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Exploring Organizational Safety Vulnerabilities on Naval Ships – A Comparative Quantitative Analysis

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ABSTRACT

There are several recent examples of major accidents involving naval ships. The starting point for this article is the collision between the frigate 'Helge Ingstad' and the oil tanker 'Sola TS'. An investigation highlighted *systemic weaknesses* in the Norwegian navy related to safety competence safety management, and handling of goal conflicts. By means of a cross-sectional survey involving crews on Norwegian vessels ($N = 9{,}344$), we explored if naval ships differed from other ships on such aspects. The results indicated that crew members on naval ships had less experience and less confidence in their colleagues' competence to work safety. There were few differences related to considerations of safety management and safety practices. There are approaches available that could supplement accident investigations in systemic analyses of complex sociotechnical systems.

Keywords: Naval ships, Safety, Safety management, Accident investigations

INTRODUCTION

Maritime transport has a long history of major accidents, and the industry continues to be associated with high risk related to ship accidents. In commercial shipping, 49 ships over 200 GT were lost in 2020 (Allianz, 2021). In Norwegian waters alone, there were 3795 ship accidents during the 10-year period from 2012 to 2021 (Norwegian Maritime Authority 2022). Modern naval ships are complex sociotechnical systems, equipped with highly advanced technology. Such vessels have not been exempted from major accidents. There are two recent examples from the US Navy, both happening in 2017. USS Fitzgerald collided with a container ship, loosing seven of its crew members and causing extensive damages to the ship. The same year, the destroyer USS John S. McCain collided with a tanker, causing ten casualties and severe material damages. The accident investigations after these events pointed to several common human and organizational causes for the accidents, including training, fatigue, navigation errors, leadership and culture (Department of the Navy, 2017). The starting point for this paper is the collision between the military frigate 'Helge Ingstad' and the oil tanker 'Sola TS' that happened on November 8th 2018 at 04:01 in the morning in the Hjeltefjord in the south west of Norway. The frigate, estimated to a value of $1,3 billion, was eventually lost, and there were minor injuries among seven of its crew members. The accident was investigated by the Accident Investigation Board Norway (AIBN, 2019), and also internally by the Norwegian Armed Forces (NAF, 2020). The aim of this paper is to explore if some of the organizational safety vulnerabilities revealed by the accident investigations could be of relevance for Norwegian naval ships in general. The empirical foundation is a quantitative survey, involving crew members from different vessel types, including naval vessels.

The 'Helge Ingstad' Accident

As described by the Accident Investigation Board Norway (AIBN, 2019), 'Helge Ingstad' was sailing south after participating in the NATO exercise Trident Juncture at a speed of 17-18 knots and had turned the automatic identification system (AIS) in a 'receive only' mode, as often was the case for naval ships in training situations. Helge Ingstad had notified the Vessel Traffic Service (VTS) that they were entering the area. Sola TS had finished loading crude oil at the Sture terminal, and at 03.40 they started heading north with a pilot on board, using navigation lights and deck lights as the crew was still working on deck securing equipment. The Helge Ingstad navigation officers observed the lights, and even if Sola TS transmitted AIS signals, they assumed that it was a stationary object, as no speed vector was transmitted. Sola TS was therefore not tracked on the radar. At 03.57, Sola TS was increasing its speed to 6.1 knots. At 03.59, VTS became aware that the two vessels were on collision course after communicating with the pilot on Sola TS. After having verified that it was Helge Ingstad that was approaching, the pilot on Sola TS called Helge Ingstad and asked them to '…turn to starboard immediately'. The distance between the vessels was then approximately 875 meters. Helge Ingstad refused, as they thought they then would be too close to what they perceived as a stationary object. At 04.00, the master of Sola TS ordered 'stop engines'. VTS also called Helge Ingstad at 04.00.44 and asked them to do something 'You are getting very close', at that point 250 m. Now Helge Ingstad realized that the 'stationary object' was moving and was on collision course. The pilot on Sola TS ordered full speed astern and Helge Ingstad tried to change course, but it was too late, and the collision was a fact at 04.01.15.

The Causes

The causal factors for the accident presented in the investigation reports (AIBN, 2019; NAF, 2020) illustrate that the accident involved a range of organizational, technical and human issues. The internal accident investigation report by the Norwegian Armed Forces (NAF, 2020), highlighted 'cultural risk factors' as contributing factors. According to this report, there might be *systemic weaknesses* in the Norwegian navy related to the acknowledgement of safety competence and systematic safety management, including handling of goal conflicts between safety and operational deliveries. Competence, Safety Management and Safety practices will thus be particularly addressed in this paper.

