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Safety in shipping: The human element

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Abstract

Introduction: There are numerous diverse papers that have addressed issues within maritime safety; to date there has been no comprehensive review of this literature to aggregate the causal factors within accidents in shipping and surmise current knowledge. *Methods:* This paper reviewed the literature on safety in three key areas: common themes of accidents, the influence of human error, and interventions to make shipping safer. The review included 20 studies of seafaring across the following areas: fatigue, stress, health, situation awareness, teamwork, decision-making, communication, automation, and safety culture. *Results:* The review identifies the relative contributions of individual and organizational factors in shipping accidents, and also presents the methodological issues with previous research. *Conclusions:* The paper concludes that monitoring and modifying the human factors issues presented in this paper could contribute to maritime safety performance. *Impact on industry:* This review illustrates which human factors issues are prevalent in incidents therefore this gives shipping practitioners a focus for interventions.

Keywords: Shipping; Safety; Human factors; CRM; Accident causation

1. Introduction

> *"Shipping is perhaps the most international of all the world's great industries and one of the most dangerous."* (International Maritime Organization [IMO], 2002a)

The shipping industry is expanding exponentially: 80 million Americans per year use U.S. flagged vessels, 90% of the U.S. population is served by domestic shipping, 97% of the UK's trade by weight arrives or leaves by sea. The United States maritime administration states that "shipping is vital to the nation's security, economy, and transportation" (U.S. Department of Transportation, 2004). The 2004 operating budget for the United States Coast Guard was 330 million dollars. Globally, statistics reflect the same fiscal importance of this industry, for instance there are around 50,000 merchant ships trading internationally, transporting a range of cargos. The world shipping fleet is registered in over 150 nations, and manned by over one million seafarers (BIMCO et al., 2004).

The shipping industry has a fairly good safety record, however maritime incidents have a high potential for catastrophes. Perrow (1999) pointed out that "Tankers carrying LNG have the potential to blow up a whole city;" he argues that there is still a strong motivation for profit in this industry and ships and their crews are pushed to the limits to meet deadlines. The first major oil spill, which was in the English Channel in 1967 and involved the tanker Torrey Canyon, exemplified this environment of high pressure and acute time demands. The captain, to save 6 hours, took a more direct route through the Scilly isles to arrive at Milford Haven in time to make the high tide. If he missed this window, his ship would be forced to wait at anchor for five days before being able to enter the bay. The oil in the tanker was moved to different tanks to raise the ship two inches to avoid a potential grounding. When passing through the Scilly Isles, the vessel came across a fishing boat and was unable to turn quickly enough and the ship ran aground, spilling 100,000 tons of oil contaminating a total area of about 300 km along the

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southwestern coastline of England and along the northwestern coastline of France.

Perrow (1999) states that the error inducing character of the system in shipping lies in the social organization of the personnel onboard, economic pressure, the structure of the industry, and insurance and difficulties in international regulation. This review examines the current status of safety in the maritime industry and the human factors that may contribute to the causal chain in shipping accidents. There is a particular combination of demands characteristic of the maritime industry such as fatigue, stress, work pressure, communication, environmental factors, and long periods of time away from home, which could be potential contributors. Exemplifying that in shipping "there are a number of workplace dangers in combination, something rare in other industries" (McNamara, Collins, & Matthews, 2000). Yet, it appears that very little human factors research has been carried out within the maritime industry.

The 21st century shipping industry faces new challenges. For instance, 25 years ago the average cargo ship would have been manned with a crew of between 40 and 50 (Grech & Horberry, 2002). Today technological advances have contributed to decreased manning, in some cases to just 22 seafarers on a Very Large Crude Carrier (VLCC). There are two sides to the technological advances. Improvements in ship design and navigation aids have reduced the frequency and severity of shipping incidents. In turn, the reduction of failures in technology has revealed the underlying level of influence of human error in accident causation.

2. Injuries and incidents

Merchant shipping is known to be an occupation with a high rate of fatal injuries caused by organizational accidents and maritime disasters (Hansen, Nielsen, & Frydenberg, 2002). The United States Coast Guard (USCG, 2004) reports their 5-year average of 673 passenger and maritime worker injuries and fatalities. Common incidents such as collisions, allisions, and groundings specifically have decreased in this period; this is attributed to enhanced technology in aids to navigation. The USCG operating expenses for safety in the fiscal year 2004 were 330.4 million dollars, illustrating that there are both fiscal and humanistic drivers to improve safety performance in shipping. The UK Marine Accident Investigation Branch (MAIB) states that "one factor still dominates the majority of maritime accidents; human error" (MAIB, 2000).

Data from New Zealand are congruent with this: 49% of shipping incidents cited human factors as a cause, while only 35% cite technical factors and 16% environmental factors (Maritime Safety Authority of New Zealand, 1995–1996). The most common human factors causes were error of judgment and improper lookout or watchkeeping, followed by failure to comply with regulations. The 'human element' as it is often termed in the shipping literature (O'Neil, 2003) has frequently been cited as a cause of these costly incidents. A USCG report states that between 75–96% of marine casualties are caused at least in part by some form of human error (Rothblum, 2000).

