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ARTICLE

Maritime safety and the ISM code: a study of investigated casualties and incidents

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Abstract In 1993, the International Maritime Organization adopted the International Safety Management (ISM) Code which requires all shipping companies operating certain types of vessels to establish safety management systems. Nevertheless, two decades later, maritime safety remains a concern. This article studies 94 maritime cases investigated by the Maritime Accident Investigation Branch in the UK. By providing an analysis of reported casualties and incidents, it highlights current challenges in maritime safety. For each casualty and incident, the study reviews the underlying causal factors. These causal factors are then coded according to the functional sections of the ISM Code, covering various aspects of safety management. To investigate human and organizational factors involved in the casualties and incidents, the human factor analysis and classification system (HFACS) is applied to code the same data. Finally, the relative seriousness of casualties and incidents is considered to discuss the findings from ISM Code and HFACS reviews. The study found that the main challenges pertain to the development of plans for shipboard operations, local shipboard management, and the ability of the company to verify when such practices deviate from best practices or required standards.

Keywords ISM Code · Maritime safety · Safety management and human factors

1 Introduction

The maritime transport industry (shipping) accounts for more than 90 % of global trade (IMO 2012) and has shown a doubling in transport capacity since 1980 (UNCTAD 2011). A 30 % increase in the loss ratio of vessels has been reported between 2006 and 2010 (IMO 2012).

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Shipping is renowned for being conservative when it comes to regulation. Most vessels conduct their main part of their operations at sea, enabling owners to bypass regulations in order to gain economic profit (Stopford 1997). However, during the 1980s and 1990s, the shipping industry experienced several very serious accidents, which resulted in a series of investigations into the causes.[1] A common factor identified was the human element, which in turn had its roots in the economic environment of the maritime industry. Rising competition had led ship owners to cut operational costs by recruiting low cost and generally less qualified labor and by re-flagging their vessels to circumvent regulations imposed by flag states (Bhattacharya 2009). Moreover, "safety" and "pollution" were generally taken to refer to problems related to construction and equipment rather than people and management systems (Anderson 2003). As a response to these developments, the 18th session of the International Maritime Organization (IMO) Assembly in 1993 adopted Resolution A. 741(18), which constitutes the ISM Code (IMO 1993). The IMO Assembly made the Code mandatory by incorporating it as a new Safety of Life at Sea (SOLAS) Chapter IX "Management for the Safe Operation of Ships" on 19 May 1994. Here, it is stated that "The company and the ship shall comply with the requirements of the International Safety Management Code" (IMO 2009). The ISM Code is designed to provide a framework for companies to establish integrated Safety Management Systems (SMS) to reduce accidents caused by human error (Rodriguez and Mary 1998–1999). It also couples organizational actors together with the DOC holder[2]—"a sweep from micro (seafarer) to meso (shipping management) and macro (maritime administration) levels" (Schröder-Hinrichs et al. 2011, p.1195). Even though a reduction in human causes is found following the introduction of the ISM code, severe accidents continue to occur and the human element is still the main cause (Tzannatos 2010; Hetherington et al. 2006). The maritime regulatory regime fails to effectively address human factors and safety management challenges (Kuronen and Tapaninen 2010), these being pretty much the same challenges as identified a century ago (Schröder-Hinrichs et al. 2012).

Previous research on the ISM Code has included methods of measuring safety standards, the relation between safety management and safety culture, stakeholders' opinions on the ISM Code, organizational learning within shipping companies, reporting and analysis procedures, compliance with the ISM Code, and the ISM Code as part of integrated quality management.[3] There is also a considerable literature on the investigation of maritime accidents, including studies of human and organizational factors (Schröder-Hinrichs et al. 2011; Chauvin et al. 2013; Xi et al. 2009; Celik and Cebi 2009). The present article focuses on the maritime casualties and incidents that have been studied, exploring what factors cause maritime accidents. We begin by locating these factors as part of the functional SMS as defined by the ISM Code. Then, by applying a modified human factor analysis and classification system (HFACS) framework, we investigate how the factors leading to maritime accidents are related to human and organizational factors. Finally, we consider the outcomes of the

[1] Notable were the tragic accident of the *Herald of Free Enterprise* in 1987 and the Lord Carver Report to the House of Lords issued in 1992.

[2] The entity that is responsible for the operation of the ship, either an owner or a company that has assumed the responsibility on behalf of the owner.

[3] See for example (Anderson 2003; Bhattacharya 2009; Celik 2009; Christophersen 2009; Oltedal 2011; Soma 2004; Tuniday and Thai 2010; Lappalainen et al. 2011).

casualties and incidents, their severity, and to what extent they can be related to the factors that caused them. The research topics of this study can be summarized as follows:

1. How are the causal factors leading to casualties and incidents distributed in terms of the functional requirements (sections) of the ISM Code?
2. How can a HFACS framework for studying human and organizational factors help us to understand the occurrence of casualties and incidents?
3. Is the severity of casualties and incidents relevant for understanding the factors that led to its occurrence?

2 Maritime regulation and the ISM code

The ISM Code constitutes part of the broader global legal framework that regulates shipping. Maritime safety was first regulated by international agreement with the Load Line Regulations of 1934. Following the Second World War, with the establishment of the United Nations and the IMO, international maritime regulation became more extensive (Anderson 2003). Here, we may note the International Convention for the SOLAS of 1974, the Standards of Training, Certification and Watchkeeping Convention (STCW) of 1978, and the United Nations Convention on the Law of the Sea of 1982 codifying the duties of flag states.

Regulation aims at limiting certain freedoms to ensure that individual actions are in line with the interests of the public good. Regulators have increasingly sought alternative approaches to the traditional dichotomy between "free market" and "command-and-control" regulation (Gilad 2010). With the ISM Code, the maritime industry has moved from being compliance-driven to being subject to enforced self-regulation (Kristiansen 2005). Enforced self-regulation is meant that the regulator (e.g., administrator/state) requires that the subjects of regulation (e.g., ship owners) develop, implement, and maintain their own management systems for regulating behavior and practice according to certain laws and regulations (Baldwin et al. 2010). This provides the regulated targets with flexibility for tailoring cost-effective measures according to their specific circumstances (Gilad 2010; Baldwin and Cave 1999; Gunningham and Rees 1997). As acknowledged in the Code, "…no two shipping companies or shipowners are the same…" (IMO 2002, p.5). In contrast to measures imposed by an "outside" regulator, measures established by a company's SMS may be more relevant and legitimate, promoting higher levels of compliance (Baldwin and Cave 1999). The primary barriers to effective self-regulation are the cost-benefit incentives (Baldwin et al. 2010) which may not favor safety measures and ensuring that appropriate sanctions are in place to foster compliance. The flexibility provided by the ISM Code may make it challenging to assess the compliance of individual shipping companies in the design of their SMS.

