KDU Journal of Multidisciplinary Studies (KJMS)
Volume 1. Issue1, 2017

KJMS 2017 VOL.1 (1): 60-70

EXPLORATORY SURVEY OF HUMAN FACTORS ON OFFSHORE PATROL VESSELS

N Rajapaksha[1]
nipunar@kdu.ac.lk
Department of Marine Engineering, General Sir John Kotelawala Defence University, Ratmalana, Sri Lanka[1],
A Abeysiriwardhane[2]
apsaraa@utas.edu.au
Australian Maritime College, an Institute of University of Tasmania, Australia[2],
N Jayarathne[3]
nirman@kdu.ac.lk
General Sir John Kotelawala Defence University, Ratmalana, Sri Lanka[3],
YSMP Prathapasinghe[4]
prathapasingheysmp@gmail.com
Department of Marine Engineering, Sri Lanka Navy, Colombo, Sri Lanka[4],
WMMW Bandara[5]
wishwamenukabandara@gmail.com
Department of Marine Engineering, Sri Lanka Navy, Colombo, Sri Lanka[5],
DMSM Dissanayake[6]
sriyanthadissnayake@gmail.com
Department of Marine Engineering, Sri Lanka Navy, Colombo, Sri Lanka[6],
WKKHMRCRB Bandara[7]
chamithruwinda@gmail.com
Department of Marine Engineering, Sri Lanka Navy, Colombo, Sri Lanka[7].

ABSTRACT

Spending up to six months or more aboard a ship, occasionally subject to harsh weather, the life of a seafarer is heavily dependent on the design of the ship. A good ship design, thus, has to take account of socio-technical requirements to fulfil the fundamental needs of safety, efficiency, and usability of the entire ship and its systems by keeping Human Factors (HF) in mind. This paper presents findings of an exploratory survey conducted on two Offshore Patrol Vessels (OPVs) with an aim to identifying the application of HF within the current designs. The study was conducted using quantitative and qualitative approaches such as questionnaires, observations, and discussions with the OPV crews. Results of this study were helpful to recognise the areas where design improvements are necessary in HF perspective including inadequate comfort in ship accommodation, low level of privacy and facilities for both individual and social relaxation, noise disturbance, ergonomics issues, layout limitations, and limited spaces for crews. As a result, different levels of compliance in various HF dimensions were also recognized, and out of them habitability and maintainability were the major concerns. Finally, significant improvements that are necessary for the upcoming naval designs in terms of physical, psychosocial and organisational aspects on-board ships were identified.

KEY WORDS: *Human Factors, Human Centred Design, Usability, Marine Design, Offshore Patrol Vessels*
Corresponding author- N N Rajapaksha, E Mail: nipunar@kdu.ac.lk

1 INTRODUCTION

Spending up to six months or more aboard a ship, occasionally subject to harsh weather, the life of the seafarer is thus heavily dependent on the ship's design dimensions such as equipment accessibility, habitability, workability, maintainability, operability, usability, and survivability (LR, 2008). To ensure a design is appropriate for the intended purpose and to the context in which it will be used, the design process should consider these aspects as an integral part to consider the users' capabilities and limitations (Lützhöft, 2004, Lützhöft et al., 2017, Earthy and Sherwood Jones, 2010, Petersen, 2012, Abeysiriwardhane et al., 2016b). Furthermore, a good design always has to ensure the fundamental requirements of the safety and efficiency of the ship or its systems, and the health, safety and wellbeing of the crew, by keeping the Human Factors (HF) in mind (Squire, 2014). The International Ergonomics Association (IEA) defines Human Factors as:

> "The scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data and methods to design in order to optimize human well-being and overall system performance." (IEA, 2016)

HF and user involvement can be applied to the ship design process through a Human Centred Design (HCD) approach. HCD is an approach, which focuses on making systems usable by applying HF, ergonomics, and usability knowledge and techniques during design (ISO, 2010). According to the ISO 9241-210 standard, this approach enhances effectiveness and efficiency, improves human well-being and user satisfaction. In addition, it is noted that the HCD process is designed to maintain the consideration on user needs, through direct and continuous involvement of the users, throughout the entire product life-cycle (Nielsen, 1993). Unfortunately, the maritime design practice today does not show explicit consideration of the end user, and thus does not apply HCD approach (Petersen, 2012, Earthy and Sherwood Jones, 2006, Sherwood Jones, 2005). Specially within naval ship designs, limited research has been carried out with respect to the application of HF and HCD to improve the users' quality of life (Wilcove and Schwerin, 2008, Ross, 2009).