Esbensen, Johnson, and Kayten (1985) in their report 'The importance of crew training and standard operating procedures in commercial vessel accident prevention' state that 43% of accidents reported to the U.S. Coast Guard cite human error as the primary cause. They go on to argue that the actual figure of incidents involving human error may be as high as 80%. They present a case that enhancing safety is not only important for the ships' staff but also in terms of fiscal drivers from the industry (often ships are chartered on the strength of their safety performance). Wagenaar and Groeneweg (1987) analyzed 100 accidents heard by the Dutch Shipping Council between 1982 and 1985. Of these cases, there were 2,250 cited causes, 345 of which were human error (15%). Only 4 of the 100 cases occurred with no human error causes. The authors purport that in 96 of 100 cases, the people involved should and could have prevented the accident, however they were rarely caused by just one human error.

The data concerning accidents at sea have primarily been generated and investigated by government agencies affiliated with countries within which the accidents have occurred or countries who flag the vessels.[1] There are no standardized accident reporting systems in the maritime domain, which poses a problem in trying to elucidate causal themes from accident data, however, some retrospective research has evaluated the causes of shipping accidents in a more general sense. Darbra and Casal (2004) sampled in port accidents through a historical analysis from the beginning of the 20th century to October 2002 as listed in the Major Hazard Incident Data Service (MHIDAS; Darbra & Casal, 2004). This review depicts a rise in the number of accidents occurring in the maritime domain, illustrating that between 1981 and 1990 there were 82 accidents, while between 1991 and 2000 there were 282 incidents listed in the MIHDAS. Of the total, 83% had occurred in the last 20 years and 59% had occurred in the past decade, human factors were cited in 16% of all in port accidents. However, the authors did not account for the developing accident reporting culture within this industry, which may potentially explain this trend. Their paper appears to have some ambiguities in classification, one of the listed accident causes is impact, which is usually a result of an incident rather than the cause.

Maritime statistics illustrate that the resolution of technical problems such as enhancing navigation aids, which has decreased the level of machine related errors, appear to have revealed the relative contribution of human error in accident causation. These statistics present the case for research into human error causes in this domain, with the aim of reducing

[1] Vessel must choose a 'flag' under which to sail. This is the country that sets legislation and guidelines within which the vessel must operate. The flag is frequently the country within which the company who mans the ship or owns the ship is based.

these errors and resulting incidents. This review will now address human error failures existing at the organizational, personnel, and design level. This organizing framework, as shown in Fig. 1, relates to the levels at which errors can occur, which can subsequently develop into precursors to incidents. This framework was adapted to reflect issues present (more specifically those that had been researched) within the maritime industry, from more general organizing frameworks developed by Stanton (1996), the UK Health and Safety Executive (HSE, 1997), and Jørgensen (2002). The review addresses each level included within the framework.

The review progresses, aligned with the model, from the inside out. Firstly, design issues are considered within this industry, which relate to automation; secondly, personnel issues, such as fatigue, stress and non-technical skills are presented, followed by organizational level issues such as safety climate and training.

3. Method

Several electronic databases (e.g., PsychARTICLES, PsychINFO, ScienceDirect, and Web of Science) were used to identify research articles on human factors in shipping by using the following search terms: maritime, shipping, stress, fatigue, situation awareness, decision making, communication, teamwork, safety, and shipping/maritime accidents. Additionally, institutions that had conducted work in these areas (including government bodies) were sourced through search engines (e.g., Google) and authors were contacted directly with requests for relevant literature. Studies that met the following criteria were included: a sample of seafarers, those in peer–reviewed journals, those with an empirical data set, conference papers or government papers, and published in English. A total of 30 studies were identified, of these 20 met the criteria. From evaluating these 20 studies it appears there is a comparatively small amount of work in the maritime domain on concepts that are relatively well established and researched in other domains. This paper presents a review of this fragmented area, and attempts to unify the body of research and present a case for where further research is required.

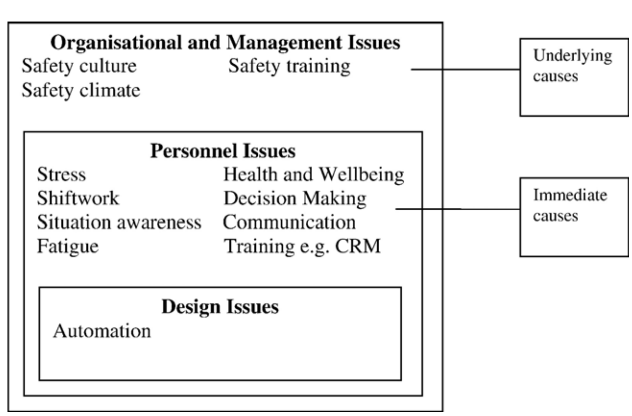

Fig. 1. An organizing framework for human factors which contribute to organizational accidents in shipping adapted from Stanton (1996), Jørgensen (2002), and HSE (1997).

4. Design issues

4.1. Automation

Due to reduced manning levels in the maritime industry there is now an emphasis on automation. There has been a cultural shift in the maritime industry toward increased levels of automation in tasks, particularly with regard to navigation systems. This increase in automation and decrease in manning levels has changed the role of the seafarer (Grech & Horberry, 2002). Sarter and Woods (1995) purport that automation can create new attentional demands. The operator has to permanently keep track of the numerous systems, what they are doing and what they will do next, which mode they are operating in and so on, this is termed "mode awareness" (Sarter & Woods, 1995). Could automation be increasing cognitive demands on the reduced workforce and contributing to observed human error influence on accident rates?