"Safety management" can be considered to mean all systematic measures taken to establish and maintain levels of safety that conform to policies, goals, and other requirements (Abrahamsen et al. 2004). The ISM Code provides a holistic and integrated approach to safety management, with its various sections dealing with different aspects. Part A of the Code states that it is the companies' duty to establish Safety Management Systems, although it does not go into detail as to how this is to be achieved. Part B concerns certification and verification: the measures available to administrators (states) for forcing companies act upon their obligations under Part A. The Code is intended to "ensure safety at sea, prevention of human injury or loss of life, and avoidance of damage to the environment, in particular the marine environment, and to property" (IMO 2002, p.7). A company's SMS shall "provide for safe practices in ship operations and a safe working environment,…assess all identified risks…and establish appropriate safe guards, continuously improve safety management skills…" (IMO 2002, p. 7). Further, the Code provides for such systems to be established to ensure compliance with customary international and national rules, regulations, codes, guidelines, and standards established by the IMO, the flag state, classification societies, and maritime industry organizations (IMO 2002, p. 7). This does not mean, however, that the Code is an all inclusive piece of legislation that establishes new obligations in this respect (Anderson 2003). The functional requirements of any SMS are outlined in section 1.4 (IMO 2002, p.7) and elaborated in greater detail in the remaining sections of the Code.

- General objective, application, functional requirement (section1)
- Safety and environmental policy and SMS (section 2)
- Company responsibility (section 3)
- Designated person (section 4)
- Master's responsibility (section 5)
- Resources and personnel (section 6)
- Developments of plans for shipboard operation (section 7)
- Emergency preparedness (section 8)
- Report and analysis (section 9)
- Maintenance of ship equipment (section 10)
- Documentation (section 11)
- Company verification, review, and evaluation (section 12)

The model of accident causation developed by Reason (1990) provides a framework for understanding the location of human errors at various system levels in an organization from corporate level to teams and persons. The model developed for accident causation has two interrelated causal sequences, an active failure pathway and a latent pathway, arguing that human failures are not restricted to the "sharp end"—those who work close to the source of danger (Reason 1995). In this model, errors made at the sharp end or active failures are labeled "unsafe acts," whereas latent failures are labeled either "preconditions to unsafe acts," "unsafe supervision," or "organizational influences." As the present article aims to shed light on the role of human errors (active or latent failures) at various levels of organization related to the ISM code, reports were analyzed using HFACS. While Reason's accident causation model provided a model, we required a more detailed framework. HFACS was developed to provide a methodological tool for accident investigation supplementing the model of Reason (Schröder-Hinrichs et al. 2011). As HFACS was originally developed for analyzing military aviation accidents, several researchers have made adaptions to the framework (Schröder-Hinrichs et al. 2011; Chauvin et al. 2013). Our study took HFACS to the machinery spaces of ships, HFACS-MSS, as a starting point, with alterations to make it more suitable for marine operations in general. We have also drawn on Xi et al. (2009), who developed an HFACS method for data collection and classification of marine human factors. One difference between the HFACS-MSS and the HFACS used in our study is the division of unsafe supervision between shore-based management and shipboard management. This has been done to differentiate between unsafe supervision carried out on board and shore-based management. Compared to the aviation industry, military aviation in particular, maritime operations in the merchant fleet are usually differently organized, with tasks distinct from those in aviation.

3 Methodology

The data in this study build on investigation reports published by the UK's Marine Accident Investigation Branch (MAIB). The MAIB is a branch of the UK Department of Transport and is responsible for investigations of maritime accidents involving or happening onboard vessels registered in the UK or other vessels in the UK territorial waters. The MAIB reports were selected because they include human factor causes based on Reason's model of accident causation (Rothblum et al. 2002; Kristiansen 2005). Understanding regulatory processes requires detailed knowledge of operations, how the agents understand the regulations, and how internal processes interact (Black 2002). Our study draws on 85 investigation reports published by the MAIB in the period from 01 July 2002 to 01 July 2010. Reports concerning only passenger vessels, fishing vessels, and pleasure crafts have been excluded from the study. The time interval for the reports selected is harmonized with the implementation of the ISM Code from July 2002 until a new edition of the Code was issued in July 2010. Some of the investigation reports include two or more vessels; each vessel is registered as one case. In total, we have coded 94 cases based on the 85 report, of which collision reports included two or more cases. The reports were divided into three categories, according to the severity of the casualties and incidents. The categorization of severity is based on IMO definitions[4] (IMO 1997): these are "very serious," involving total loss of the ship, loss of life, or severe pollution; "serious," involving casualties not qualifying as very serious, such as fire, explosion, and damage to hull resulting in the ship being unseaworthy and any pollution; and "less serious," to denote marine incidents where the ship or human life person was imperiled. Table 1 provides an overview of the distribution of seriousness for the cases used in this study.

Of the cases studied, 37 solely involved UK-registered vessels; the remaining 57 vessels involved a total of 27 different ship registries. Each case has been coded and may have several causal factors. All the reports were published by MAIB, with some variations in structure and content during a time span of 8 years. The reports vary in focal area, depending on the type of accident and the level of details. Compliance with the ISM Code was notably less in focus during the first years of our sample.

Coding of the reports was done using the qualitative data analysis software NVivo 10. Nodes were developed for the four levels of failure described by HFACS, with sub-nodes for causal categories labeled tier two and tier three by Schröder-Hinrichs et al. (2011). We did not introduce a fifth level of statutory/outside factors (as used in some other studies, e.g., (Reinach and Viale 2006; Schröder-Hinrichs et al. 2011; Chauvin et al. 2013), as regulation is the unit of analysis in our study. Using HFACS,

[4] The categorization severity of casualties and incidents has been amended by the IMO on 01 January 2010.

