Incorporate good practice into ship design process; Future ship designers meet end users

Apsara Abeysiriwardhane1, Margareta Lützhöft, Erik Styhr Petersen, Hossein Enshaei

Australian Maritime College, an Institute of the University of Tasmania, Tasmania, Australia.

A good ship design is one that takes account of socio-technical requirements and challenges; it has to fulfil the fundamental requirements of the safety, efficiency, and usability of the entire ship system by keeping Human Factors (HF) in mind. Human Centred Design (HCD) is an approach which designers can use to apply HF and user involvement into ship design. Thus the ship designers' expertise on HCD is of paramount importance for a good ship design.

This paper presents part of an ongoing research study to integrate HCD knowledge into the maritime design engineering education. A "Designers Meet Users" workshop was conducted with Bachelor of Engineering students at Australian Maritime College. A team of seven maritime field experts were present as end users to provide HF feedback to improve final year 'Design Projects' done by the students. Students facilitated a walkthrough of their designs to the field experts. Data collection included debriefing meeting with experts, student feedback, and researchers' observations.

Field expert team highlighted the possible design alterations within the general arrangement and other layout drawing to make the designs more user friendly than its original, indicating that the students had little or no HF knowledge or experience. Thus it is needed to integrate HF/HCD knowledge into maritime design engineering education system in a more targeted engineering-oriented fashion.

Keywords: human factors, human centred design, ship design, maritime designer, education

1. Introduction

'Everybody complains about the weather, but nobody does anything about it'. This quote is attributed to the American novelist Charles Dudley Warner (1829-1900), and is possibly expected to indicate that humans are habitually talking about things they certainly cannot do anything about. Arguably, Petersen (Petersen, Dittmann, & Lützhöft, 2011) understood something similar for the application of Human Factors (HF) in the maritime industry: '*Many talk about Maritime Human Factors, but few are doing anything about it*'. There are few records (Dobbins, Rowley, & Campbell, 2008; Petersen, 2012) of the industrial application of maritime HF in the systematic literature of the maritime domain. Nevertheless there are no accounts in the literature, of any systematic industrial application of maritime HF knowledge in ship design process. Moreover, in addition to a comprehensive literature on maritime HF, there are no regulation requirements for HF engineering in the maritime domain. However "*The past is already gone, the future is not yet here. There's only one moment for you to live, and that is the present moment (p 13)* (Kannings, 2014)": thus now is the moment to consider how can we contribute to increasing the inclusion of HF consideration in ship design process – having an impact on the future.

The life of the seafarers is heavily dependent on the ship's design characteristics such as equipment accessibility, habitability, workability, maintainability, operability (Alert!, 2004; Hemmen, 2003; Lloyd's Register, 2008), usability, reliability, supportability, and acceptability (Alert!, 2010). Some

design features affect the mental workload, some affect the crew's ability to sleep, and others affect the level of physical stress on the crew (Ellis, 2009; IMO, 2001). To ensure that a design is fit for the intended purpose and appropriate to the context in which it will be used, the designers and the design process should consider these aspects, an integral part being to consider the users' capabilities and limitations (Squire, 2014) through 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 the direct and continuous involvement of end users, as a minimum for the duration of the development process or better, throughout the entire product life-cycle (Nielsen, 1993). Involving users in the design and development processes of new products, systems and workspaces has become increasingly important in order to improve the quality if the product, to increase the flexibility of their functions, and to prevent disturbances in system performance (Launis, 2006). End users can contribute important knowledge on workplace processes, tasks, equipment, and potential risks, and feedback on the design. Similarly the end user participation and feedback on maritime designs provides important information about how ships, their components and services are used, and can assist with informing design, improving usability aspects and enhancing operation. In more detail, user feedback informs designers of the good features to be continued and developed, the failures and weaknesses, potential risks and even ideas about how to improve them. A lack of user feedback and involvement during design stage increases the risk that the new design or innovation does not fit its user, the purpose and the context of use of actual practice.