Alternatively, there is the view that operators will monitor less effectively when automation has been installed and even less effectively if the automation has been functioning efficiently for a period of time (Lützhöft & Dekker, 2002). Therefore, does automation result in some kind of cognitive lackadaisicalness? Whereby accidents may, in the instance of increased automation, be a result of over reliance on machines. Lützhöft and Dekker (2002), propose that automation creates new human weaknesses and amplifies existing ones. They use the example of the Royal Majesty (RM), which ran aground when bound for Bermuda as a result of incorrect positioning information, to demonstrate the negative effects of automation. In this case, one positioning system was functioning incorrectly because the antenna had broken (Global Positioning System), however, there were additional radar data that could have been used to cross check the system. Although this did not occur, differences observed in the points were unnoticed and so the incorrect course was plotted on the chart. Those on watch searched for information to confirm their initial hypotheses of the course they were on, and thus interpreted markings incorrectly. For example the officer on watch expected to come across buoy BA in the Boston traffic separation scheme and so upon coming across a buoy, identified this as BA, however it was actually AR, a buoy 15 miles west to southwest of BA. Furthermore, two fishing vessels tried to contact the RM to warn of the imminent danger, however these calls were dismissed, potentially because the radar was set to a range of six miles and therefore the fishing vessel did not appear and so the officer may have presumed they were trying to contact someone else. Additionally when the fishing vessels tried later to contact the RM, and quoted the ships position to identify that it was the RM they wished to speak to, RM was at this point the 16.5 nautical miles from where they thought they were and so again may have dismissed the call presuming that the fishing vessel was trying to contact another vessel. These calls were made 1 1/2 hours prior to the grounding. An over reliance on the data displayed by the bridge technology possibly made those officers on the watch ignore the information that would have potentially prevented the grounding of the RM. In this incident 1,000 passengers were injured and the accident cost the company $7 million in lost revenues (Lützhöft & Dekker, 2002).

5. Personnel issues

This first section deals with human performance factors or behaviors that may contribute to maritime incidents and presents research that has evaluated the contribution of these factors in accident causation.

5.1. Fatigue

Research has illustrated that there are potentially disastrous outcomes from fatigue in terms of poor health and also diminished performance (Josten, Ng-A-Tham, & Thierry, 2003). In the 24 hours prior to the grounding of the Exxon Valdez in 1989, the watchkeeper had only had 5 or 6 hours of sleep (National Transportation Safety Board [NTSB], 1990), suggesting that fatigue may have been a contributing factor to this environmentally catastrophic grounding. Fatigue is not a new issue in the maritime domain. However, the conditions in which seafarers work are becoming increasing demanding. There are shorter sea passages, higher levels of traffic, reduced manning, and rapid turnaround. Extended hours on duty and hours worked in the last three days are associated with marine accidents that could be attributable to fatigue (Raby & McCallum, 1997). In their research, investigating officers were presented with 98 ship casualty reports and identified in 23% of cases that fatigue was a contributory cause.

Despite the introduction of work rest mandates by the IMO, there are still occasions where individuals simply have to work for more than 12 hours with a 6-hour break. During discharging operations, the chief officer must be present at all times. A tanker with a 300,000 tonnage takes approximately 44 hours to discharge, so this means that the chief officer is required to be awake and present throughout this period. In a report by the National Transportation Safety Board (1999) attempting to address operator fatigue, seafarers were identified out of the occupational groups included to have the second highest number of maximum work hours in a 30-day period, behind rail operators. A study by the National Union of Marine Aviation and Shipping Transport Officers (NUMAST, 1995, as reported in Cole–Davies, 2001) surveyed 1,000 officers; 77% felt that fatigue has significantly risen in the past 3–10 years, 84% felt that stress was also more prevalent. A further study by NUMAST (as reported in Cole–Davies, 2001) surveyed 563 seafarers, 50% of whom indicated that they worked more than 85 hours in a week and 66% felt that extra manning was necessary to reduce fatigue. Results from a study of Australian seafarers revealed that 70% of seafarers report poor to very poor sleep (Parker, Hubinger, Green, Sargent, & Boyd, 2002).

Smith (2001) analyzed data from the Maritime Coastguard Agency (MCA) as supplied to the Marine Accident Investigation Bureau (MAIB) between 1989 and 1999. The results indicated that fatigue related accidents were most prevalent at the beginning of the tour (first week), in the first four hours of a shift, between the hours of 09:00 and 16:00, and in calm conditions. He also identified differences between an onshore and offshore sample in reaction time tasks (assessing alertness), both prior to and post shift completion. Differences were also evaluated between the day and night shift onboard vessels, a marked increase was observed in reaction times after the shift. In a second study focusing on the short sea and coastal shipping industry, there were higher reported levels of fatigue and poorer health than in phase one (Smith et al., 2003). In this phase 53% of respondents said that there was no opportunity for them to have 6 hours of uninterrupted sleep, as compared with 44% in phase one. Additionally, 52.6% of respondents in phase two believed their working hours to be a danger. Onboard assessments of fatigue (objective and subjective) were also conducted with 177 seafarers over seven vessels (of different types—ferries or tankers). These consisted of subjective reports of fatigue in logbooks, a computerized assessment of performance both before and after work and, actimetry, an objective measure of sleep. The authors concluded that fatigue is greater in the near sea sector than in support shipping. They identified exposure factors predicting fatigue: working hours, sleep problems, tour length (longer tours equate to less fatigue), shift length, job demands, stress at work, and standing watch. Ship type also had a role in predicting fatigue; seafarers based on ferries reported higher levels of fatigue than other vessel types. One difficulty with this type of research is that there is no outcome measure to relate the impact of the subjective and objective reports of fatigue to seafarer's performance. Therefore, although illustrating the nature and perception of fatigue in shipping, this research does little to confirm the effect of fatigue in accident causation, although this could be due to inadequacies in maritime accident databases that often fail to capture time based information (McNamara et al., 2000).