Table 1 Distribution of degree of severity

Accident category	Very serious	Serious	Less serious	Total
Number	22	23	49	94

some adaptions have been made to the sub-nodes as compared to the initial methodology developed by Wiegmann and Shappell (2003). Coding of reports into the HFACS framework was done by the first author; only coding facts stated in the reports. A 20 % random sample was coded to HFACS by an independent, second person with sound knowledge of human factors and experience in the use of HFACS. The interrater methods used were both Cohen's Kappa (κ) and Krippendorff's Alpha (α), yielding κ coefficient of 0.823 and α of 0.824. This indicates an acceptable agreement between the coders, allowing conclusions to be drawn from the results of the HFACS coding (Bakeman et al. 1997; Krippendorff 2004). A Krippendorff Alpha interrater assessment was also conducted for the main levels of HFACS (organizational influence, unsafe supervision, preconditions for unsafe acts, and unsafe acts), resulting in α value of 0.837.

The causal factors resulting from the coding to HFACS were further coded into the first 12 sections of the ISM Code (IMO Resolution A. 741(18) as amended by resolution MSC.104(73)). This was based on a qualitative assessment by the first author.[5] In order to avoid subjective interpretation, each coding of causal factors to the sections of the ISM Code was controlled and discussed with the second author.

3.1 Limitation of the study

A limitation of this study is that the results and conclusions are based on investigation reports dealing only with casualties and incidents in UK territorial waters and UK-registered vessels. Also, the methodology used in conducting the accident investigation and the biases of the investigators may represent further constraints on validity. There are several studies on the challenges of investigation which may limit the value of investigations. In their article, "What-You-Look-For-Is-What-You-Find—the consequences of underlying accident models in eight accident investigation manuals," Lundberg et al. (2009, p.1310) found that all manuals represented in their study made use of complex linear accident models "[causing] a preoccupation with parts and a lack of focus on the whole." Sklet (2004) argues that a complex accident should be investigated using a combination of methods as major accidents seldom result from single causes. The studies of Hassel et al. (2011) and Psarros et al. (2010) have identified underreporting of maritime accidents. This also limits the validity of our study, as it can be assumed that some casualties and incidents may not have been reported, giving perhaps a skewed dataset. A further limitation concerns the interrater method applied using Cohen's Kappa. Bakeman et al. (1997) found that the Cohen Kappa coefficient may be unreliable, depending on the number of codes and the variability of the code's simple probabilities. We have not tested the coders' capability

[5] The first author, a Master Mariner with several years' experience as senior navigator, has also worked as a Quality, Health, Safety, & Environment Manager for a company operating vessels worldwide and has PhD course level training in human factors.

for accurate coding, assuming instead that the coders will perform at an accuracy level of 90 % or less.

4 Results

In this section, we first present the results of the coding of causal factors distributed on the functional sections of the ISM Code. This will indicate where in the companies' SMS, the causal factors that led to the maritime casualties and incidents studied here are located. In the next section, we present the coding of the causal factors based on an HFACS framework to show the human and organizational factors behind the casualties and incidents covered by our study.

4.1 The ISM code

Coding of causal factors to the various sections of the ISM Code is presented in Table 2. We find that 7.9 % (*N*=38) relate to section 1 "general" of the ISM Code and 1.9 % (*N*=9) to the policy level of the safety management system represented by section 2 and 3 of the ISM code. The regulation of the activities and processes required for a safety management system represented by sections 5 to 8 and 10 of the ISM Code accounts for 66.1 % (*N*=316) of the causal factors, whereas the SMS monitoring and control elements represented by section 4, 9, 11, and 12 account for 24.1 % (*N*=115).

From the first 12 sections of the ISM Code, the highest number of causal factors (*N*=134) stem from section 6 "resources and personnel." This section accounts for 28.0 % of all causal factors, of which slightly more than half (53.0 %) are assigned to cases categorized as less serious. Table 3 shows in further detail the distribution of coding to section 6 of the ISM Code.

In all the cases, the crew members satisfied the formal national and international requirements for qualification and certification, but still proved to lack the knowledge and skills necessary to operate the vessel or equipment safely. In many cases, the companies had failed to ensure that crew members were properly qualified in terms of knowledge and skills to actually deal with operational problems.

"The decisions the master took when attempting to anchor the vessel indicated a lack of seamanship skills and anchoring experience" (MAIB 2006, p.31). "The master showed a fundamental misunderstanding of the principles of anchoring" (MAIB 2007, p.39).

A full 59 of the causal factors relate to failure of the company to ensure that crew members were qualified (12.3 %). Matters of training and familiarization represent 8.2 % of all causal factors. There seemed to be an unrealistic expectation that basic operational practice would be transferred between vessels when new crew members signed on. Further, 4.4 % of the causal factors relate to the inability to communicate effectively.

Section 12 accounts for 16.9 % (*N*=81) of the causal factors distributed over 38 of the cases with a relatively equal spread across the three categorization of seriousness. Table 3 shows the coding under section 12. Here, we see that 13.2 % of the causal factors coded to this section relate to failures to verify departures from existing

Table 2 Coded causal factors distributed to section of the ISM Code

Sections of the ISM Code	Very serious		Serious		Less serious		Total	
	No.	%	No.	%	No.	%	No.	%
1. General	21	4.4	7	1.5	10	2.1	38	7.9
2. Safety and environmental protection policy	1	0.2	0	0.0	1	0.2	2	0.4
3. Company responsibility and authority	1	0.2	1	0.2	5	1.0	7	1.5
4. Designated person(s)	3	0.6	3	0.6	9	1.9	15	3.1
5. Master's responsibility and authority	13	2.7	19	4.0	37	7.7	69	14.4
6. Resource and personnel	31	6.5	32	6.7	71	14.9	134	28.0
7. Development of plans for shipboard operations	20	4.2	20	4.2	25	5.2	65	13.6
8. Emergency preparedness	6	1.3	4	0.8	2	0.4	12	2.5
9. Reports and analysis of NCs, accidents, and hazardous situations	2	0.4	8	1.7	6	1.3	16	3.3
10. Maintenance of the ship and equipment	8	1.7	15	3.1	13	2.7	36	7.5
11. Documentation	2	0.4	0	0.0	1	0.2	3	0.6
12. Company verification, review, and evaluation	25	5.2	24	5.0	32	6.7	81	16.9
Total	133	27.8	133	27.8	212	44.4	478	100.0