Strong (2000) performed a survey to investigate habitability and accommodation facilities on naval ships. Based on a literature review, initial interviews, and a pilot survey, he reported on the crew's evaluation of the existing ships and their preferences for the design of future warships. Adequate levels of privacy and facilities for both individual and social relaxation are considered important aspects in the ship's accommodations (Ellis, 2009). A North Atlantic Treaty Organisation (NATO) human performance assessment was developed in the form of a questionnaire, and it was used on seven frigates and destroyers in the NATO Standing Naval Forces Atlantic fleet for two weeks, involving 1026 participants and 16,000 completions (Colwell, 2000). A method for calculating motion sickness with habituation for a changing motion environment was proposed.

Hardwick (2000) carried out a comparative study on accommodations in the Royal Navy and merchant naval fleets by visiting ships and submarines and interviewing their crews. They suggested factors based on their study that include a drive toward cabin-based accommodations for all cabin crew, increased space for sleeping and personal storage, improved ambient conditions (noise and temperature), and provision of other facilities to create user friendly designs. Dalpiaz et al. (2005) used a 3-D computer model to review a new US Navy ship design. They reported incorrect height/orientations for equipment, machinery, and other manually operated technology as the most common mistakes. Stair, ladder, step, and walkway designs were also found to be inadequate. Other deficiencies in inaccessibility to valves, hand wheels, and hand pumps, incorrect control panel, console, control, and display designs, and problems with personnel access and movement were found.

Wilcove and Schwerin (2008) analysed data of the 2002 Navy Quality of Life (QOL) survey to reveal the facets of shipboard habitability viewed as most and least satisfying. They used the data to create

habitability subscales, and to apply those subscales in a multiple regression to better understand satisfaction with shipboard life. The findings indicated that despite the amount of time seafarers spend at sea in their careers, the variety of ship platforms, and the complexity of the shipboard experience, little research has been conducted on shipboard life. As a result, further research is necessary and opportunities for such research are plentiful.

As discussed above, though at least a few studies have been conducted around the world with respect to HF consideration of ship designs, it is still a field of research that has not yet been sufficiently discussed in the Asian context. In addition, it is difficult to find such studies conducted within the naval and defence domain in this region. Thus, this research study focusses on identifying and analysing the current HF related design concerns on Offshore Patrol Vessels (OPVs) operating under the custody of Sri Lanka Navy (SLN) as its case study. The findings of this study are beneficial for naval ship designers to understand the areas where they should improve on their future naval designs.

2 METHODOLOGY

Two different OPVs were selected for this study. However, due to the classified nature of the data gathered, their identities are not revealed. Therefore, these OPVs are named as OPV-A (Length > 100m), and OPV-B (100m >Length > 50m).

Data were collected through a survey questionnaire. Open-ended questions, closed-ended questions and scaled questions were included in this questionnaire. It consisted of three parts, firstly, general questions about their on-board life, secondly questions about their particular working areas (engine room, bridge, mess and galley), and finally the questions related to the accommodation and recreational facilities available on-board. Moreover, it included a place for the crew to provide their suggestions to improve the usability of the OPVs.

Prior to distributing the questionnaire, everybody was briefed on the purpose of this study. Furthermore, they were informed that it was totally up to them to decide whether they wanted to participate in this survey. The questionnaire was then distributed to the focus groups including sailors and officers working on-board these two OPVs during two field visits while they were in the Port of Colombo, Sri Lanka.