In other industries it is known that shift patterns contribute to fatigue and in turn cause poorer health and safety performance (IskraGolec, Folkard, & Noworol, 1996). Thus it could be inferred that this would also be found within the maritime domain with additional issues such as rolling, pitching, vibrations, and noise, which would only serve to magnify any present effects of shift work based fatigue (McNamara et al., 2000).

5.2. Stress

Stress has been identified as a contributory factor to the productivity and health costs of an organization as well as to personnel health and welfare (Cooper, Dewe, & O'Driscoll, 2001). In a comparative study of Australian seafarers and normative data from an onshore population (Australian Maritime Safety Agency–AMSA), Parker et al. (2002) observed that there were a number of health and stress-related differences between the two samples. Using a self report questionnaire, respondents were asked to rate how frequently they felt stressed and at what level. Additionally how frequently and to what extent did they engage in health-related behaviors (e.g., exercising, drinking, and smoking). The survey had 1,806 respondents comprising: crew, masters, mates, pilots, and engineers. Seafarers reported significantly higher levels of stress from sources of work pressure than did the normative group, especially on items that assessed relationships with others and the home/work interface. Most seafarers reported occasional to frequent stress at sea (80%). There were inter-departmental differences in stress levels, over 65% of engineers, 60% of crew, and over 60% of masters report moderate to high stress levels. Frequency and levels of reported stress tended to be lower in the crew than all other groups. Exposure to elevated stress levels for an extended period of time leads to negative mental and physical health outcomes (Quick, Quick, Nelson, & Hurrell, 1997).

5.3. Health

Research from other domains such as the offshore oil industry indicates a positive relationship between health management and safety performance (Mearns, Whittaker, & Flin, 2003). In the AMSA seafaring sample around a third of seafarers (32%) exceeded the National Heart Foundation (NHF–Australia) guidelines for safe limits of alcohol consumption (Parker et al., 2002). Furthermore, 28% of individuals smoked as compared with 24% of the Australian male population. Of the seafaring sample, 81% failed to reach minimum exercise levels required for good health (as recommended by the NHF–Australia), however, reports noted a wide variety in quality of exercise facilities made available to personnel. There were also inter-departmental differences, a higher percentage of crew smoked as compared with other departments. Furthermore a higher proportion of crew failed to reach NHF (Australia) exercise guidelines and exceeded NHF (Australia) alcohol consumption guidelines.

Although the research on stress and health behaviors establishes that this occupational group suffer from high level of these aforementioned factors as compared with other occupational groups, there is an absence of literature that aims to evaluate the relationship between seafarers health, and performance. In this aforementioned AMSA study, analogous to the other studies cited, there is no outcome measure to assess the impact of health and stress on subsequent performance.

6. Personnel issues

6.1. Non-technical skills

Non-technical skills are an additional set of competencies that are used integrally with technical shipping skills, such as those to manoeuvre the vessel, or set down the anchor. They encompass both interpersonal and cognitive skills such as situation awareness, communication, team working, and leadership. Research in the aviation, medical, and nuclear power industries has exposed these underlying skills in best practice. The following is a review of research that has focused on non-technical skills within the maritime domain.

6.2. Situation awareness (SA)

Situation Awareness is the ability of an individual to possess a mental model of what is going on at any one time and also to make projections as to how the situation will develop. An often cited definition is; "….the perception of the elements in the environment within a volume of space and time, the comprehension of their meaning, and the projection of their status in the near future" (Endsley, 1988). Endsley postulates three levels: (a) first, individuals must have the correct perception of the elements in the situation in order to form an accurate picture; (b) the second level involves the combination, interpretation, storage, and retention of the acquired information to form a picture of the situation whereby the significance of particular objects and events are understood; and (c) the third level of situation awareness is projection, and occurs as a result of the combination of levels one and two. This stage is an extremely important component of SA, as it means possessing the ability to use information from the environment to predict possible future states and events, in order to reduce surprise.

Wagenaar and Groeneweg (1987) state in their review of 100 shipping incidents that cognitive problems were responsible for 70% of observed human errors. Grech, Horberry, and Smith (2002) examined human error in maritime operations from 177 maritime accident reports, accidents occurring between 1987–2000, from eight countries. They observed that 71% of all human error types on ships are situation awareness related problems. Using Endsley's error taxonomy to define three levels of situation awareness, the most commonly occurring SA based errors were at level one (59%, 33% at level 2, and 9% at level 3). This is congruent with the rates of SA errors occurring per level as reported within the aviation industry (Grech et al., 2002).