Competence: The Officer of the Watch (OOW) on 'Helge Ingstad' had limited experience, possibly because of a lack of qualified personnel in the navy, resulting in early clearance. The OOW also served as an instructor of a OOW trainee during the event, a task that the OOW was not sufficiently trained for by the Navy. The navy had no competence requirements for instructors (AIBN, 2019). The NAF report points to a possible overconfidence in each other's competence, to the extent that it contributed to 'the perception of them being in full control of the situation'. This is an issue that is also actualized in the AIBN (2019) report, where it is suggested that "A more experienced OOW would probably have had a greater capacity to pick up weak signals of danger and be better equipped to suspect that his/her own situational awareness suffered from misconceptions." Complacency was also mentioned as a weakness, possibly produced by a combination of well-educated and self-confident personnel, a strong hierarchy and perceived previous successes (ibid: 66). Complacency might reduce vigilance and negatively affect safe working practices. **Safety management:** The NAF (2020) report points to a fragmented safety management system in the navy, which might have led to information not reaching the intended personnel. The allocation of roles, responsibilities and authority was found to be complex and possibly confusing. The reporting culture might vary in the navy, and the analysis of reports were found to be delayed, and there might be underreporting of near misses. Further, there might be a limited recognition of safety-related competence, and identification of safety-related goal conflicts. There might also have been a lack of management support and follow-up related to safety management and cultural issues from the Navy. **Safety practices:** The internal report (NAF, 2020) also points to other challenges that could be related to the navy in general. The combination of extensive training, self-confidence, respect for rank and achieved successes could contribute to complacency, and in turn to a lower awareness of weak signals of something being wrong. The basic assumption of 'having full control' that seems to be prevalent according to the report, could also make it difficult for some to notify others about operational concerns. Thus, complacency and overconfidence could have some negative implications for safe working practices.

Hypotheses

Based on the investigation reports, the following four hypotheses will be explored:

H1. Crew members from naval ships have less experience than crew members from other ships. **H2.** Crew members from naval ships have greater confidence in their collegues' competence than crew members from other ships. **H3.** Crew members from naval ships have a more negative perception of the safety management system (reporting, procedures) than crew members from other ships. **H4**. Crew members from naval ships have a more positive perception of safety practices onboard than crew members from other ships. The empirical foundation is a quantitative analysis of results from a large questionnaire survey distributed to respondents on Norwegian ships in early 2019. In the analyses, we will compare the results from crews on Norwegian naval ships with responses from crews from other ships.

Table 1. Demographics of the sample ($N = 7772$).

Variable		Naval ships (%)	Other vessels (%)
Age (years)	> 26	20,8	10,7
	26-35	39,8	20,9
	36-45	20,5	21,1
	46-55	13,9	24,3
	55<	5,0	23,0
Gender	Male	94,3	92,0
	Female	5,7	8,0
Position/Department	Deck	25,8	19,9
	Bridge	35,4	41,5
	Engine	27,5	37,1
	Catering	11,3	1,5

METHOD

Data Collection and Sample

The Norwegian Maritime Authority (NMA) has since 2016 performed a cross-sectional survey involving crews on Norwegian vessels (Aalberg et al., 2020). In our study, we use data distributed in January 2019 by e-mail ($N = 9{,}344$). The questionnaire was based on existing questionnaires within the maritime industry, petroleum industry and experts in the industry were involved to validate and create new items. We excluded respondents from fishing vessels because many small fishing vessels have a crew of 1-2 persons. Further, respondents from movable offshore installations were removed, considering that their operation is more like a fixed offshore installation than a sailing ship. The final sample consisted of 337 crew members from naval vessels and 7,435 crew members from other vessels ($N = 7772$). The category of 'other vessels' consists of a heterogenous pool of respondents from various ship categories ranging from smaller coastal cargo ships to larger passenger ships and offshore supply vessels. The respondents from naval ships are distributed across the Coast Guard (149), frigates (51), minesweepers (18), Submarine (14), Corvette (13), research vessels (12), Commando logistics (12), whereas the remaining 68 reported to work on diving vessels, high-speed crafts, royal yachts, search and rescue, reconnaissance vessels, or "other" naval ships.

There are some differences in the demographics (Table 1). The respondents from naval ships are younger and involve a larger proportion of captains and other officers, and a smaller proportion of crew members compared with other vessels. The sample generally consists of predominantly male respondents.

