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Communication and Cultural Factors Influencing Human Performance and Errors in Ship Navigation

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Objective: The aim of this study is to identify the factors influencing the performance and errors of seafarers when navigating a ship.

Background: Similar to other complex systems, human error is regarded as one of the most important contributing factors in ship accidents. That is natural because the reliability of electrical/mechanical systems is getter better as technology advances whereas the human performance remains the same as before. Previous research showed that socio-technical systems influence on the performance of operators in many ways. Factors including organization structure, workplace culture, and social distances may influence on the system performance and reliability. Those factors determines the communication style and hierarchical structures that make the organizational structure either flexible or rigid.

Method: A survey was conducted asking primary factors involved in accidents happened during navigation. Total number of 106 respondents represents a range of experience and nationality: from 22 countries across 5 continents. Questionnaire has three parts asking overall problems, communication issues, and cultural problems. Participants rated the perceived severity of each problems by 5-point Likert scale.

Results: Overall the most serious human factors related issues in maritime operations are communication failure, lack of situation awareness, and improper training. Especially for the communications, contents organization and equipment failure are listed as serious problems. Language proficiency also worked as a barrier for correct and efficient communications. On the other hand, senior officer's rejection of suggestions from juniors was the most serious problem in workplace cultures. Strong hierarchy and blame culture are also listed as problems.

Conclusion: Although marine industry has started to notice the impact of human factors on the system safety and reliability, the importance of them is not well appreciated yet. As majorities of seafarers acknowledge the importance of human related issues, implementation and execution of safety guidelines and building up the safety culture are critically important for the safe ship operations.

Application: Findings of this paper can help choosing training topics for new and experienced seafarers. Teamwork and bridge resource management training can benefit by organizing topics for mitigating serious issues identified in this study.

Keywords: Human error, Ship navigation, Communication failure, Workplace culture

1. Introduction

Despite great advances in marine navigation technology, collisions and groundings

still occur every year, and the number of casualties and material damage connected with navigational accidents is considerable. Such avoidable disasters even occur when every equipment is functioning without any problem, labelled simply as the result of 'human errors'. According to one organization dedicated to recognized Standards of Training, Certification and Watchkeeping (STCW), it is the human element on board ship that can either provide the skills that may prevent a disaster, or the frailty or plain lack of competence that can cause one. Although there are many regulations, rules, and guidelines on the design, manufacturing and operation of marine vehicles, these regulations and safety systems have not achieved the desired effects in averting marine accidents caused by human errors. It accounts for 80% of those occurring worldwide. Rothblum (2000) indicated that human error contributes to 84~88% of tanker accidents, 79% of towing vessel groundings, 89~96% of collisions, 75% of fires and explosions.

In order to reduce human errors, International Maritime Organization (IMO) released the International Safety Management Code (IMO, 2008), which has played a significant role in addressing this issue through training and education of crew members. The fundamental philosophy is continuous improvement, which has applied in other industries, such as, aviation and construction, by anonymous reporting of accidents and near misses to every stakeholders. The procedures for reporting the incidents and performing the corrective actions are the essential features of the continuous improvement. If this information is not provided the successful cycle of continuous improvement cannot function (Lappalainen and Salmi 2009). Voluntary reporting is highly related with the organization's safety culture. Some traits of organizations, such as, too much emphasis on the performance/cost, strict and rigid hierarchical structure discourages the member's elective reporting of their own or colleagues errors or near misses.

Safe operation of marine vehicle requires several stakeholders' collaborative efforts including seafarers on board and management ashore. Thus effective communication between stakeholders is of paramount importance, and related influencing factors in the socio-technical systems should be considered together to achieve the goals of utmost safety. In spite of the importance of cultural, technical and organizational factors, there are not many previous studies investigating the abovementioned factors together to understand the mechanics of effective communication in maritime industry.

This study tried to demonstrate areas of maritime operations that needs more attention in the viewpoint of human factors. Human factors cover wide range of areas from physical, cognitive and macro ergonomics. In the view point of ship navigation, physical and environmental factors, such as, the design of navigational equipment, the arrangement of control and display panels play a significant role for human performance and operational outcome. However, it is limited to cognitive factors in communications and interpersonal factors in collaborative work environments in this study because these factors were not highlighted enough in the previous work by other researchers. The main objective of the study is to identify and detail out the human elements involved in the marine mishaps and to conclude with reliable positive recommendations. A questionnaire survey was conducted in the process to understand the issues of communication as per the language, social and cultural barriers.