Koester (2003) conducted a study of situation awareness in Denmark based on observations of eight voyages (on combined passenger and car vessels). Communications on the bridge were recorded at set time intervals to assess situation awareness at levels one and two (perceiving and comprehending elements in the current situation). Communications were categorized into actual, relevant, and general. Communication levels of all types rose as the vessel approached the port. At the times when actual and relevant communications reached their peak, general communication decreased. Koester (2003) observed that this decrease in general communication reflected an adaptation to a potentially critical situation. He proposed that the rise in actual communication reflects the preparation before a change in situation and also reflects an attempt to maintain situation awareness. This preparation and anticipation, is "a clear indication of situation awareness on level 3" (p5) (making projections of future events).

6.3. Decision making and cognitive demands

Hockey, Healey, Crawshaw, Wastell, and Sauer (2003) used an experimental study to investigate the cognitive demands of collision avoidance in simulated ship control. The participants were 12 undergraduate computing students (selected for their familiarity with software) who were given 12 hours of nautical training. They were required to steer a simulated ship along a pre-planned course avoiding collisions for six minutes, while monitoring a separate display to "maintain engine oil temperature within tolerance limits." Hockey et al. (2003) demonstrated that higher levels of collision threat were associated with an increase in self-rated mental workload and also in a detriment in performance on a secondary task. Although this study may initially present with some issues of ecological validity, these appear to have been well controlled for by the authors, through extensive training in appropriate literature on how to use the system and in repeating trials to the equivalent level that an actual seafarer may have encountered. Hockey et al. (2003) demonstrate the costs of monitoring. High mental workloads create a detriment in performance on a secondary task. This shows the potential consequences of having to monitor numerous pieces of equipment concurrently; this detriment in performance on one task could have potentially serious consequences in a real life situation.

6.4. Communication

One of the core skills central to effective and safe production and performance in all high-risk industries is communication, this also influences team SA as well as team working and effective decision-making. The Canadian Transportation and Safety Board (CTSB) reviewed 273 incidents from 1987–1992 with vessels in Canadian pilotage waters (waters on approach to a port where a pilot comes on board and guides the vessel either in or out of the channel). There exists an important teamwork relationship between the OOW (officer of the watch), master, and pilot. Port state authorities demand that all vessels above a certain dead weight tonnage must have a pilot to guide them in and out of port, in order to reduce the number of groundings and collisions in busy port areas, which are also subject to strong tidal movements. The pilot boards the ship as it exits or enters a port and gives instructions to the captain on what actions are to be executed in mooring operations and navigation. The captain is still legally responsible and liable for the vessel but is expected to yield to the judgment of the more experienced pilot. The captain is also the individual responsible for giving the instructions to the ship's staff on what the pilot has suggested or instructed. Of the incidents sampled by the CTSB, 42% involved misunderstandings between pilot and master or the officer of watch or lack of communication. Although these are fundamentally communication issues, this figure could also reflect deficits in other skills. The term "misunderstanding" potentially reflects a lack of situation awareness and poor team working as well as inadequate communication.

Subsequent to the retrospective analysis of incident data, the CTSB conducted interviews and developed a questionnaire to measure teamwork, communication, and to evaluate the master, pilot, and OOW relationship. Of the questionnaires distributed, 324 were returned: 40% pilots, 43% masters, and 16% bridge officers. Approximately 80% of each group responded that communications are "often" or "always" effective. When asked if a pilot makes sure his/her orders are understood and acknowledged by the OOW, 84% of pilots responded that this was the case, while only 50% of masters and 50% of OOWs agreed with this statement. When asked whether OOW asks for clarification if he/she is unsure of the pilot's intentions, 90% of OOW, 76% of masters, and only 39% of pilots respond that the OOW "always" or "often" asks for clarification. There appears to be a discrepancy here between an individual's self-perception of effective communication and other's interpretations of these interactions. When asked whether bridge officers were reluctant to question a pilot's decision: 92% of masters and 81% of bridge officers said "sometimes," and 12% of bridge officers said they were "always" reluctant to question the pilot. These communication issues can often result in errors or accidents.

One factor, which the authors suggest could be a contributing cause to these findings, are language problems. The Standards of Training Certification and Watchkeeping for seafarers (STCW) specify a required level of fluency in the ship's declared language, and they suggest that this may not be currently adhered to. Or alternatively, there is compliance solely with the unavoidable minimum requirements in terms of communication, which may in actual fact be insufficient.

6.5. Language and cultural diversity

In the maritime industry, employees of many cultures and nationalities work within the same environment. A study at the Seafarers International Research Centre (SIRC) illustrated that approximately only one third of ships have a single nationality crew (ships sampled were of all different varieties, n = 10,958) (Kahveci & Sampson, 2001). This can potentially create language issues, therefore flag states require that each ship must have a working language that each employee must speak to a certain standard, deemed competent. However, is this always the case? In emergency situations can individuals speak coherently and competently in their second language where other cognitive demands are high?