The maritime design practice today does not show explicit consideration of the end user, and therefore does not apply HF, ergonomics and usability knowledge during design to their full extent (Calhoun & Stevens, 2003; Costa & Lützhöft, 2014; Petersen et al., 2011), if at all. In addition the design process does not appear to involve end users or obtaining end user feedback. There are few opportunities for maritime designers to communicate with end users, and no systematic feedback from users to designers. Designers and end users are by nature distanced by professional upbringing, knowledge and culture, and often also distanced both geographically and organisationally, due to the globalised nature of the maritime industry, all of which poses challenges to collaborative design. However it is of paramount importance for the designers to have early focus on end users, tasks and environment, to have an active involvement of users if possible and to incorporate end user derived feedback into the design. These points are what enables applying an HCD approach. Yet most of the maritime design engineers involved in the maritime design process seem to be unaware about HF, HCD and – noteworthy in the present context – the operational issues which ships' crew face during their sea time (Petersen, 2012; The Nautical Institute, 1998; Walker, 2011). This lack of knowledge can be traced back to the educational system which present maritime design engineering students are not fully aware of the HCD approach in ship design, maritime HF issues and HF guidelines (Abeysiriwardhane, Lutzhoft, & Enshaei, 2014; Abeysiriwardhane, Lutzhoft, Petersen et al., 2015). Examining their education system, it is clear that it is heavily biased towards the technological field and very few have been exposed to such topics as HF (Kuo & Houison-Craufurd, 2000; Walker, 2011). Furthermore there are rare opportunities for maritime design engineering students to communicate with those who work onboard the ships during their study period to stimulate their knowledge on operational issues and to establish a clear understanding of the situation in which the design will be used.

This paper presents part of an ongoing research study aiming at mitigating this knowledge gap, explicitly attempting to integrate HF/HCD knowledge into the maritime design engineering

education. A "Designers Meet Users" workshop was conducted with 62 final year Bachelor of Engineering students (hereafter referred to as the 'students') at the Australian Maritime College (AMC) at the University of Tasmania in July 2015. A team of seven maritime field experts were present as end user representatives to provide HF feedback to improve final year 'Design Projects' done by the students. Students facilitated a walkthrough of their designs to the field experts. Data collection included debriefing meeting with experts, student feedback, and researchers' observations. The findings of this three-hour workshop are presented in this paper.

2. Methodology

The "Designers Meet Users" workshop was arranged as a part of the Bachelor of Engineering degree final year course unit 'Design Project', which has participation from the branches of Naval Architecture, Marine & Offshore Engineering, and Ocean Engineering. This unit has been developed at the AMC, and allows students to use and integrate knowledge acquired during their previous years of study, helping them to develop their ability to plan, research, conduct and manage a complex design project (Thomas, Harte, & Pointing, 2013; Thomas, Lawrence, & Furness, 2006). Students were invited to participate in the "Designers Meet Users" workshop by the Unit's lecturer seven days in advance and requested to be prepared with their designs to facilitate a walkthrough for the field experts in order to obtain their feedback and suggestions. Following instructions were given to all design project teams to facilitate field experts; 1) explain your design project, 2) show your 2D or 3D design drawings, 3) explain expected operations and situations in which your design will be used, 4) obtain expert's feedback to improve your design. Twelve design project teams were present at the workshop as listed in the Table 1.

The team of seven maritime field experts as listed in Table 2 were invited to walkthrough the students' designs to provide feedback and suggestions and to offer an opportunity for the students to interact with those who have experience onboard ships. The field expert team members were selected based on their seafaring and maritime experiences in regards to the students' final year design projects. The research team had reported to the expert team about the students' design projects, workshop procedure, and their role in the workshop about seven days in advance. Maritime field experts were assigned to different design projects as end user representatives (see Table 2).

A main moderator led the workshop that was undertaken in a computer workroom. Additionally, assistant moderators were present throughout the workshop to gather written informed consent from the participants, to take notes, and distribute feedback forms. In addition the assistant moderators provided general help and guidance to the workshop participants and expert team members. The feedback forms distributed to the students contained two questions; one scaled question and one open ended questions. The scaled question contained three verbal anchors, "Useful", "Neutral" and "Irrelevant" to indicate the students' satisfaction with the workshop. The open-ended question was included to obtain the students' suggestions and feedback on the workshop activity. The results of the feedback are given in section 3.2.

Table 1. Design project teams.