2. Background

Research in human factors in maritime organizations has focused on providing the theory and explanations on why people make mistakes, thus proposing appropriate remedial action. In the initial stage, researchers concentrated to demonstrate that shipping should be treated as is a system of people, not just a set of machinery (Hetherington et al., 2006). Introduction of state-of-the-art technology into maritime system ironically emphasized the need of human factors considerations for the best performance. In this context, human factors research in shipping produced valuable information towards the detection of weaknesses in this interface and paved the way to achieving an improved collaboration between shipboard equipment and operators (Grech et al., 2008; Mills, 2005; Whittingham, 2004; Baker and Seah, 2004; Tzannatos, 2002; Pomeroy and Sherwood Jones, 2002). Previous investigation on human factors issues related with the accidents in ship and offshore platform pointed out major contributing factors as personal problems (e.g. fatigue, health conditions), organizational incongruity (e.g. lack of proper training, strictly hierarchical structure, ineffective communication), and socio-technical failures (e.g. equipment malfunction, suboptimal design). Based on

these investigation results, regulation bodies put several standards for reducing accidents.

2.1 Contributing factors

Surveys of mariners, conducted in both human factors and peripheral fields, demonstrate clear trends in attitudes and perceptions towards the effect of human factors on work performance. Past studies help to illustrate the relationship between navigation officers and their equipment, their approach to risk assessment, and their methods for coping with the pressures and isolation of life at sea. In 2010, a research group with the seafarers international research center (SIRC) collected surveys from international mariners, gauging their perceptions of accident risk. The degree to which a mariner considered a type of accident to be more likely, measured against both the real likelihood of such an accident and the opinions of the mariner's peers from other countries. Overall trends, irrespective of nationality, indicate systematic acceptance of risks and low confidence in risk management procedures (Bailey et al., 2010).

Another survey of mariners from around the world provided insight of the navigation equipment and related training systems in place (Sampson and Tang, 2011). Funded by the Lloyd's Register Educational Trust (LRET) charity, the survey polled marine navigation officers from across the industry, representing seafarers from the Philippines, China, India, Europe and several other prominent maritime regions. The results illustrate several pressing concerns of navigation officers, particularly in their familiarity toward new and technologically advanced equipment. Covering senior and junior watch officers, and spread across a range of ages and experiences, the responses concerning perceived weaknesses in equipment-related training are alarmingly consistent. Mariners reported greatest comfort with automated identification systems (AIS) and global positioning systems (GPS), with 93% claiming to be confident with their knowledge of such systems. However, a much smaller percentage of mariners felt their knowledge of automatic radar plotting aid (ARPA) and electronic chart display and information systems (ECDIS) could be considered 'good' or 'excellent', suggesting watch officers may be less likely to monitor those systems as often as AIS or GPS displays. This is partly because these displays are not mandatory, but the suboptimal design of ARPA and ECDIS also played a role for the unfamiliarity (Sauer et al., 2002). When facing unexpected or unknown equipment output, majority of respondents preferred to consult a manual for information about the equipment, but there were many cases when the manual of the equipment did not provide useful information.

The costs associated with training mariners could be a major deterrent to further effort by shore-based management. In fact, many of the mariners surveyed were required to pay for their own training on new equipment, with more than half of Filipino respondents reporting doing so. The group from the Philippines were also least likely to be compensated for time spent in training, which otherwise would have been personal leave time. Placing the responsibility for training on new equipment solely on employees constitutes an assumed risk by shore-based management. Chinese seafarers surveyed in the SIRC study were least likely to incur personal costs for their training, but most likely to consider administered training 'adequate'. Over one third of European seafarers surveyed claimed they did not have opportunities to attend refresher training, despite clear cost benefits to such programs (Sampson and Tang, 2011).

Weakness in bridge organization and management has been cited as a major cause of marine casualties around the world. Organizational factors, both crew organization and company policies, affect human performance. A strict hierarchical command structure can inhibit effective teamwork, whereas free, interactive communications can enhance it. Work schedules not providing the individual with regular and sufficient sleep time, cause the fatigue of seafarers. Company policies with respect to meeting schedules and working safely will directly influence the degree of risk-taking behavior and operational safety.

The findings of literatures consistently suggests mariner attitudes toward risk are reliable and should be accounted for in the design of bridge systems and planning of bridge resource management (Bailey et al., 2010).

