *possible* causality.

Although the proposed model had a good fit to the data obtained from crews on HSCs, it should also be tested for other parts of the maritime industry and in other parts of the world. Some of the research cited above substantiates that individual relationships in the model are valid in other maritime contexts, in more particular the safety climate–safety relationship (Oltedal and Wadsworth 2010). Still, research on the other associations and for the model as a whole is generally lacking. An international, comparative study, using the model as a starting point, will be of particular interest, as both the quality of regulatory activities and the efficiency demands should vary considerably between different countries and regions.

5. Conclusion

The study has revealed that shipboard safety can be influenced by internal crew-related factors, as well as external factors involving the shipowners and regulatory authorities. One important general implication from the study is that simultaneous involvement of various levels of the maritime system (crews, shipowners, regulators) can be effective for safety improvements.

Both shipowners and regulators are key actors with the power to influence working conditions, the climate for safety and the safety results in the industry. One further implication from the study is that shipowners should carefully consider how efficiency demands are imposed and communicated to the crew level, as this may have an effect on the local safety climate and shipboard safety. For the regulators, the study shows that improvements in how they apply their policy instruments could change the safety climate on vessels, and further contribute to better safety results in the industry. Regulators such as the NMA should continuously arrange for structures and processes that give access to constructive criticism from competent maritime practitioners.

Maritime regulators monitor risk, usually by analysing accident statistics for the most frequent accident types (groundings, collisions, allisions, and fires/explosion). Such analyses may serve as input to the prioritizing of regulatory resources and as a basis for a risk-based supervision. The current study illustrates that *monitoring of safety climate* may be complementary and is an activity which maritime regulators should also consider. The safety climate may serve as a proactive safety indicator. In the petroleum industry, safety climate is already monitored on a regular basis, and is used as one input when considering the risk level (Skogdalen, Utne, and Vinnem 2011). Regulators in the maritime industry might have something to learn from other industries regarding risk monitoring.

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