The participants were informed to write their honest answers since information provided were considered anonymous and treated strictly confidential. Furthermore, they were advised that submitting this questionnaire implied their consent to participate in the study. However, some persons found it difficult to express their responses to the questions. Therefore, for such participants, structured interviews using the questions given in the questionnaire were carried out and the researchers wrote their answers on the questionnaire. The answers were verified by reading them back to the particular participant (Lapan et al., 2011, Brinkman and Kvale, 2015).

The answers to the questionnaire were collected on the same day and 45 responses from OPV-A and 55 responses from OPV-B were received making up a a total of 100 responses. None of the responses were rejected since all the necessary information was given by the participants. All the answer scripts were then collected and separated according to the departments within the OPVs for easy analysis of the collected data. The content analysis method was used to analyse answer scripts (Harwood and Garry, 2003). The significant findings were presented in a quantitative manner in accordance with the three main focused areas namely working, accommodation, and recreation.

3 RESULTS AND DISCUSSION

In order to improve the clarity of the discussions, the results are discussed based on three main sections including working area, accommodation area, recreational facilities and general feedback.

3.1 Working area

Upon analysis, the findings under four main working areas are summarised and discussed below.

Engine room (ER):
The results from both vessels mainly show many deficiencies in ER that did not comply with

ergonomics principles or even with the on-board health and safety requirements. The disappointments voiced by marine engineers regarding the space within the engine room and the accessibility to frequently operated valves and other equipment are critical (see few quotes below). These quotes are only a few of them extracted from the answers.

> "there should be more space between the machinery for maintenance (OPV-A)"
> "there are two pumps in engine room that are not using, these have to be removed to improve workflow obstructions (OPV-B)"
> "there are valves we have to operate daily, but because of the low space it was difficult, and they are not reachable (OPV-A) (see Figure 1)"
> "a ventilation duct is there to obstruct access to the oil distribution box and turning gear of the main engine and RGB (OPV-B)"

During the analysis of data from the exploratory survey, it was discovered that there were many criticisms highlighting the design of the engine room and working environment. According to the participants, the nature of their job is different from those of the other departments. They deal more with problems and troubleshooting alongside routine maintenance activities. Therefore, uncertainty and the unknowns are dominant in their work, yet they do not get enough support from the design to ease their job.

> In addition to the limited space and inadequate accessibility issues, the sailors of both vessels highlighted many other concerns such as inadequate headroom clearance, noise, vibration, lighting, ventilation, steep stairs and ladders, insufficient landing spaces, unused and malfunctioned machines in the engine room, and visibility of the engine room from the engine control room. Furthermore, the location and storage capacity of engine room stores was a common complaint from 56% of the engine room crew of OPV-A. The engine room store is located at the forecastle of the vessel, far from the engine room location, affecting the level of mental and physical stress on the crew (Ellis, 2009, Houtman et al., 2005, IMO, 2001). However, 100% engine crew of OPV-B was satisfied with their workshop, which is located close to the engine room.

Figure 1: Bad valve placement in OPV-A

With regard to the control room design, it was 50% of the OPV-A engine room crew who stressed the need of a good design that can aid them to quickly identify the unusual incidents in the engine room while they are in the control room. In addition to that, the crew of OPV-B stressed the need of proper access without obstructions between these two places for them to move rapidly.

Bridge:

Contrary to the engine room layout, all the participants from the bridge departments of both vessels were satisfied with the bridge layout design. Participants from OPV-A wrote that "all the equipment have been located correctly", "all bridge equipment are properly arranged", "bridge is good, no disturbances for daily tasks". Similarly, a participant from OPV-B mentioned that "this ship bridge has enough space and open bridge area, which is good". However, some of the crew from OPV-B suggest that, it is more user-friendly for them if there is an access from the equipment room to the chart room.

Among the participants from the bridge departments, 45% from OPV-A and 31% OPV-B highlighted that it is good to improve the bridge visibility due to some

obstructions they see in the current design. When they were asked about a reassignment on the same OPV, 64% of bridge crew from OPV-A and 63% from OPV-B said that if they get another chance to work on-board these OPVs, they will be happy to take the opportunity.