2.2 Regulations and standards

Maritime professionals are adapting to the changes underway in response to a growing awareness of human factors. To overcome organizational inertia and standardize practices, public regulators and international bodies have distributed guidelines aimed at assisting companies in the implementation of new policies. While such guidelines demonstrate a consensus of acceptance across the maritime domain, these are rarely detailed enough to serve as a complete organizational directive on human factors.

As one of the largest maritime industry regulatory bodies, the IMO began efforts to integrate human factors into seafaring as early as 1989, with its Guidelines on management for the safe operation of ships and for pollution prevention (IMO, 2011). While initial research into the effects of human factors in transportation continued, the IMO developed the International Safety Management (ISM) Code to establish minimum safety requirements required on all ships. The ISM requires the implementation of Safety Management Systems (SMS) on compliant vessels, to promote ongoing awareness of all safety requirements. The goals of the ISM Code fit within the larger framework of the International Convention for the Safety of Life at Sea (SOLAS). To accomplish its goals of standardizing the equipment and manning required to safely operate ships, the convention is regularly amended and updated.

A separate convention under the IMO, aimed at establishing minimum standards of competence and training in navigational skills, came into effect in 1978 under the STCW. Also amended regularly to ensure continued relevance, the STCW includes guidelines indirectly pertaining to safety, such as minimum rest periods and prescribed training and certification in particular ship navigation systems. Increased research in human factors motivated the IMO's formation of a working group in 1991 to address the effects of human factors on both safety and maritime pollution. Its role has evolved, from analyzing the influence of human factors in marine accidents, to providing general guidance to marine operators in evaluating human factors within each workplace. The resulting Human Element Analyzing Process (HEAP) is designed as a checklist to be used by organizations seeking improvements related to human factors.

The generalized guidelines provided by regulators such as the IMO must be translated into usable procedures and specific rules by each company, manager, or operator through human factors integration. A method of adopting a "safety culture" within each organization, as prescribed by the IMO's initiatives, requires adaptation by high-level management to meet the needs of each company, crew and operator. Decades into the study of human factors on transportation safety, the subject still causes controversy between operators and regulators. The first sector to apply human factors in its operations, aviation, has endured a variety of difficult lessons in the process of human factors implementation. An appreciation of the similarities and differences with maritime operations is required to exploit findings in that industry, selectively applying some of the same aspects on ships. For example, while fatigue is almost universal in any transport environment, jet lag is a major element in aviation crew rest, while round-the-clock watches are a feature fairly exclusive to ships.

Private transportation consultancy Lloyd's Register issued their Human Element: Best Practice for Ship Operators in 2007 to increase awareness of HFI advantages among ship-owners (Lloyds Register, 2009). Encouraging whole-system approaches to managing human factors in the operation of ships, it recommends particular application of known practices in good design and management of resources, rather than attempt to draw cause/effect relationships in solving individual flaws. Lloyd's Register offers maritime companies a tailored application of these guidelines with its Human Element Gap Analysis (HEGA), further simplifying the process for organizations ready to invest in such initiatives.

In spite of continuing efforts of various organizations and research groups to emphasize the importance of human factors, still the acceptance of human factors consideration into the marine operation is not very high. The motivation for investment must overcome resistance to cost-critical short-term planning in organizations, a significant challenge to many companies during periods of economic downturn. Focus on human factors does not always require a big facility investment, identifying the weakest

point in the organization and reinforcing timely and continuously can make the whole system robust and resilient. Along this line, this study tried to identify human factors issues in maritime industry in operations focusing on the communications and organizational cultures.

3. Method

In order to identify influencing factors for ship navigation safety a survey was conducted to elicit their real opinions and experiences on human factors in marine industry (see Appendix for full questionnaire). Total number of 106 respondents represents a range of experience and nationality: from 22 countries across 5 continents. The participants' age ranges from 21 to 66 (m = 28) and they have 1 to 41 years of experience in marine industry (m = 15). Because of the characteristics of the job, only 3 of 106 participants were female while others were male (see Figure 1 & 2 for details).