The percentage numbers are to 478 causal factors

Table 3 Sub-categories of selected sections of the ISM Code

Sub-categories of section 6	*N*	%
Ensuring qualified crew	59	12.3
Training and familiarization	39	8.2
Ability to communicate	21	4.4
Other	15	3.1
Sub-categories of section 12	*N*	%
Failure to verify departure from procedures and good practice	56	11.7
Review of the efficiency of the SMS	11	2.3
Failure to verify knowledge gap related to SMS	7	1.5
Timely corrective action	6	1.2
Independent of audit area	1	0.2
Sub-categories from section 5	*N*	%
Poor or absent orders and instructions	44	9.2
Failure to verify specific requirements	25	5.2
Sub-categories from section 7	*N*	%
Lack of checklists	11	2.3
Lack of procedures	31	6.5
Lack of instructions	11	2.3
Lack of ship specific instructions, procedures, or checklists	12	2.5

procedures and practice and to verify the crew members' knowledge of the SMS. Failure to implement timely corrective action is found in 1.2 % of the causal factors, while failure/inadequacy in evaluating the efficiency of the SMS accounts for 2.3 %.

The obligation to conduct risk assessments, establish safeguards, providing for safe practice and a safe working environment is to be found in section 1 of the ISM Code. Of the total identified causal factors, 7.9 % are coded to this section. Twenty-two causal factors (4.6 %) coded to section 1 related to either limited or no risk assessment. One example of the coded material is from the MAIB report number 15 2010: "The hazards inherent in the rigging of the vessel's crane, one of the vessel's key operations, were not assessed. Consequently, several important safety barriers were not in place" (MAIB 2010, p.26).

In 42 cases, 69 causal factors indicate failure to instruct the master of his responsibilities, as required by section 5 of the ISM Code. Of the causal factors, 63.8 % (N=44) relate to poor or no orders and instructions, while in 36.2 % of the cases (N=25), the master failed to verify specified requirements. Of all the causal factors related to section 5, 53.6 % were found in cases categorized as less serious.

The investigations disclosed a lack of formal routines related to basic shipboard operations like navigation, cargo handling, and watchkeeping. Without formal routines, informal ways of conducting operations tended to develop on board. A full 65 causal factors relate to section 7 of the ISM Code (see Table 6). Of the 13.6 % of causal factors coded to this section, a lack of necessary procedures accounts for 6.5 % and lack of checklists and instructions for 4.6 %. Lack of ship specific instructions, procedures, or checklists is involved in 2.5 % of all causal factors.

The maintenance of ship and equipment (section 10 of the ISM code) has 7.5 % (*N*=36) of the causal factors ascribed to it. Just above half of these relate to the failure to identify equipment and technical systems where sudden operational failure which could have resulted in hazardous situations (4.0 %). Poor inspection routines and improper inspection intervals account for 1.9 %, and lack of maintenance records and lack of corrective actions for 1.7 %.

4.1.1 Concluding remarks on the ISM code

The largest share of causal factors coded to the functional requirements of the ISM Code is found in sections 5, 6, 7, and 12. All causal factors coded to these four sections tend to appear in cases categorized as less serious. Failure to ensure that crew members are properly qualified and have received necessary training and familiarization is frequent, representing 20.5 % of all causal factors. Also, the failure to comply with section 5 (clearly defining and documenting the master's responsibilities) is found in a high number of causal factors. Notably, established instructions, procedures, and checklists in the safety management systems were not followed. Several reports draw attention to the limited ability of audit practices to detect failure as regards to intentions and scope of instructions, procedures, and checklists—ranging from policy implementation to operational issues. This study coded 56 causal factors (11.7 %) to company failure to verify departure from procedures and good practice, mainly in less serious cases. Concerning the functional requirement of appropriate instructions, procedures and checklists for key shipboard operations, the highest number of causal factors related to failure to develop procedures (6.5 %).

4.2 Results from coding to HFACS

During the coding of the 94 reports using the HFACS framework, 478 causal factors were identified at the third tier. Table 4 presents the distribution of these; 478 factors by HFACS tiers and the severity of the incident. The causal factors are rather evenly distributed, with the highest allocation of third tier factors placed at unsafe supervision (30.8 %) and unsafe acts (28.0 %). Further, 23.4 % of the coding concerns on preconditions for unsafe acts and 17.8 % are coded to organization influences. Latent conditions, gathered under the first tier categories of organizational influences, unsafe supervision, and preconditions for unsafe acts, account for a full 72 % of the causal factors.

4.2.1 Unsafe acts

Of the causal factors coded under unsafe acts, slightly more than half (50.7 %) relate to errors, while 49.3 % relate to violations. Of the causal factors coded to errors (14.2 %), skill-based errors are represented by 6.3 % (*N*=30), decision and judgment errors 7.3 % (*N*=35), and perceptual errors a mere 0.6 % (*N*=3). Routine violations account for 90.9 % of all factors coded under violations. For the causal factors coded to unsafe acts, 50.0 % are from cases categorized as less serious, relatively evenly spread between errors and violations.