Mess and Galley:

Based on the answers given by the crew from the mess department, it can be seen that 75% of them from OPV-A and 80% of them from OPV-B were somewhat satisfied with the current mess and galley layouts. However, the responses highlighted the concerns in order to take into account for future improvements of the design (see below quotes).

> "it is good to have extra racks near the hot steam ovens and to place kitchen towels etc. (OPV-A)"
> "it is difficult to clean some equipment due to inadequate accessibility (OPV-A)"
> "It is good to have anti slip prevention to avoid slips and falls in wet areas (OPV-B)"
> "when supply takes to galley, we have to walk too many times per day due to the long distance between stores and the galley. The walkways are narrow. (OPV-A) (see Figure 2)"

In addition, findings showed that the users of the mess (87% of OPV-A and 80% of OPV-B crew) are satisfied with the current mess location. It was easy for them to move food and cutlery even during rough weather since mess and galley are located next to each other on both OPVs. However, in both OPVs the users of the galley and mess do not have sanitary facilities nearby.

Figure 2: Walkway in OPV-A

3.2 Accommodation area

Among 100 participants of this survey, only two officers of OPV-A and three officers of OPV-B use private cabins, which was only 5%. As illustrated in Figure 3, more than 65% respondents from OPV-A and 75% from OPV-B share their cabins at least with 8 other members.

Within these shared cabins, 70% of them use triple bunk beds (see Figure 4) on OPV-A, and it was 63% for OPV-B (see few quotes below).

> "no enough space between beds, we have small lockers attached to our beds (OPV-A)"
> "need space to hang our clothes, keep our shoes and good lockers (OPV-B)"
> "need to have single bunk beds instead of triple bunk beds" "hard to sleep on bunk beds (OPV-A)"
> "my cabin is not suitable for 5 people (OPV-B)"
> "due to compactness and hardness (live inside the cabin), our stress level increases and there is no relaxed mind (OPV-A)"
> "no privacy, no freedom, no happiness, no one feels like home in here (OPV-A)"

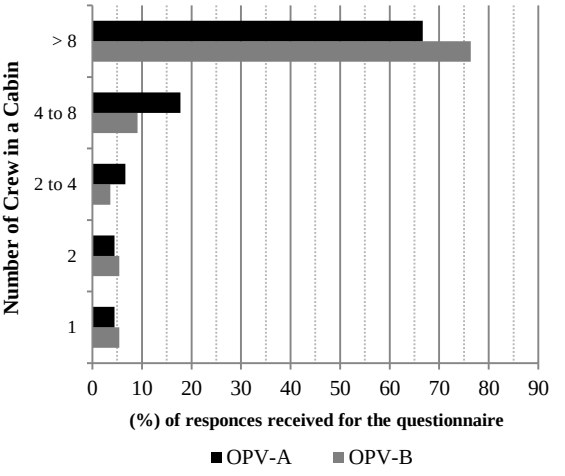

Figure 3: Percentage of crew in different type of cabins

Another major finding of this survey was that, except 3 crew members on-board these OPVs, remaining 97 participants were using shared toilet and bathroom facilities. In addition, natural ventilation inside the cabins was found as one of the major concerns these crews were facing. The participants wrote that

"though there are openings (for ventilation), quality of the fresh air circulation inside the cabins is poor", "there is no fresh air at all in the cabin, after a day overwhelmed by tough work, it is important to get fresh air inside the cabin".

Figure 4: Triple bunk bed in OPV-A

In addition to that, 57% respondents from OPV-B and 75% from OPV-A face difficulties in having a good sleep due to excessive vibration inside their cabins. The interesting fact was that 95% of the participants from both the vessels wanted to change their accommodation if possible. These responses are a good example to understand how these design features affect the crews' ability to sleep and to be free from mental and physical stress (Ellis, 2009, Houtman et al., 2005), which in turn will directly reduce the crews' safety, effectiveness, efficiency, and satisfaction (IMO, 2001).