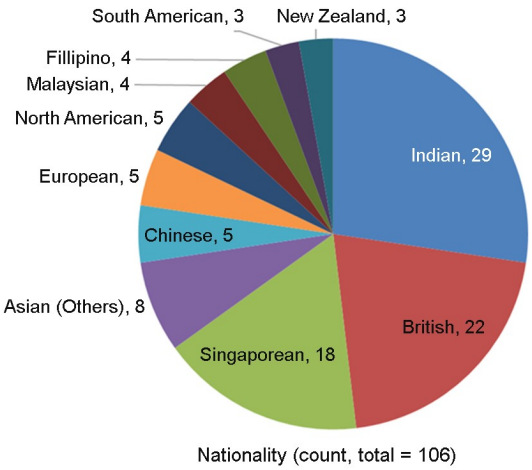

Figure 1. Nationality of the participants

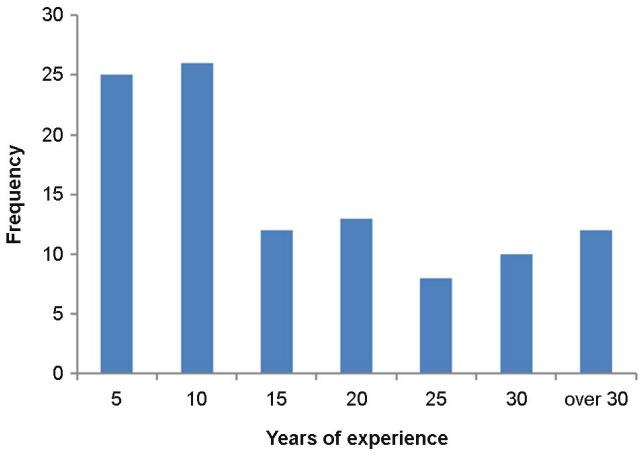

Figure 2. Years of experience of the participants

Based on their personal experience and perceptions, participants evaluated the severity of problems identified in the literature review. Answers provided in a numeric scale expressed the respondents' opinion on the severity of a specific challenge to marine communication. For the design of questionnaire, there was an interview session with two subject matter experts who have more than 15 years of experiences along with literature review.

Questionnaire has three parts asking overall problems, communication issues, and cultural problems. Questions asking overall problem includes problems related with human factors; equipment, communication, rules & regulations, training, lack of attention, hierarchical structure, and situation awareness. Communication problems includes lack of positive identification, message clarity, communication network congestion, noise, and equipment failure. Cultural factor questionnaire includes fear of disagreeing with superiors, blame cultures, hierarchical structures, accepting without question, and rejecting without deliberation. Participants rated the perceived severity of each problems by 5-point Likert scale. Questionnaires were distributed through seafarers union and personal acquaintance. Among them, 82 out of 106 participants (77%) were native English speakers or from countries using English as common language, and the rest took basic English communication trainings for seafarers.

4. Results

In addition to identifying patterns of concern and prioritizing contentious areas, the results provide an intimate picture of communication on modern vessels. The response reflects issues in human errors in navigation, communication challenges, and social factors.

4.1 Overall problems

The highest average rating of all surveyed issues was attributed to the communication issues (3.9 out of 5; 1 not severe, 5 most severe) as was indicated in other literatures (see Table 1). Over 72% of respondents answered either 4 or 5 out of 5, and no answers of "not severe" were given. No significant correlations were found with experience or age. Respondents from primarily English-speaking countries answered only slightly lower severity in this area than non-native speakers. Other questions in the category eliciting responses of high severity were improper training (3.9 out of 5) and lack of situation awareness (3.9 out of 5). Negative responses for training issues were 65% and that of situation awareness were 67%. Similarly, no significant patterns with nationality, experience or type of employment were observed, further implying the industry-wide nature of the problem regardless of countries.

Table 1. Responses of overall problems

Items	Avg. score (SD)	Negative response N = 106
Incorrect use of navigational equipment	3.8 (1.1)	55 (52%)
Communication problem	3.9 (0.8)	77 (73%)
Misinterpretation of rules & regulations	3.7 (1.1)	62 (58%)
Improper training	3.9 (1.0)	69 (65%)
Failure in attention	3.3 (1.0)	47 (44%)
Hierarchical structure in bridge	3.5 (0.9)	50 (47%)
Situation awareness	3.9 (0.9)	71 (67%)

Equipment problem showed a slightly different patterns with others; the percentages of rating it as very severe problem was highest (36%), but the neutral answer were also very high (36%) thus it ended up with the fourth serious problem. The loss of attention due to performing routine tasks was rated as least severe problem (3.3 out of 5.0) followed by the hierarchical structure in bridge (3.5 out of 5.0). Failure in attention showed marginally significant correlation with the year of experience (r = 0.185; p = 0.057) and hierarchical structure has significant correlation with the year of experience (r = 0.192; p = 0.049).