Table 4 Presentation of the 478 causal factors coded in HFACS

	Accidents						Total	
	Very serious		Serious		Less serious			
	No	%	No	%	No	%	No	%
1. Organizational influences	33	6.9	19	4.0	33	6.9	85	17.8
1.1 Resources	10	2.1	2	0.4	12	2.5	24	5.0
1.1 1. Human resources	2	0.4	0	0.0	8	1.7	10	2.1
1.1 2. Technology resources	0	0.0	0	0.0	0	0.0	0	0.0
1.1 3. Equipment/facility resources	8	1.7	2	0.4	4	0.8	14	2.9
1.2. Organizational climate	1	0.2	3	0.6	2	0.4	6	1.3
1.1 2. Structure	0	0.0	0	0.0	0	0.0	0	0.0
1.2 2. Policies	0	0.0	0	0.0	1	0.2	1	0.2
1.2 3. Culture	1	0.2	3	0.6	1	0.2	5	1.0
1.3. Organizational processes	22	4.6	14	2.9	19	4.0	55	11.5
1.3 1. Operations	1	0.2	1	0.2	3	0.6	5	1.0
1.3 2. Procedures	8	1.7	5	1.0	7	1.5	20	4.2
1.3 3. Oversight	13	2.7	8	1.7	9	1.9	30	6.3
2. Unsafe supervision	51	10.7	34	7.1	62	13.0	147	30.8
2.1. Inadequate supervision	31	6.5	20	4.2	42	8.8	93	19.5
2.1.1. On board	13	2.7	6	1.3	7	1.5	26	5.4
2.1.2. Shore-based	18	3.8	14	2.9	35	7.3	67	14.0
2.2. Planned inappropriate operations	17	3.6	9	1.9	13	2.7	39	8.2
2.2.1. Shipboard operations	15	3.1	4	0.8	8	1.7	27	5.6
2.2.2. Shore-based planning	2	0.4	5	1.0	5	1.0	12	2.5
2.3. Failed to correct know problems	1	0.2	2	0.4	2	0.4	5	1.0
2.3.1. On board related failures	1	0.2	1	0.2	1	0.2	3	0.6
2.3.2. Shore-based failures	0	0.0	1	0.2	1	0.2	2	0.4
2.4. Supervisory violations	2	0.4	3	0.6	5	1.0	10	2.1
2.4.1. On board violations	1	0.2	3	0.6	4	0.8	8	1.7
2.4.2. Shore-based violations	1	0.2	0	0.0	1	0.2	2	0.4
3. Preconditions for unsafe acts	24	5.0	38	7.9	50	10.5	112	23.4
3.1Environmental factors	12	2.5	10	2.1	16	3.3	38	7.9
3.1.1. Physical environment	3	0.6	0	0.0	1	0.2	4	0.8
3.1.2Technological environment	9	1.9	10	2.1	15	3.1	34	7.1
3.2Crew conditions	7	1.5	8	1.7	13	2.7	28	5.9
3.2.1. Cognitive factors	5	1.0	6	1.3	7	1.5	18	3.8
3.2.2. Physiological state	2	0.4	2	0.4	6	1.3	10	2.1
3.3. Personnel factors	5	1.0	20	4.2	21	4.4	46	9.6
3.3.1. Crew interaction	5	1.0	19	4.0	19	4.0	43	9.0
3.3.2. Personal readiness	0	0.0	1	0.2	2	0.4	3	0.6
4. Unsafe acts	25	5.2	42	8.8	67	14.0	134	28.0
4.1. Errors	13	2.7	20	4.2	35	7.3	68	14.2

Table 4 (continued)

	Accidents						Total	
	Very serious		Serious		Less serious			
	No	%	No	%	No	%	No	%
4.1.1. Skill-based errors	8	1.7	12	2.5	10	2.1	30	6.3
4.1.2. Decision and judgment errors	4	0.8	7	1.5	24	5.0	35	7.3
4.1.3. Perceptual errors	1	0.2	1	0.2	1	0.2	3	0.6
4.2. Violations	12	2.5	22	4.6	32	6.7	66	13.8
4.2.1. Routine	11	2.3	20	4.2	29	6.1	60	12.6
4.2.2. Exceptional	1	0.2	2	0.4	3	0.6	6	1.3
Total	133	27.8	133	27.8	212	44.4	478	100.0

The percentage numbers are to 478 causal factors

4.2.2 Preconditions for unsafe acts

Causal factors coded to the precondition for unsafe acts account for 112 of the total of 478. Of these, 41.1 % (N=46) are coded to personnel factors; further, 38.4 % (N=43) of personnel factors relate to crew interaction, such as internal and external communication on board the vessel and coordination of activities on board. Another prominent category is the technological environment, coded under environmental factors, amounting to 7.1 % of all causal factors as against to only 0.8 % for the physical environment. The coding shows that 5.9 % of the causal factors relate to crew conditions, divided into cognitive factors (inattention, distraction, interference, confusion, etc.), which amount to 3.8 % and physiological state, amounting to 2.1 %.

4.2.3 Unsafe supervision

The material coded under unsafe supervision is divided into supervision on board and supervision at shore-based management. A total of 56.5 % of the causal factors under unsafe supervision are coded to shore-based management. Inadequate supervision accounts for 63.3 % of causal factors coded to unsafe supervision, with 17.7 % being inadequate supervision on board and 45.6 % inadequate supervision by shore-based management. Planned inappropriate operations account for 26.5 % of unsafe supervision. The remaining 10.2 % relate to failure to correct known problems and supervisory violations.

4.2.4 Organizational influences

Of the causal factors coded to organizational influences, 64.7 % relate to organizational processes of which 35.3 % concern oversight (poor procedural guidance, organizational training issues, and organizational risk management). The reports assigned less contribution from organizational climate (structure, policies, and culture), which account for only 1.3 % of all causal factors. It is noteworthy that non-causal factors are attributed to technological resources.

4.2.5 Third tier findings on HFACS

The coding to HFACS highlights some third tier nodes. Table 5 below presents the third tier categories ranked as containing most causal factors. We see that seven third tier nodes represent 62.6 % (*N*=299) of the causal factors in this study.

Inadequate supervision from shore-based managers accounts for 14.0 %; this involves inadequate tracking qualification, failure to provide proper training, and failure to provide proper publications/adequate technical data and procedures. In contrast, inadequate supervision on board, though still high, account for only 5.4 % of the causal factors. Ranked second highest are routine violations under unsafe acts, accounting for 12.6 % of all causal factors. The causal factors are here represented by failure to comply with company SMS and maritime regulations. Most frequently noted was the absence of a night-time look-out. The third tier node that is ranked number 3 is crew interaction under preconditions for unsafe acts. Here, the main issues are bridge resource management, having enough resources but allocating them poorly, and internal communications on the bridge, as well as communications between the engine department and the bridge. Errors of decision and judgment rank fourth; these mainly concern inappropriate maneuvers and inadequate knowledge of systems.