3.3 Recreational facilities

Regarding the recreational facilities, 69% on OPV-A and 67% of OPV-B agreed that they have some sort of facilities to use on-board at the time of the survey. However, respectively 76% and 53% of them identified the need for improvements in the existing facilities. Following thoughts are extracted from their answers: "we have a gym, but ventilation is poor", "need a good sound system and a TV in mess", "junior sailors need a place to relax", "for junior sailors it is good to have a place for a small gathering".

Among the respondents 71% on-board OPV-A and 73% on-board OPV-B did not have a common office area for reading or studying. The following are some of their thoughts on the study area: "need a study area similar to mess", "I do not have an office space to do my work", "it is good to have a place to do some studies", "we want a place to study", "no place to do any documentation work", "if we have a place to read a book, it is good", "we have only one office for engineering department, officers have to share it or do their work in the cabin, separate are for officers' office work is beneficial".

When the participants were asked to give their suggestions about the facilities that they would like to see on-board these OPVs soon, most of them highlighted the need of internet connection. In addition, regarding the future designs, they commented as follows: "our living area should be re-designed to satisfy sailors, medical facilities should be accessible from the engine room and need office spaces", "recreational facilities should be well equipped and modern, adequate washrooms and designs should be upgraded to current day standards", "it is good to allocate proper recreational facilities for junior sailors and there should be a maximum limit for the number of crew", "since the officers and crew are on-board for a long period on-board a OPV, it is good to discuss with crew during re-design".

3.4 General feedback

There was a question that requested their feedback about the survey and some of their thoughts are given below.

> "this is a good work; however, it would be great if you can improve these issues in future designs"
> "if our voice is being heard and improve future designs, we can work happily and effectively"
> "this is really a good activity and we really hope next new build ships of SLN will be user friendly"

"expecting to see our suggestions in the next OPV"

"even if you consider our needs, there is no point in designing a ship that is not suitable for its intended work, therefore the design should be specific for its context and that is one of the major issues we are facing right now".

3.5 Discussion

As an overall summary, this research study indicated similar issues previously raised by other researches (Table 1). These findings ultimately reveal that the current OPV design features cause mental and physical stress for the crew (Ellis, 2009, Houtman et al., 2005), which will directly reduce the on-board safety, effectiveness, efficiency, and satisfaction (IMO, 2001).

As a consequence, the sailors' dissatisfaction with shipboard life will significantly affect their retention plan and actual retention behaviours as previous studies of Wilcove and Schwerin (2008) identified. One can argue that these design inadequacies are there because these ships were designed many years back and just for naval operations – OPV-A is approximately 30 years and OPV-B is approximately 50 years old. However, the fact is that these OPVs are still operational today when the world is prioritising human needs and their values. Thus, this study suggests to seriously consider these design issues to mitigate similar failures in future OPV designs. Otherwise, a design made in 2017 too would cause an enormous physical and mental effect on its crew, continuously throughout the next five decades, until it will be decommissioned.

Table 1: Findings of current surveys and issues that arose in previous studies

Previous studies and publications	**Claims**	**Comments based on OPVs surveys**
Meister (1971)	Design engineer does not consider HF in his design.	Findings of both surveys confirmed these claims.
Reason (1990)	Poor design of ship layouts.	
Squire (2007)	Ship is designed without input from the crew.	
Strong (2000), Wilcove and Schwerin (2008)	Adequate levels of privacy needed. Facilities for social relaxation are expected.	
Hardwick (2000), Wilcove and Schwerin (2008)	Cabin-based accommodations are suggested. Room in the berthing area, space in the racks and personal stowage is expected. Improved ambient conditions are expected (temperature, lighting, and Noise). On-board social needs, recreation, office space, and computers are expected.	
Grundevik et al. (2009)	Visibility problems.	
Dalpiaz et al. (2005)	Incorrect height/orientation. Stairs, ladders, steps, and walkways. Inaccessibility to valves, hand wheels, and hand pumps. Problems with access and personnel movement.	