4.2 Communication challenges

The second section of the survey addressed problems particular to marine communications (see Table 2 for details). Of the six problems described in this section, poorly intended message was marked as the most severe problem (3.8 out of 5.0). While the composition of proper message may be dependent on the level of language competency, there is no significant difference between native vs. non-native English speakers' responses. There are slight differences between native and non-native English speakers, but not statistically significant.

Other items show similar level of severity ratings. Noise and signal distortion problems implies that equipment has technical limitations. Although practices with radio communications can assists seafarers to develop a top-down model that may help understanding messages impaired with noise and distortion, experience level did not play an important role for this issue. Respondents reacted with slightly less concern toward the issue of equipment failure. Although it is not statistically significant, respondents with five years or less experience disproportionately rated equipment failure with high severity (with a 3.92 average). For the all questions, neither experience nor age showed significant influences on the responses.

Table 2. Responses of communication challenges

Items	Avg. score (SD)	Negative response N = 106
Lack of positive identification	3.4 (1.1)	44 (42%)
Poorly intended message	3.8 (0.8)	69 (65%)
Congested network	3.4 (1.0)	50 (47%)
No response from relevant party	3.5 (1.0)	53 (50%)
Noise	3.5 (1.0)	48 (45%)
Equipment failure	3.5 (1.2)	57 (54%)

4.3 Workplace cultures

The third section of the survey listed specific situations when cultural factors influence communications between mariners (see Table 3 for details). Rejecting without deliberation was rated as the most serious problems among five cultural questions. The question specifically names the motivations for this behavior as a lack of understanding of the situation or the questioned posed. In other words, seafarers do not understand the seriousness of situations which may be because of lack of required knowledge. Responses to 'accepting without question', 'blame culture', and 'hierarchical structures' were similar in scores and the percentage of negative responses. These three issues are inter-related one another. Since hierarchical structure stiffens the organizational structure, workers tends to follow the received orders rather than think deeply of the situations. Wrong decision of workers or deviation from received orders tend to be blamed without discreet review or careful investigation. This reinforces hierarchical structures and make the workers simply follow orders without an effort to understand the situations.

Table 3. Response of workplace culture questions

Items	Avg. score (SD)	Negative response (%) N = 106
Fear of disagreeing with superiors	3.2 (1.0)	38 (36%)
Blame culture	3.5 (0.9)	50 (47%)
Hierarchical structure	3.4 (1.0)	51 (48%)
Accepting without question	3.4 (1.1)	56 (53%)
Rejecting without deliberation	3.8 (1.0)	70 (66%)

In almost every question of this last section, the average responses of participants from nations with high power-distance was slightly higher than others. Since the difference is very small but consistent, this could indicate the appreciation of the increased barriers to communication caused by this cultural dimension. The only exception to this trend is the highest severity situation: replying "yes, sir" so as to avoid embarrassment, despite not understanding the situation or the questioned posed. This phenomenon is weighted as the most severe equally across all cultures, and it can be associated with natural social tendencies of human beings unconnected with power-distance in the workplace.

5. Discussion

Analysis of human factors can be motivated through accident prevention or performance optimization. While this paper focuses on the former, the potential for benefits in the latter may attract more attention from organizations debating whether to adopt human factors in its policy. The risks of an accident may not provide a significant motivator for companies to consider human factors in on-board procedures, but gains to productivity and employee output create a universal incentive.

The survey result showed that communication and situation awareness are two most serious problems in maritime safety, which is similar to other industries (Adams et al., 1995; Leonard et al., 2004). Communication problems can be separated into intra-organization and inter-organization communications according to the information exchange partners. On the other hand, the communication problem could occur in organizing contents, delivering message, and achieving common understanding depending on the stages of communications. Respondents rated 'poorly intended message' as the most serious problems in communication, which means that the message does not contain useful or necessary information. This may happen for both intra- and inter-organizational communications. Failure in organizing communication message could be due to the language barrier. In maritime industry, seafarers are from many different countries with various level of English proficiency, thus both message organization and delivery of message are dependent on the English language skills. The language barrier becomes even worse if they cannot exchange massages through suboptimal communication media. As the respondent of survey indicated as the second most serious issue, communication quality and equipment failures may make the communication problem even worse. In order to reduce language problems, the IMO proposed The Standard Marine Communication Phrases (SMCP), which is a set of key phrases in the English language. It limits the word and expressions to be used both ship to ship & ship to shore communication and onboard communication (IMO, 2001). Additional benefits can also be gained from upward discussion of mariner observations in human factors, including clearer definition of effective bridge and system designs. Once mariners are able to provide input to designers on which innovations improve usability, these features can set an industry standard, reducing inefficiencies caused by variation of interfaces on each ship. Poor layout of systems can be eradicated by involving mariners in the process of new ship conception. In each case, allowing the human user to describe his needs from experience provides the designer with the necessary information to invent better bridge layouts that contribute to safer ship navigation.