4.2.6 Concluding remarks on HFACS

Unsafe supervision (*N*=147) emerges as the biggest challenge, representing 30.8 % of the causal factors. Differentiating between kinds of inadequate supervision helped to demonstrate that shore-based is the main challenge (14 %). Unsafe acts (*N*=134) with 28 % of all causal factors, and in particular, routine violations (12.6 %), also stand out in that regard. Preconditions for unsafe acts represent 23.4 % (*N*=112), with crew interaction as the largest third tier score (9 %). Finally, the lowest score is organizational influences (17.8 %, *N*=85).

Table 5 High ranking third Tier HFACS coding

Rank	First tier	Second tier	Third tier	*N*	%
1	Unsafe supervision	Inadequate supervision	Shore-based	67	14.0
2	Unsafe acts	Violations	Routine	60	12.6
3	Preconditions for unsafe acts	Personnel factors	Crew interaction	43	9.0
4	Unsafe acts	Errors	Decision and judgment errors	35	7.3
5	Preconditions for unsafe acts	Environmental factors	Technological environment	34	7.1
6	Organizational influences	Organizational processes	Oversight	30	6.3
6	Unsafe acts	Errors	Skill-based errors	30	6.3
	Total			299	62.6

The percentage numbers are to 478 causal factors

4.3 The cross-tabulation of ISM code and HFACS

In this section, we cross-tabulate the findings from the coding of causal factors in previous sections. This enables us to shed light on how the causal factors distributed on the functional requirements of the ISM Code also relate to human and organizational factors based on HFACS.

As seen in Table 6, there are differences regarding how factors coded according to the functional requirements of the ISM Code score along the human organizational dimension (HFACS). For example, causal factors under section 5 Master's responsibility and authority (14.4 %) relate predominantly to preconditions for unsafe acts (6.1 %) and Unsafe acts (5.9 %). Moreover, almost half of the causal factors under section 7 on development of plans for shipboard operations are related to unsafe supervision. The challenges identified regarding section 6 Resource and personnel (28 %) appear throughout the human organizational dimension, though less so under the category of organizational influences. Finally, we note that causal factors under section 12 of the ISM Code (16.9 %) concern mainly on organizational influences (6.1 %) and unsafe acts (6.9 %).

4.4 Severity of cases

Of the 478 causal factors coded in this study, 133 were related to the 22 very serious cases, 133 to the 23 serious cases, and 212 to the 49 less serious ones (see Appendix Tables 7, 8, and 9). Cases categorized as very serious had a mean of 6 causal factors while the mean number of causal factors for serious cases was 5.8. For less serious cases, the mean number of causal factors was 4.3. This indicates that the number of causal factors involved increases with the severity of the case.

Only in 18.6 % of the cases are unsafe acts (*N*=134) identified as causal factors leading to very serious accidents. In 50 % of the cases, unsafe acts are related to less serious accidents and the remaining 31.3 % to serious one. As to preconditions for unsafe acts (*N*=112), in 21.4 % of the cases, they are causal factors leading to very serious accidents (in 33.9 % leading to serious and in 44.6 % to less serious accidents). Unsafe supervision (*N*=147) was a causal factor leading to very serious accidents (34.7 %), to serious accidents (23.1 %), and to less serious accidents (42.1 %). Finally, organizational influence (*N*=85) was a factor leading to very serious accidents in 38.8 % of its occurrences, in 22.4 % to serious accidents, and in 38.8 % to less serious accidents.

In sum, causal factors coded under HFACS category of unsafe supervision were the highest overall scorer (30.7 %)—especially as regards very serious accidents, where they represented 38.3 % of the causal factors.

5 Discussion

This section will present highlights from the results of this study and discuss the findings in relation to previous research on maritime safety and the ISM Code. First, the findings from the coding into the different requirements of the ISM Code will be discussed followed by a discussion on the findings of the coding into the HFACS framework.

Table 6 Cross-tabulated results from coding to ISM and HFACS

HFACS ISM Code	Organizational influences	%	Unsafe supervision	%	Preconditions for unsafe acts	%	Unsafe acts	%	Total	%
1. General	13	2.7	15	3.1	8	1.7	2	0.4	38	7.9
2. Safety and environmental protection policy	2	0.4	0	0.0	0	0.0	0	0,0	2	0.4
3. Company responsibility and authority	4	0.8	3	0.6	0	0.0	0	0.0	7	1.5
4. Designated person(s)	4	0.8	2	0.4	9	1.9	0	0.0	15	3.1
5. Master's responsibility and authority	0	0.0	12	2.5	29	6.1	28	5.9	69	14.4
6. Resource and personnel	15	3.1	47	9.8	28	5.9	44	9.2	134	28.0
7. Development of plans for shipboard operations	9	1.9	30	6.3	14	2.9	12	2.5	65	13.6
8. Emergency preparedness	1	0.2	10	2.1	0	0.0	1	0.2	12	2.5
9. Reports, analysis of non-conformities, accidents, and hazardous occurrences	4	0.8	3	0.6	2	0.4	7	1.5	16	3.3
10. Maintenance of the ship and equipment	4	0.8	14	2.9	12	2.5	6	1.3	36	7.5
11. Documentation	0	0.0	1	0.2	1	0.2	1	0.2	3	0.6
12. Company verification, review, and evaluation	29	6.1	10	2.1	9	1.9	33	6.9	81	16.9
Total	85	17.8	147	30,8	112	23.4	134	28.0	478	100.0

The percentage numbers are to 478 causal factors

5.1 Coding to the ISM code

Maritime investigation reports were developed into 94 cases which were analyzed using HFACS and further coded to the relevant sections of the ISM Code. The analysis provides insights into the challenges in maritime safety concerning the functioning of the ISM Code and how human and organizational factors affect maritime safety. Further, our analysis offers insights into the role of the regulatory regime currently directing maritime safety.

The greatest numbers of causal factors involve sections 5, 6, 7, and 12 of the ISM Code. We have seen that companies have failed to provide their onboard managers, the masters, with clear instructions on responsibilities, resulting in poor or no orders and a lack of verifications expected to be carried out by the masters. The high percentage of causal factors found under section 5 "Master's responsibility and authority" (12 % points out of 14.4 % assigned to preconditions for unsafe acts and unsafe acts) indicates company failure to facilitate and enable local management. This echoes the study by Oltedal and Engen (2009), where the role of ship board management was identified as a key factor in achieving safe operations.