In the aforementioned SIRC study, 14 vessels were used as part of a case study. On these vessels the stated common working language was English, which was the second language for everyone onboard. Kahveci and Sampson (2001) found that seafarers frequently suggested that communication difficulties were the only or main drawback of mixed nationality crew. They also found that the results of miscommunication ranged from mild annoyance to formation of potentially hazardous situations. The study also illustrated the effects of culture on teamwork using the example of the loss of the mv *Green Lily* (MAIB, 1999). The vessel's Master, Chief Engineer, 2nd Engineer, Chief Officer, 2nd Officer, and 3rd Engineer were all Croatian. Although the MAIB report did not list communication as a cause, the report insinuated that the master's autocratic style of management was a contributory factor (Kahveci & Sampson, 2001). Thus, the national culture of the individuals onboard impacted on the overall safety climate of the vessel, this is congruent with other research in this domain (Håvold, 2003).

Håvold's (2003) sample also illustrates the cultural diversity present on ships (here the sample was obtained through individuals working in Norwegian shipping companies). Respondents were from 27 different countries including: Nepal, Italy, Sri Lanka, the Philippines, Indonesia, and Latvia. On any one ship there may be no more than one individual from each country (with the exclusion of the Philippines).

6.6. Teamwork

In the CTSB study, there were questions evaluating teamwork: 96% of masters, 100% of bridge officers, and 85% of pilots stated that teamwork was "often" or "always" as important as technical proficiency. It appears there is a comparative lack of appreciation from the pilots of the importance of teamwork. Pilots were asked if it is possible to establish an effective working relationship with the master and OOW: 45% said it was "always" possible, and 36% said it was "often" possible. However, when asked about their experience of the master, OOW, and pilot working as a team, only 51% of masters, 46% of bridge officers, and 38% of pilots stated that they "always" work as a team (Canadian Transportation Safety Board, 1995).

Other flag states have also acknowledged the importance of improving crew interaction. The U.S. National Transportation Safety Board (NTSB) has cited the lack of proper crew interaction as a factor in several marine incidents and has made numerous recommendations to introduce Bridge Resource Management (BRM) in training for deck officers on U.S.–flag vessels (Canadian Transportation Safety Board, 1995). This is discussed below as a potential intervention to address non-technical skills training.

7. Organizational Issues

7.1. Safety training

> *"Another logical venue for the application of CRM is in maritime operations"*(Helmreich, Wilhelm, Klinect, & Merritt, 2001).

As the previous section of the review has demonstrated, there are many non-technical skills in shipping, which have been established through research as being integral to best practice. In his book *Normal Accidents*, Perrow (1999) notes that it is not unusual for a deck officer to remain aghast and silent while his captain grounds the ship or collides with another (p 178), it appears that deficiencies in non-technical skills, in the previous example communication, sometimes result in the occurrence of incidents.

There are currently initiatives in place in the maritime industry that aim to address deficiencies in performance of non-technical skills. Crew resource management (CRM) is a training initiative based on the core non-technical skills integral to best practice, developed in the light of many well publicized aviation incidents, resulting in the loss of many lives. CRM refers to a set of defined cognitive and social skills: communication, teamwork, situation awareness, leadership, assertiveness, decision making, and workload management, which contribute to enhanced ability to work in teams and also enhanced safety performance (Salas, Burke, Bowers, & Wilson, 2001; Salas, Fowlkes, Stout, Milanovich, & Prince, 1999). CRM skills training and assessment are now mandatory in the UK for all commercial pilots (CAA, 2003), and there appears to be literature from the shipping domain that suggests that there is a demand for similar mandatory enforcement in the shipping industry (Canadian Transportation Safety Board, 1995).

Enhancing non-technical skills through CRM training may reduce human factors related causes of incidents and in turn incidents themselves. The IMO recognizes the need for non-technical training and competence, although at present this is in its early stages and is described in the STCW as "competence in crisis management and human behavior skills for senior officers who have responsibility of passengers in emergency situations" (STCW Code Table A–V/2). However, the code does little to suggest what the human behavior skills may be or what an adequate level of competence is. Standards and assessment of human behavior-related training initiatives like CRM are immature in comparison with understanding of non-technical skills and their assessment within the civil aviation domain (Barnett, Gatfield, & Pekcan, 2003). In the shipping industry, there is now a focus on training of non-technical skills and many companies are introducing CRM skills into their training programs. However the question still remains (Barnett et al., 2003): how effective is the training?

7.2. Bridge resource management/Bridge team management (BRM/BTM)

The maritime equivalent of CRM is termed Bridge Resource Management (BRM), or bridge team management (BTM), and has been used in the maritime industry for the last decade. However, a review of the literature reveals that there appears to be no empirical foundation for this type of course beyond research that was originally conducted in the formation of aviation CRM courses. However, a preliminary survey of seafarers in several countries revealed similar human factors as those revealed in the aviation domain (Helmreich & Merritt, 1998). This appears to suggest that the use of CRM in the maritime industry is valid. Bridge Team Management courses are a recommended aspect of the International Safety Management (ISM) code and therefore are adopted by many companies.

Following the grounding of the tanker "World Prodigy" (1989) the NTSB recommended that deck officers on U.S. flagged ships over 1600 gross tons attend BRM training. Again in 1992 the NTSB reiterated this suggestion in light of the 1990 grounding of the U.S. tank ship "Connecticut." However, even if it were the case that the U.S. flag made BRM training mandatory, there will still be ships from other flag states lacking in this training, which may cause potential incidents. It would be necessary for the IMO to implement guidelines for this to become internationally recognized as important.