Furthermore, the findings indicate that the design process of these OPVs had not adequately considered the end users, and thus, had not applied HF concepts to their full extent. This appears to be the case in mainstream maritime design today (Petersen, 2012, Petersen et al., 2010, Lützhöft et al., 2017). Recent research studies stressed that this is mainly due to maritime designers' unawareness about HF, HCD and the operational issues which the ships' crews face during their sea time (The Nautical Institute, 1998, Walker, 2011). Furthermore, the designers' limited understanding of HF and HCD is likely due to the combined effect of poor maritime HCD education (Abeysiriwardhane et al., 2014) in maritime design courses and poor post-design contact with those who work on-board the ships (Kuo and Houison-Craufurd, 2000, Walker, 2011). To change this situation several efforts have been made to

intervene at ship design and education level (Abeysiriwardhane et al., 2017, Abeysiriwardhane et al., 2016a, Abeysiriwardhane et al., 2015b, Abeysiriwardhane et al., 2015a, CyClaDes, 2014, NI, 2015).

Furthermore, Maritime Labour Convention (MLC) was formally established and enforced on 20 August 2013 to emphasise the rights of every seafarer to a safe and secure workplace that complies with safety standards; to fair terms of employment; to decent working and living conditions on-board a ship; and to health protection, medical care, welfare measures and other forms of social protection (MLC, 2006). In addition, International Maritime Organisation (IMO) has published a number of codes and guidelines within the area, such as the code on noise levels, guidelines for engine-room layout, design, and arrangement and guidelines on ergonomic criteria for bridge equipment and layout. Furthermore, a number of new ergonomic notations (ABS, 2014) were developed to promote an ergonomically-focused design and construction on vessels, specifically with respect to enclosed spaces (ERGO ES) and maintenance (ERGO MAINT), as well as topsides (ERGO TOP) and valves (ERGO VALVE). However, these regulations and recommendations do not in themselves solve the problem (Rasmussen, 2005). The professional knowledge and skill of the designers and builders of ships is of paramount importance in order for us to get ships that are really 'usable'. Therefore, the findings of this study could be used as a valuable guidance to make future OPV designers aware of HF issues within the current designs and to motivate them to mitigate those concerns in their upcoming designs.

4 CONCLUSION

Despite the amount of time seafarers spend at sea in their careers, the variety of ship platforms, and the complexity of the shipboard experience, little research has been conducted on shipboard life within naval and defence domain in the Asian context. This study was conducted as exploratory surveys on OPVs to explore HF concerns within the current designs. Two different OPVs were selected for this study as mentioned in the section 2.

It can be concluded that very less emphasis has been made on HF in the design stages of the current OPVs. Major concerns that were recognized including inadequate comfort in ship accommodation, low level of privacy and facilities for both individual and social relaxation, noise disturbance, ergonomics issues, layout limitations, and limited space. As a result, different levels of compliances in various HF dimensions were recognized, and out of them, habitability and maintainability were the least satisfactory. Ultimately, significant improvements that are necessary for the upcoming naval designs in terms of physical, psychosocial and organisational aspects on-board ships were identified.

According to the operators' voice, what they were stressing was that 'Designers, please consider HCD concept in your designs. We are the people who work on-board your designs, therefore please leave a space for our voice too in your design spiral'. Therefore, future ship designs should include consultation with users – who will actually spend significant proportion of their lifetime on board – during the design stage, and by this the authors do not only mean the master of the ship!.

5 ACKNOWLEDGEMENTS

Authors would like to acknowledge the approval granted by the Commander of the Sri Lanka Navy, extensive support given by the Head of Department, Captain (E) HDAK Amarawardhana and all the other staff members of the Department of Marine Engineering of General Sir John Kotelawala Defence University, and authentic support given by the ship officers and crew members of the two vessels to complete this study.

6 REFERENCES

Abeysiriwardhane, A., Lützhöft, M. & Enshaei, H. 2014. Human Factors for Ship Design; Exploring the Bottom Rung. *Transactions of the Royal Institution of Naval Architects Part C1: International Journal of Marine Design,* (156)**,** 153-159.

Abeysiriwardhane, A., Lützhöft, M., Petersen, E. S. & Enshaei, H. 2015a. Future Ship Designers

and Context of Use; Setting the Stage for Human Centred Design. *International Conference on Marine Design 2015.* London, UK: RINA.