The main challenge lies in section 6 of the ISM Code, where 134 causal factors are coded. This study reveals that companies failed to ensure that crew members were suitably qualified beyond the necessary certificate and courses. Further, they failed to provide the necessary training and familiarization. There seemed to be an unrealistic expectation that basic operational practice would be transferred between vessels when new crew members sign on. This corresponds with the findings of Oltedal and Engen (2009), where competence was identified as one of five safety-related dimensions on board.

Our findings concerning section 7 of the ISM Code highlight the lack of effort to develop suitable plans for key shipboard operations. This concerns poor or lacking instructions, checklists, and procedures and coincide with the findings from Oltedal (2010) that poor procedures is a problem in daily work. Also evident is the practice of developing generic procedures and checklists for vessels which coincide with the finding from Oltedal and Engen, arguing that "standardized measurement will therefore never align with reality" (2011, p.91). They found that there was a clear tendency to standardize the procedures and checklists, not taking into consideration facts such as the differences among vessels, crew configuration, and organizational power constellations. Procedures that are inaccurate or ill-suited are less likely to be adhered to in real life operations (Antonsen 2009a). The low level of dedication we found as regards details and accuracy in relation to section 7 of the ISM Code may also be reflected in the low compliance with regulations set out in the SMS as crew members may consider these less useful or even irrelevant. Bhattacharya (2012) found disparity in the understanding of the ISM Code between shore-based managers and the seafarers sailing for the same company. Shore-based management considered the ISM Code as a management tool, resulting in a low trust work environment and lack of crew participation in developing the SMS.

5.2 Coding to HFACS and cross-tabulation

In order to provide a fine-meshed presentation of the causal factors distributed to the functional requirements of the ISM Code, we applied the framework of HFACS. This allowed us to detach causal factors originating from an organizational level from those originating from an individual level. It allowed us to say more about where the challenges are located in maritime safety management.

The coding to HFACS identifies inadequate supervision from shore-based management as a major contribution to casualties and incidents. This includes failure to ensure that qualified personnel are sent onboard the vessels and to ensure that crew members receive proper training in SMS, equipment, or systems. Another key contributor is violation of routines, such as the failure to comply with the company SMS, rules, and regulations. This may be ascribed to the structuring of many ship management companies, with a separation between ownership and management. This may influence the perspective of the shore-based managers on how to cooperate with the personnel onboard the vessels. However, as noted in the previous section, the failure to comply may also be due to on board personnel's local optimization of rules and regulations presented in the SMS (Dekker 2003).

At the level of unsafe acts, there is an even distribution of causal factors between errors and violations. This is different from the findings of Chauvin et al. (2013) who found a majority of causes from collision cases coded to violation. The explanation may be due to the difference in the selected case-studies. While Chauvin et al. (2013) studied collision cases only, our study has a broader scope and it may be reasonable to assume that collision cases have more causal factors coded to violation considering that rules of the road most likely will have been broken. Schröder-Hinrichs et al. (2011) have a different finding in their study of machinery space fires and explosions, where most of the causal factors under unsafe act were coded to errors. This difference may reflect the gap between navigation and engine room accident investigation and the fact that our study only contained three cases related to engine room fires and explosions. In contrast to bridge resources management (BRM), engine room resource management has to a limited extent been exploited, neither in practice nor in the investigation of the accidents (Hetherington et al. 2006). Violation of procedure and drifting operational practice in the merchant fleet has been reported in other studies as well (Dai et al. 2013; Oltedal 2012; Antonsen 2009b) and may be expected if procedures, instructions, or checklists are considered inefficient or meaningless by the crew. In this study, we also found that a high number of causal factors were coded to section 7 of the ISM code representing lack of or poor instructions, procedures, and/or checklists. From the cross-tabulation, section 6 is represented with the highest number of causal factors, presenting the possibility that unsafe acts relate to lack of competence, training, and familiarization.

Possessing a shared mental model of the situation is considered an element that strongly influences performance when crew members are working together (Chauvin 2011). While BRM training has been part of the STCW for some time, it was significantly improved following the Manila Amendments 2010 (Yabuki 2011). Under precondition for unsafe acts, our study found the largest number of causal factors related to crew interaction which includes BRM. From the cross-tabulation, the highest numbers under preconditions for unsafe act are in the intersection with section 5 (Master's responsibility and authority) and 6 (resource and personnel) of the ISM Code. The lack of teamwork, poor communication on the bridge between the bridge and the engine control room, and the failure to conduct an in-operation brief for crew members were main causal factors. Lack of supervision and team communication was also reported as important contributing factors by Macrae (2009) in the study of grounded vessels.

At the level of unsafe supervision, the results show that inadequate supervision from shore-based management occurs frequently. The companies often fail to provide proper training, assigning crew members to tasks they do not have the necessary knowledge or skills to perform safely. Planning of inappropriate operations often origin from the crew on. Typically, for the cases studied, the master or senior officers have failed to provide proper brief prior to an operation. Supervisory violations originating from the leaders on board are less frequent, a result that contradict with the findings from Chauvin et al. (2013), but is similar to the results found by Schröder-Hinrichs et al. (2011). This may be due to the possibility that supervisory violations occur more frequently in cases concerning collisions with respect to both speed and watchkeeping.

At the level of organizational influences, the main causal factor is failure to ensure proper risk management and efficient audit regimes. This coincides well with the findings from Chauvin et al. (2013) who point to the weakness of the audit regime used in the maritime industry. It is predominantly subject to process audits (controlling for compliance through inspection of documents and interviews) as opposed to "line audits," where the auditors are following the vessel in-operation, attaining a "picture of normal operations" (Thomas 2004). The process audits are often subject to limited time for the audit to be conducted thoroughly as they are most usually conducted alongside quay (Batalden 2012). Auditor independence from a personal relationship with client, auditor skills, unclear audit criteria, and paperwork for the sake of the audit are among categories of failure to the existing occupational health and safety audit practice reported by Blewett and O'Keeffe (2011).