7.3. Engine Room Resource Management (ERM)

Engine Room Resource Management, the version of CRM for ships engine room personnel, was introduced in the 1980's and has been used to train teams in skills of systems resource and crisis management (Barnett et al., 2003). ERM also appears to have derived from the principles and skills base of aviation CRM, but there appears to be no literature on formation or evaluation of these courses. These courses are in the main simulator based, although there are more issues here in that engine rooms are less generic and potentially more difficult to simulate, thus are the newly acquired skills transferable to the worksite? There is little work evaluating the impact of these courses.

The majority of the limited work conducted in this area has focused on human factors and interventions at the individual level: situation awareness, decision-making, fatigue, automation, communication health and stress, and teamwork. There is less research on organizational factors, which may mediate relationships between organizational climate and behavior and then outcome measures such as accident data. As proposed in Fig. 1, climate factors potentially contribute to accidents. Therefore in order to complete the picture one must consider this element in accident causation to fully address and reduce the level of incidents in this industry. The following is a synthesis of the research within shipping on safety climate and culture, although within the general psychological literature the definitions of these items are distinct (Guldenmund, 2000), these terms are often used synonymously within the shipping literature, which may reflect the level of theoretical input.

7.4. Safety climate and safety culture

The following section details human factors issues arising as a result of decisions or policies made at the organizational level, such as safety climate and safety culture (management values and practices).

7.5. Safety culture

Interest was generated in "safety culture" in industry after the International Atomic Energy Agency (IAEA) developed the concept in relation to the disaster at the Chernobyl nuclear power plant (IAEA, 1991). The report defined safety culture as the "assembly of characteristics and attitudes in organizations and individuals which establishes that, as an overriding priority, nuclear plant safety issues receive the attention warranted by their significance" (p. 1). There is a current focus in the maritime industry on safety culture after an address of the IMO stated that "safer shipping requires a safety culture" (International Maritime Organisation, 2002b).

8. Safety climate: measurement and safety performance

Organization safety climate is like a snapshot of selected aspects of organization safety culture at that particular point in time (Mearns et al., 2003). Although there is some debate on the definition of safety climate, definitions proposed consistently feature either employee's attitudes or perceptions of safety (Clarke, 2006). One commonly used definition was proposed by Zohar (2000), where essentially climate perceptions relate to "procedures as patterns," whereby consistent procedures represent patterns that reflect the importance and prioritization of safety over competing goals. Zohar presents a group level model of safety climate, whereby there is a distinction between the organizational level of policies and procedures and then the group level of supervisory practices in implementation and prioritization of these procedures.

There exists an important relationship between safety climate and performance, indicating that a robust measure of safety climate could be used as a predictive safety performance indicator. Griffin and Neal (2000) propose a method through which safety climate translates into organizational performance. They propose that there are antecedents of safety climate (management values and additional sub dimensions) that contribute to safety performance. Then they argue that the mediating variables between safety climate and safety performance are the workers level of knowledge, skill, and motivation. The components of safety performance they measure are safety task performance and safety contextual performance.

Safety climate has been measured in many different domains: Israel–production (Zohar, 1980); UK electricity (Glendon, Stanton, & Harrison, 1994); U.S. construction (Dedobbeleer & Beland, 1991); and UK offshore industry (Mearns et al., 2003). Interest in safety climate has now diversified into the maritime domain.

8.1. Safety climate in shipping

Håvold (2003) used a composite scale from existing instruments to measure safety culture, national culture, and risk in Norwegian shipping companies. About one third of his items are taken from a safety climate scale developed for the offshore oil industry (Mearns, Whittaker, Flin, Gordon, &

O'Connor, 1998). Håvold's scale was made up of the following factors: management/employee commitment to safety, safety norms/compliance to rules/occupational risk behavior, workload/work pressure/stress, fatalism, knowledge/competence, espoused safety values, degree of conflict between safety and work/priorities, reporting culture, work appreciation, officers awareness of risk, learning culture/learning from accidents/organizational learning, safety communication, actions based on accidents, perception of safety instructions, work itself, and safety behavior. The dependent variables in this study were not stated.

The questionnaire was administered to 2,558 seafarers from 27 different countries including: Philippines, Norway, Poland, India, Latvia, Netherlands, Romania, Indonesia, Great Britain, and Cuba (all of these had greater than 10 respondents). These individuals were all working on Norwegian owned vessels. Håvold (2003) demonstrated a potential existence of regional cultures (cultural views as measured by the Value Survey Module [VSM 94]; (Hofstede, 1980) espoused by a group of individual cultures), which had the same attitudes to safety. Norway and Netherlands, Poland and Latvia, and the Philippines and India grouped into cultural subsets (on greater than 12 of 16 fators).

All nations seemed to show positive attitudes toward safety and risk issues, but there were significant differences between the countries in the sample. Håvold (2003) also discovered that there were correlations between most safety and risk factors and national culture indexes. This suggests that this is an interesting area to investigate further, how to promote best practice from the highest performing national cultures to reduce these differences. He also found that vessels with crews from a single country or from two countries had better attitudes toward safety and risk than did those with multinational crews. Furthermore, he also established that cultures are a powerful index of work performance.