Team	Project name
01	Design proposal for 70m Anchor Handling Tug Supply vessel
02	Design proposal for 60m Super Yacht
03	Design proposal for 52m Sailing Yacht
04	Design proposal for 45m Research and Training vessel
05	Design proposal for Disaster Relief barge
06	Preliminary design of a Submarine

07 Concept design of a Submarine Rescue Suite
08 Design proposal for Offshore Decommissioning vessel
09 Design proposal for Yacht Club Marina
10 Antarctic Gateway Project: AUV Launch and Recovery System design proposal
11 Redesign proposal for Davis Cat – AMC Research vessel
12 Design proposal for Naval Littoral Operational Support vessel

Table 2. Maritime field experts.

Team member	Assigned design project
Master Mariner 01	01,08
Master Mariner 02	12
Master Mariner 03	04,11
Seafarer (Submariner)	06,07
Seafarer/ Lecturer 01	02,03
Seafarer/ Lecturer 02	05
Naval Architect/ lecturer	09,10

2.1 Procedure of the workshop

A briefing was given to the students on how the workshop would be conducted and the maritime field experts were introduced and assigned to their design projects as end user representatives. The research team requested design groups to use their design tools such as 2D/3D design software or printed drawings to walkthrough the respective field experts in their designs. Each design project team was given 60 minutes to communicate with their field expert (see Figure 1). The research team also encouraged the students to communicate freely with any of the field experts after they completed the walkthrough. Once all teams finished their design walkthrough with field experts, a feedback form was distributed to the students and they were given 10 minutes to complete them. Finally, students were requested to ask any relevant questions and, as a closing event the research team had a closed debriefing session with field experts to discuss and share individual comments and feedback on each design project. Notes taken by the field experts during the walkthrough, and notes and observations recorded during the workshop were discussed in detail during the debriefing and individually with each field expert afterwards.

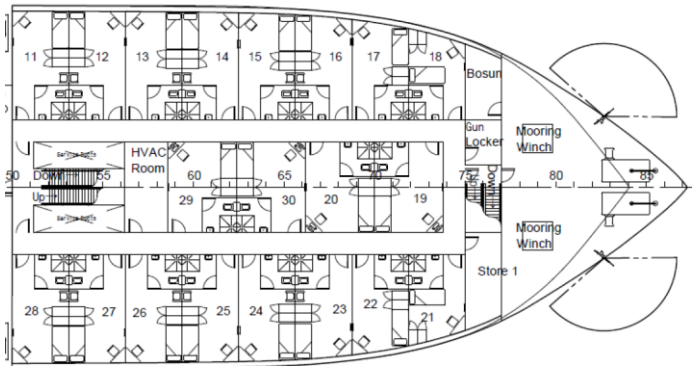
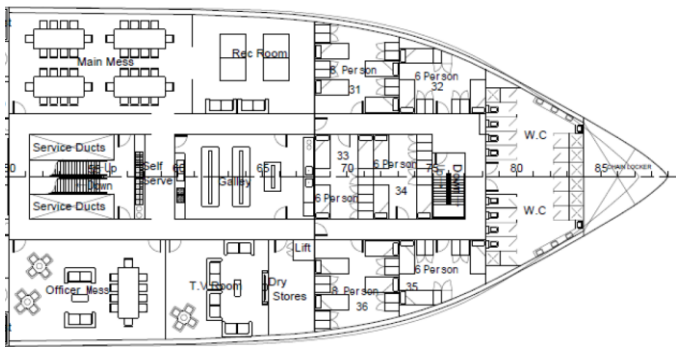
Figure 1. Field experts as end user representatives meet future maritime designers