Abeysiriwardhane, A., Lützhöft, M., Petersen, E. S. & Enshaei, H. (2015b): Investigate and Stimulate Future Maritime Designers' Context of Use Knowledge: A Workshop Approach. *Transactions of the Royal Institution of Naval Architects Part C1: International Journal of Marine Design,* (157)**,** 179-193.

Abeysiriwardhane, A., Lützhöft, M., Petersen, E. S. & Enshaei, H. (2016a): Human Centred Design Knowledge into Maritime Engineering Education; Theoretical Framework. *Australasian Journal of Engineering Education,* (21)**,** 49-60.

Abeysiriwardhane, A., Lützhöft, M., Petersen, E. S. & Enshaei, H. (2016b): Incorporate Good Practice into Ship Design Process; Future Ship Designers Meet End Users. *ERGOSHIP 2016 : Shaping Shipping for People* Melbourne, Australia.

Abeysiriwardhane, A., Lützhöft, M., Petersen, E. S. & Enshaei, H. (2017): Stimulating Human Centred Design Understanding and Awareness in Maritime Design Students: A Demonstration of an Action Research Approach. *Transactions of the Royal Institution of Naval Architects Part C1: International Journal of Marine Design***,** (Accepted for publication).

ABS (2014): Guidance Notes on the Application of Ergonomics to Marine Systems. Houston, TX, USA: American Bureau of Shipping.

Brinkman, S. & Kvale, S. (2015): *Interviews: Learning the Craft of Qualitative Research Interviewing*, Thousand Oaks, CA: Sage.

Colwell, J. (2000):. NATO Questionnaire: Correlation Between Ship Motions, Fatigue, Sea Sickness and Naval Rask Performance. *Human Factors in Ship Design and Operation, Royal Institute of Naval Architects.* London UK: Royal Institute of Naval Architects.

Cyclades. (2014): *Crew Centred Design and Operation of Ships and Ship Systems* [Online]. Available: http://www.cyclades-project.eu/CyClaDes/index.xhtml [Accessed 30 June 2015].

Dalpiaz, T. M., Emmrich, M., Miller, G. & Mcquillan, D. Conducting a Human Factors Engineering 3-D Computer Modelling Ship Design Review. Human Factors in Ship Design, Safety and Operation, The Royal Institute of Naval Architects, 23-24 February 2005 London, UK. 57-64.

Earthy, J. & Sherwood Jones, B. (2006): Design for the Human Factor; The Move to Goal Based Rules. *World Maritime Technology Conference.* London, UK.

Earthy, J. & Sherwood Jones, B. (2010): Best Practice for Addressing Human Element Issues in the Shipping Industry. *International Conference on Human Performance at Sea (HPAS).* Glasgow, UK: University of Strathclyde.

Ellis, N. (2009). Vessel Design and the Well-Being of Seafarers. *Seafarers International Research Centre Symposium.* Cardiff, UK.

Grundevik, P., Lundh, M. & Wagner, E. (2009): Engine Control Rooms Human Factors - Field Studies. *Human Factors in Ship Design and Operation, Royal Institute of Naval Architects.* London, UK: Royal Institution of Naval Architects.

Hardwick, C. (2000): A Comparative Assessment of Priorities for Accommodation Standards Between Royal Naval and Merchant Naval Fleets. *Human Factors in Ship Design and Operation Conference, Royal Institute of Naval Architects.* London, UK: Royal Institute of Naval Architects.

Harwood, T. G. & Garry, T. (2003): An Overview of Content Analysis. *The Marketing Review,* 3**,** 479-498.

Houtman, I., Miedema, M., Jettinghoff, K., Starren, A., Heinrich, J., Gort, J., Wulder, J. & Wubbolts, S. (2005): Fatigue in the Shipping Industry. Netherland: Netherlands Organisation for Applied Scientific Research.

IEA. (2016):. *Definition and Domains of Ergonomics* [Online]. International Ergonomics Association. Available: http://www.iea.cc/whats/index.html [Accessed 15/12 2015].