Of Håvold's sample, over 50% of respondents were from the Philippines and the majority were male, which is a reflection of the industry. Håvold demonstrated that different nationalities produced significantly different scores on the safety culture scale, therefore this large proportion of the data set generated by Filipino respondents may have skewed the data set as a whole. An additional caveat to note is that Håvold administered the "safety culture" questionnaire in either English or Norwegian; he does not acknowledge that the Filipino sample may not have had the level of English necessary to understand the questions.

Ek, Olsson, and Akselsson (2000) developed a bespoke scale to measure safety culture for use on different types of passenger ships. When defining safety culture they use a working definition that encompasses the following nine dimensions; reporting culture, flexible culture, just culture, learning culture, working conditions, safety related behavior, attitude toward safety, communication, and risk perception. The first four dimensions were proposed by Reason (1997), but the authors do not provide a rationale for the selection of the other dimensions. Two studies have been conducted using this questionnaire. The first was conducted on a Swedish registered passenger/cargo ship, completed by 48 respondents, 90% of whom hailed from European countries. The first purpose of the study was to investigate the usability of the questionnaire. Alpha levels were calculated from each scale, all yielded high enough alphas to show internal consistency, despite a low sample size. Ek et al. (2000) noted that most respondents were able to complete the questionnaire with few unanswered questions. Considering that one of the aims of this initial phase of the project was to establish the usability of the measure the authors could have selected a more robust outcome measure, than completion of questions, to assess participant's understanding. They found as a whole that the crew generally gave a positive response for all safety culture dimensions. There were significant differences between the officers from both departments and the catering staff on five of nine safety culture dimensions, the officers rated flexibility, communication, safety behavior, reporting and working conditions more positively than did the catering staff. The authors acknowledge that the sample size is small and that future research should be conducted with a larger sample size. They do not make any reference to the language the instrument was used in which is another key issue when trying to interpret the results.

Ek (2003) conducted a follow-up study using the same measure of safety culture, on a high-speed craft (HSC; 16 officers 36 crew) and a passenger/cargo ferry (ROPAX; 17 officers 40 crew) both from Sweden. The author also used observations, open interviews with crew members (to get experience on which risk and safety situations exist on board), a standardized interview with crew members at different work levels in all departments, and a collection of facts and statistics about the vessel. Officers on both vessel types had significantly more positive mean scores on the safety culture dimensions than the crew (for 4/9 safety culture dimension on the HSC, and for 8/9 dimensions on the ROPAX). The author explains the significant differences between the two ships by the small sample size on the HSC making it more difficult to reach levels of significance, however the sample size in both cases is small. Therefore this cannot really be adequately used as an explanation for these results. Another interesting finding to note was that on the ROPAX there were no significant differences found on safety culture dimensions between engine officers and crew or between officers and catering staff. Ek purports that the results indicate that safety culture differs across different levels of the organization on board, which is congruent with their previous findings (Ek et al., 2000) and also with other safety climate work (e.g., Mearns et al., 1998).

Safety climate research within this domain is in its early stages, and there still appear to be issues in classification of safety climate or safety culture research. When using a questionnaire to assess shipboard staff it is difficult to provide rationale as to how this is measuring safety culture. The research previously conducted has small sample sizes and often fails to link findings with any tangible outcome measures such as safety performance.

9. Conclusions

There are many demanding aspects of seafaring such as the inability of employees to leave the worksite, extreme weather conditions, long periods away from home, and motion of the workplace. Some of these are unchangeable and are a reflection of the nature of the domain. However, it is possible to modify, supplement, and introduce new strategies or interventions to potentially reduce the impact these factors have on the health and welfare of the individual seafarer (Parker et al., 2002).

There are many human factors influencing safety in this domain as have been presented in this review: fatigue, automation, situation awareness, communication, decision making, team work, and health and stress. These issues were reviewed within a framework that proposed that these individual factors can be contributory causes in accident causation, however the safety climate on ship will also influence whether or not an individual engages in safe behaviors or not. The review also considered the current status of attempts to address these human factors issues prevalent in the maritime industry, looking at CRM, BRM, and ERM. The review demonstrated that there are many "gaps" in the maritime literature, and a number of methodological problems with the studies undertaken to date.

The methodological problems within the shipping literature appear to be consistent and are based around five themes. Firstly, there are questions of ecological validity of previously conducted research (Hockey et al., 2003), which could be addressed with future research. Secondly, there are issues with access to a transient sample who are not easy to reach by any medium and therefore often sample sizes are small (Ek, 2003; Ek et al., 2000; Koester, 2003), which is a partial explanation to the aforementioned issue. Thirdly, a large proportion of the work that has been conducted within the maritime domain, is retrospective (e.g., Grech & Horberry, 2002; Lützhöft & Dekker, 2002). Fourthly, there are issues of validity in that some research administered items to individuals in their second language in which they may not have been fluent (e.g., Ek, 2003; Ek et al., 2000; Håvold, 2003; Smith et al., 2003). Finally, many of the cited pieces of research in this review lack outcome measures that could assess the influence particular human behaviors or conditions (e.g., fatigue) have on a measure such as accident data or reports of hazards or incidents.

In conclusion, the paper establishes that there are behaviors (both individual and organizational) common to accidents and methods through which these can be moderated and reduced that could potentially enhance shipping safety.

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