Measures and Statistical Analysis

The survey consisted of more than 70 items on organizational and safety topics. Items from the survey were selected for analyses based on the hypotheses and on face value. *Experience and competence* were measured with two items addressing the years of experience as a sailor, and years of experience

Table 2. 'How many years of experience do you have as a sailor?' Distribution of answers from naval ships (n = 307) and other vessels (n = 7149) – percent.

	< 1 year	1–3 years	4–10 years	> 10 years
Naval ships	6.2	14.3	25.7	53.7
Other ships	1.6	7.3	19.5	71.6

Table 3. 'How many years of have you worked on the type of vessel where you are currently working?' Naval ships (n = 307) and other vessels (n = 7149) – percent.

	< 1 year	1–3 years	4–10 years	> 10 years
Naval ships	11.1	26.4	37.1	25.3
Other ships	6.3	17.6	34.1	41.9

on their current vessel type. *Safety management* was measured through three categories of items: i) shipboard safety management, ii) onshore safety management, and iii) procedures. Safety practices was measured using five items relating to mindful safety practices and reporting. Based on factor analyses (PCA), structural equation modelling (SEM), a promising level of convergent and discriminant validity of the scales in the survey has been demonstrated in previous research (Aalberg et al., 2020). Descriptive statistics was applied in the analyses of the present study. For the hypotheses, statistical analyses were conducted using chi square tests (X^2) and analysis of variance (ANOVA).

RESULTS

Experience and Competence

The first two hypotheses were related to experience and competence. It was explored if crew members from naval ships had less experience than crew members from other ships, and also if crew members from naval ships had greater confidence in their collegues' competence than crew members from other types of vessels.

The crew members from naval ships reported less experience as a sailor than crew members from other ships. Approximately 20 % of the sailors from naval ships reported less than or equal to three years of experience, whereas crew members from other vessels reported approximately 9 %. A chi square analysis showed that differences in experiences were statistically significant ($X^2(3) = 73.196$, $p < .001$), thus supporting the first hypothesis.

The crew members from naval ships reported shorter experience from their current vessel type than crew members from other vessel types. Differences in reported years experiences was statistically significant $X^2(3) = 42.883$, $p < .001$), also supporting the first hypothesis.

Results from an ANOVA showed that crew members on naval ships agreed to a lesser extent to the statement regarding adequate competence than crew members on other vessel types ($F(1, 7407) = 6.533$, $p < .001$). The second hypothesis was not supported.

Figure 1: Level of agreement from 1 ('Totally disagree') to 5 ('Totally agree') on the statement 'Everyone on the vessel I work have the competence to execute their work tasks safely' – means.

Safety Management

The survey included four categories of items related to safety management: shipboard safety management, onshore safety management and procedures. It was explored if crew members from naval ships had a more negative perception of the safety management system and prrocedures than crew members from other vessel types (Table 4).

No statistically significant differences were found related to shipboard safety management items. The groups differed on one of the six items related to onshore safety management. Crews on naval ships had a more negative view on the shipowner's response to reported incidents than other respondents, $F(1, 6948) = 9{,}214$, $p < .001$. However, the effect size was small ($\eta^2 < .01$) indicating little practical implication. Thus, hypothesis 3 received limited support.

Safety Practices

Five survey items were related to safety practices, considering reporting, the stopping of dangerous work and notification of colleagues (Table 5), analyzed with ANOVA.

There were small and no significant differences on the mean scores on items related to safety practices for naval and other ships. Crew members from naval ships did to a lesser degree agree with a statement regarding stopping work ($F(1, 6950) = 14.391$, $p < .001$ and regarding whether colleagues report incidents ($F(1, 6872) = 5.467$, $p < .05$. Effect sizes were small as measured by eta squared, $\eta^2 < .01$ and thus implicates low practical implication of the differences. The results yield limited support hypothesis 4.

DISCUSSION

Naval ship crew members reported less general and specific experience as a sailor compared with crew members from other vessels. Naval ship crew

Table 4. Level of agreement from 1 ('Totally disagree') to 5 ('Totally agree') on statements related to safety management – means.