In the context of maritime, intra-organizational communication issues includes both language barrier and hierarchical structures. As well as the multi-lingual work groups in maritime, strictly separated hierarchical structure also prevents effective communication within the organization. Responses to workplace culture questions showed that senior's rejection of suggestions without deliberately considering the validity and usefulness of the communication messages is the most serious problems. This phenomenon may often occur in an organization with strict hierarchical structures. Aviation industry has experienced a number of accidents caused by hierarchical workplace culture and lack of team behaviors, thus the crew resource management (CRM) training was introduced to the whole aviation sectors. Maritime industry also established bridge resource management (BRM) training programs and is trying to spread out whole through the industry, but the effectiveness of the training system was just partially approved by the industry. Thus, the needs for well-targeted and customized team training program is very high (Salas et al., 2006; O'Connor, 2011). Alternative programs showing great potential, such as Crew Endurance Management and English language exercises on multi-national ships, also offer promising gains in mariner performance (USCG, 2006). These unconventional approaches produce benefits

such as social integration and empowerment of employees, which lead to more constructive organizational culture.

6. Conclusion

The human factors movement underway in many areas of transportation has great relevance to all mariners, especially those responsible for the navigation of a ship. Profit-driven marine enterprises and publicly-managed ship organizations alike have much to gain from the findings of studies in human factors, and much to lose from ignoring the effects they have on crews.

Despite pressure from regulators such as the IMO and some national governments through the PSC process, some companies are still avoiding rising standards of safety-consciousness. The globalization of the industry has contributed to opportunities for companies to reduce costs with a flexible work force, but it has also resulted in frequent practices of substandard labor conditions and unchecked reductions in manning. In an effort to preserve certification while saving costs, organizations created a proliferation of paper reports between ship and shore, which has distanced management from mariners and prevented a more proactive safety culture from developing. The risks from continuing such inefficient practices in the maritime industry threaten to negate the benefits of initiatives in application of human factors.

The result of this survey cannot convey or reflect the full spectrum of human factors problems happening in the ocean. There are still unknown technical, social, and cultural problems that can directly lead to catastrophic disasters. Although human related issues are referred as frequent causes of accidents, survival from disaster is also possible through human driven approach. International efforts to educate seafarers on the benefits of human factors programs, combined with organizational policy adjustments, do not affect change alone. For the success of initiatives in this growing field, each mariner must consider the implications of human factors in his daily routine and the impacts they may have on safe navigation of the ship.

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Appendix

Questionnaires asking causes of human errors in ship navigation.
Please rate the severity of the problems that you have experienced or observed during your work as a seafarer with 1 (not severe at all) to 5 (very severe)

1. Incorrect use of navigational equipment
2. Suboptimal communications with your colleague, land officers and VTS
3. Misinterpretation of maritime rules & regulations
4. Lack of training, poor manning levels and ineffective procedures
5. Performing the same task as a routine without paying enough attention
6. Fear of questioning supervisor, fear of disagreeing with the superiors as ‘no’ is considered to be impolite
7. Unable to assess the situation well and hence lead to poor decision making that may cause confusion

Questionnaire asking the VHF communication problems
Please rate the severity of the problems that you have experienced or observed during your work as a seafarer with 1 (not severe at all) to 5 (very severe)

1. Lack of positive identification
2. Poorly intended messages requiring clarification
3. Congested communication network
4. Relevant party not responding to call
5. Poor transmission due to noise and distortion
6. Equipment failure of VHF radio

Questionnaire asking workplace cultures
Please rate the severity of the problems that you have experienced or observed during your work as a seafarer with 1 (not severe at all) to 5 (very severe)

1. Afraid of disagreeing with superiors
2. Unable to make decision due to pressure or fear of failure
3. Fear of questioning supervisors about ambiguous orders or pointing out errors committed
4. Replying 'Yes, Sir' despite not being able to understand the situation or questions being asked
5. Rejecting suggestions from juniors without deliberation