IMO (2001): Guidance on Fatigue Mitigation and Management. *MSC/Circ.1014.* London, UK: International Maritime Organisation.

ISO (2010): Ergonomics of Human-System Interaction - Part 210: Human-Centred Design for Interactive Systems (ISO 9241-210). *ISO 9241-210.* Geneva: International Organisation for Standardisation.

Kuo, C. & Houison-Craufurd, S. (2000): Managing Human Error in Maritime Activities. *Human Factors in Ship Design and Operation, Royal Institute of Naval Architects.* London, UK: Royal Institute of Naval Architects.

Lapan, S. D., Quartaroli, M. T. & Riemer, F. J. 2011. *Qualitative Research: An Introduction to Methods and Designs*, John Wiley & Sons.

LR (2008): *The Human Element - An Introduction*, London, UK, Lloyd's Register Marine.

Lützhöft, M. (2004): *"The Technology is Great when it Works": Maritime Technology and Human Integration on the Ship's Bridge.* Doctor of Philosophy, University of Linköping.

Lützhöft, M., Petersen, E. S. & Abeysiriwardhane, A. (2017): The Psychology of Ship Architecture and Design. *In:* MACLACHLAN, M. (ed.) *Maritime Psychology: Research in Organisational and Health Behavior at Sea*. 1 ed. Switzerland: Springer.

Meister, D. (1971): *Human Factors: Theory and Practice,* USA, John Wiley and Sons.

MLC (2006): Maritime Labour Convention 2006. *Accommodation, recreational facilities, food and catering.* International Labour Organisation.

NI. (2015): Alert! The International Maritime Human Element Bulletin. *Improving awareness of the human element in the maritime industry, Issues 1 to 40* [Online]. Available: http://www.he-alert.org/.

Nielsen, J. (1993): *Usability Engineering,* San Diego, Elsevier.

Petersen, E. S. (2012): *Engineering Usability.* Doctor of Philosophy, Chalmers University of Technology.

Petersen, E. S., Dittmann, K. & Lützhöft, M. (2010): Making the Phantom Real: A Case of Applied Maritime Human Factors. *3rd International Symposium on Ship Operations, Management and Economics.* Athens, Greece.

Rasmussen, J. (2005): Designing Usable Ship. *Human Factors in Ship Design, Safety and Operation, Royal Institute of Naval Architects.* London, UK: Royal Institute of Naval Architects.

Reason, J. (1990): *Human Error,* Cambridge, Cambridge University Press.

Ross, J. M. (2009): *Human Factors for Naval Marine Vehicle Design and Operation,* Farnham, England, Ashgate.

Sherwood Jones, B. (2005): Twenty Years on the Wrong Heading Dead Ahead. *Human Factors in Ship Design, Safety and*

Operation, Royal Institute of Naval Architects. London, UK: Royal Institute of Naval Architects.

Squire, D. (2007): 'Fit for Purpose'-Keeping the Crew in Mind. *Human Factors in Ship Design, Safety and Operation,Royal Institute of Naval Architects.* London, UK: Royal Institute of Naval Architects.

Squire, D. (2014): Human Element Competencies for the Maritime Industry. *Human Factors in Ship Design and Operation, Royal Institute of Naval Architects.* London, UK.

Strong, R. (2000): RN Habitability Survey : Ship Design Implications : Some Important Social and Architectural Issues in the Design of Accommodation Spaces. *Human Factors in Ship Design and Operation, Royal Institute of Naval Architects.* London, UK: Royal Institute of Naval Architects.

The Nautical Institute (1998): *Improving Ship Operational Design,* England, O'Sullivan Printing Corporation.

Walker, O. (2011): The Human Element Competency Required for Design Appraisal. *Human Factors in Ship Design and Operation, Royal Institute of Naval Architects.* London, UK: Royal Institute of Naval Architects.

Wilcove, G. L. & Schwerin, M. J. (2008): Shipboard Habitability in the US Navy. *Military Psychology*, (20)**,** 115.