	Statements	Mean (St.dev)		p-value
		Naval ships	Other ships	
Shipboard safety management	I am confident that I get support from ship management if I prioritize safety in all situations	4.50 (0.86)	4.44 (0.94)	NS
	The ship management leads by example when it comes to ensuring one's own and others' safety	4.21 (1.00)	4.27 (0.99)	NS
	Safety has first priority on the vessel I work on	4.34 (0.91)	4.39 (0.95)	NS
Onshore safety management	The shipowner responds to incidents we report	3.56 (1.2)	3.76 (1.19)	<.01
	I think that the shipowner's responses to breaches of rules and procedures are fair	3.71 (1.05)	3.76 (1.13)	NS
	We receive feedback on changes that are initiated based on reported adverse events	3.95 (1.06)	4.08 (1.06)	NS
	Following the safety routines is not valued by the shipowner I work for*	4.22 (1.11)	4.12 (1.2)	NS
	As long as the work is done, the shipowner does not care how we do the work*	4.11 (1.11)	3.97 (1.23)	NS
Procedures	The safety procedures are adequate for my tasks	4.34 (0.93)	4.43 (0.87)	NS
	I have easy access to procedures and instructions that apply to my work	4.54 (0.9)	4.62 (0.8)	NS

*the items has been reversed.

members had less confidence in the colleagues' safety competence compared with crew members on other ships. There was little or no evidence of naval crew members having a more negative perception of the safety management system. Crew members on naval ships were less positive to stop working in dangerous situations and had less confidence in the reporting behavior of their colleagues.

The mandate for the internal navy investigation after the accident was to uncover systemic risk factors (NAF, 2020). In general, systemic analysis builds on open systems theory and an input-process-output model (Harrison, 1994). In a safety perspective, systemic analysis involves investigating complex interactions between components in a sociotechnical system, and approaches such as FRAM, Accimap and STAMP have been developed and applied for such analyses (Patriarca et al., 2020). The internal report highlighted safety competence and safety management as systemic factors, and describes some cultural risk factors, including complacency, as a general overarching casual category, considered to be of relevance to the Navy in general.

Table 5. Level of agreement from 1 ('Totally disagree') to 5 ('Totally agree') on statements related to safety practices – means.

Statements	Mean (St.dev)		p-value
	Naval ships	Other ships	
I report if I see hazardous situations	4,60 (0,62)	4,65 (0,66)	NS
I stop working if I think it can be dangerous for me or others to continue	4,43 (0,81)	4,61 (0,77)	<.001
My colleagues stop me if I work in a hazardous way	4,19 (0,83)	4,24 (0,94)	NS
I notify my colleagues if he/she does not use the required protective equipment	4,52 (0,68)	4,45 (0,84)	NS
My colleagues report any adverse events or near misses	3,60 (1,13)	3,77 (1,18)	<.05

Even if the level of experience seems to be lower on Naval ships, which could be explained by the enrollment of conscripts in the Norwegian navy, there are no clear signs of complacency, as the trust in collegues' safety competence is medium and lower compared to crew members from other ships. Also, the perception of key elements of the safety management system is positive, including the support from ship management, prioritization of safety and procedures for their work. The safety practices addressed in the survey are also perceived to be adequate among the naval crew members, although less positive on reporting behavior compared to other crew members.

In total, there are no clear indications of systemic risk factors based on the survey results. In classical contributions from safety science, naval ships have in fact been put forward as examples of 'High-Reliability Organizations' (LaPorte & Consolini, 1991). Even if naval ships can be described as complex and tightly coupled sociotechnical systems and characterized by a high turnover of young and inexperienced personnel, aircraft carriers were found to operate quite safely. To consider a single accident and start looking for systemic causes made applicable for a whole category of cases (the navy in general) could lead to inaccurate generalizations. It is clearly commendable that the navy has searched for organizational root causes and weaknesses. Still, some of the issues identified could be independent of the navy and represent general challenges in maritime organizations. The two accident investigations have applied established methods and build on a general accident model, considering root and immediate causes (ILCI), and a MTO (man, technology, organization) perspective. As mentioned, there are also other perspectives available, suitable for systemic analyses (Patriarca et al., 2020).

There are also some methodological weaknesses that could have influenced the results, including a relatively low number of navy respondents and some demographic differences between the two subsamples. The group of crew members selected for comparison is also quite heterogenous when it comes to missions, tasks and work processes. It might be that characteristics are 'leveled out' and become unsuitable for comparison. There are also raised some general concerns related to applying questionnaire surveys and self-reporting for considering organizational safety (e.g. Dahl & Kongsvik, 2018). In general, the results could be subject to Type II error; there might be differences between the subsamples even if the analyses have not been able to reveal them.

CONCLUSION

The crew members on naval ships had less experience and less confidence in their colleagues' competence to work safety, compared with crew members from other ships. There were few and relatively small differences on other measures included in the analysis. There are several approaches available that could supplement traditional accident investigations when investigating systemic analyses of complex sociotechnical systems.

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