6 Conclusions

This study has found that the main challenges pertain to the development of plans for shipboard operations, local shipboard management, and the ability of the company to verify when such practices deviate from best practices or required standards. This is evident from the findings regarding the master's responsibility and authority (section 5); resources and personnel (section 6), in particular, as regards crew qualifications, training, and familiarization; failure to develop plans for shipboard operations (section 7), and finally, failure to verify departure from procedures and good practice (section 12). In cases coded as very serious accidents, section 7 of the ISM Code concerning "development of plans for shipboard operations" is high, reflecting the lack of developing good instructions, procedures, and checklists.

The study confirms the importance of resource management skills among the crew members identified by Chauvin et al. (2013). Companies seem to fail in ensuring that the crew members are properly qualified for the tasks they are assigned to or expected to do. Familiarization and training within maritime safety management seem to have the potential of being reconsidered. A more thorough and structured work in mapping the knowledge and skills possessed by crewmembers, perhaps linking it to thorough risk assessment of key shipboard operations is needed. Another area of concern is the vast amount of deviation from existing systems. Even though there has been done research on the link between the formal SMS and the actual conduct of operations, there seems to be a need for more research in this area. The study of inspection and audit regimes does also seem to be in need of attention.

Appendix

Table 7 Cross-tabulated results from cases categorized as very serious (N=133)

ISM	Organizational influence		Unsafe supervision		Preconditions for unsafe acts		Unsafe acts		Total	
	N	%	*N*	%	*N*	%	*N*	%	*N*	%
1. General	7	5.3	9	6.8	4	3.0	1	0.8	21	15.8
2. Safety and environmental protection policy	1	0.8	0	0.0	0	0.0	0	0.0	1	0.8
3. Company responsibility and authority	1	0.8	0	0.0	0	0.0	0	0.0	1	0.8
4. Designated person(s)	1	0.8	0	0.0	2	1.5	0	0.0	3	2.3
5. Master's responsibility and authority	0	0.0	5	3.8	4	3.0	4	3.0	13	9.8
6. Resource and personnel	4	3.0	12	9.0	5	3.8	10	7.5	31	23.3
7. Development of plans for shipboard operations	4	3.0	13	9.8	3	2.3	0	0.0	20	15.0
8. Emergency preparedness	1	0.8	5	3.8	0	0.0	0	0.0	6	4.5
9. Reports and analysis of NCs, accidents, and hazardous situations	2	1.5	0	0.0	0	0.0	0	0.0	2	1.5
10. Maintenance of the ship and equipment	0	0.0	4	3.0	1	0.8	3	2.3	8	6.0
11. Documentation	0	0.0	1	0.8	1	0.8	0	0.0	2	1.5
12. Company verification, review, and evaluation	12	9.0	2	1.5	4	3.0	7	5.3	25	18.8
Total	33	24.8	51	38.3	24	18.0	25	18.8	133	100.0

The percentage numbers are to 133 causal factors coded to very serious cases

Table 8 Cross-tabulated results from cases categorized as serious (*N*=133)

	Organizational influence		Unsafe supervision		Preconditions for unsafe acts		Unsafe acts		Total	
ISM	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%
1. General	3	2.3	2	1.5	1	0.8	1	0.8	7	5.3
2. Safety and environmental protection policy	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
3. Company responsibility and authority	0	0.0	1	0.8	0	0.0	0	0.0	1	0.8
4. Designated person(s)	0	0.0	1	0.8	2	1.5	0	0.0	3	2.3
5. Master's responsibility and authority	0	0.0	3	2.3	12	9.0	4	3.0	19	14.3
6. Resource and personnel	2	1.5	8	6.0	8	6.0	14	10.5	32	24.1
7. Development of plans for shipboard operations	2	1.5	4	3.0	6	4.5	8	6.0	20	15.0
8. Emergency preparedness	0	0.0	4	3.0	0	0.0	0	0.0	4	3.0
9. Reports and analysis of NCs, accidents, and hazardous situations	1	0.8	3	2.3	1	0.8	3	2.3	8	6.0
10. Maintenance of the ship and equipment	3	2.3	6	4.5	4	3.0	2	1.5	15	11.3
11. Documentation	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
12. Company verification, review, and evaluation	8	6.0	2	1.5	4	3.0	10	7.5	24	18.0
	19	14.3	34	25.6	38	28.6	42	31.6	133	100

The percentage numbers are to 133 causal factors coded to serious cases

Table 9 Cross-tabulated results from cases categorized as less serious (*N*=212)

	Organizational influence		Unsafe supervision		Preconditions for unsafe acts		Unsafe acts		Total	
ISM	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%
1. General	3	1.4	4	1.9	3	1.4	0	0.0	10	4.7
2. Safety and environmental protection policy	1	0.5	0	0.0	0	0.0	0	0.0	1	0.5
3. Company responsibility and authority	3	1.4	2	0.9	0	0.0	0	0.0	5	2.4
4. Designated person(s)	3	1.4	1	0.5	5	2.4	0	0.0	9	4.2
5. Master's responsibility and authority	0	0.0	4	1.9	13	6.1	20	9.4	37	17.5
6. Resource and personnel	9	4.2	27	12.7	15	7.1	20	9.4	71	33.5
7. Development of plans for shipboard operations	3	1.4	13	6.1	5	2.4	4	1.9	25	11.8

Table 9 (continued)

ISM	Organizational influence N	Organizational influence %	Unsafe supervision N	Unsafe supervision %	Preconditions for unsafe acts N	Preconditions for unsafe acts %	Unsafe acts N	Unsafe acts %	Total N	Total %
8. Emergency preparedness	0	0.0	1	0.5	0	0.0	1	0.5	2	0.9
9. Reports and analysis of NCs, accidents, and hazardous situations	1	0.5	0	0.0	1	0.5	4	1.9	6	2.8
10. Maintenance of the ship and equipment	1	0.5	4	1.9	7	3.3	1	0.5	13	6.1
11. Documentation	0	0.0	0	0.0	0	0.0	1	0.5	1	0.5
12. Company verification, review, and evaluation	9	4.2	6	2.8	1	0.5	16	7.5	32	15.1
Total	33	15.6	62	29.2	50	23.6	67	31.6	212	100

The percentage numbers are to 212 causal factors coded to less serious cases

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