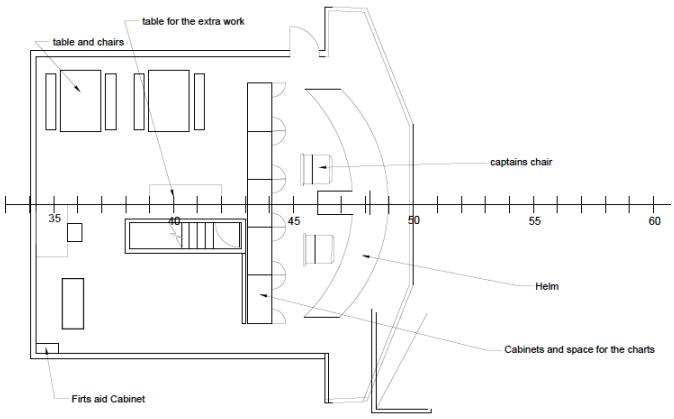
3. Results

3.1 Field experts debriefing session and researcher's observations

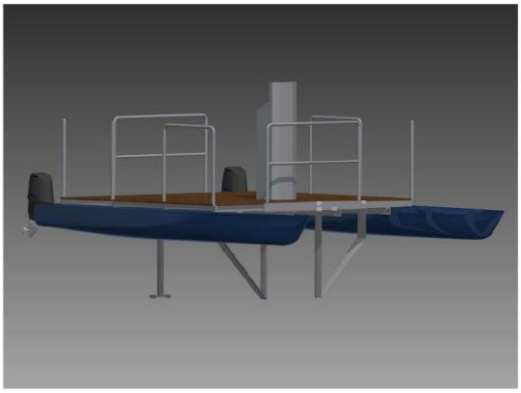
The field experts observed many instances in the concept design proposals, where students did not consider the user requirements of their designs such as habitability, maintainability, and workability. The experts identified a lack of consideration of the provision of adequate and comfortable accommodation, including location, space allocated, furnishings, and washing facilities. In addition, most of the teams did not consider the variations in the size, shape, and gender of the seafarer, and did not allow for the various environmental stressors such as noise, heat and vibration. Furthermore the consideration of access, designing operational maintenance routes, placing the machinery, and headroom considerations had to be improved in many design proposals. However, most of the designs could have been rearranged without deviating from the original design specification to make improvements in the crew habitability by rearranging the cabin locations, rearranging the furniture within cabins considering the directions, changing the staircase locations and angles, providing better headroom and providing natural light. Few examples taken from students' designs can be listed as below (seen Table 3).

Table 3. Few examples in changes highlighted within designs.

Example	Description
	Team 08 – Deck B Plan Team placed the bunks athwartships where roll motion is high and uncomfortable for the seafarers. Expert team suggested them to rearrange the layout to improve the crew habitability.
	Team 08 – Deck A Plan Main mess tables placed fore and aft direction where users feel uncomfortable while using them. Also a few 6-person cabins were placed within a busy area close to the recreation room and toilets. The layout could be rearranged to improve the crew habitability.



Team 04 – Bridge Plan
There was a row of tall cabinets with a few switchboards placed approximately 500mm behind the captain's chair making difficult for them to access them and obstructing rear visibility. This could have been rearranged to improve the visibility, equipment maintainability and accessibility requirements.



Team 11 – 3D Model
This small boat travels at 40knot speed with 6 people on-board it. The railing height is 600mm and also there are gaps between the railings. Expert team advised the team to consider the safety of its users during operation by redesigning it.

The general findings from the debriefing session with field experts can be summarised as follows.

- Most of the teams were prepared for the walkthrough of their designs and were ready with good questions to find out operational issues;
- A few teams were not well prepared for the walkthrough of their designs and they did not ask questions on operational issues which crew may face;
- A few teams tried to get the solutions to their design issues from the end users rather than devising a solution to satisfy the end user requirements;
- All field experts identified habitability, maintainability and workability issues within the designs and they suggested possible modifications to overcome them;
- A few teams were focused more on luxury than crew requirements and they were reluctant to alter their designs because they think it is a painful process;
- Most of the teams were not very sure about whether their design solutions met user requirements or not, but they thought their solution may be acceptable;
- All field expert team members experienced enthusiasm in most of the students.

Based on the debriefing session findings and the researcher's observations it was noted that the students highly appreciated the effort taken by the researcher to arrange such workshop to give them a chance to meet the possible end users. It was noted that a few students were not completely engaged in the discussion between field expert and their team. However, most of the students were taking notes during the discussion and most of the teams spent more than one hour with their field expert. Finally all field experts appreciated the effort taken to setting up a common stage to meet seafarers and future maritime designers to share their seafaring experience and knowledge and provide feedback to improve the designs to make a happy ship. In addition they appreciated the effort taken to integrate the HF and HCD knowledge into future maritime designers' education.

Apart from the field experts, the design project unit lecturer had not experienced this level of motivated engagement from all design teams prior to this workshop.

3.2 Student feedback forms

There were a total of 50 valid responses received for the feedback forms out of 62 participants.

3.2.1 Students' level of satisfaction about the workshop

The responses for the scaled question was summarised under students' level of satisfaction about the workshop and 92% of the students were satisfied with the workshop and they identified it as a useful event to meet the end users (see Figure 2). 2% of them were identified the workshop as an irrelevant activity and the rest were neutral.

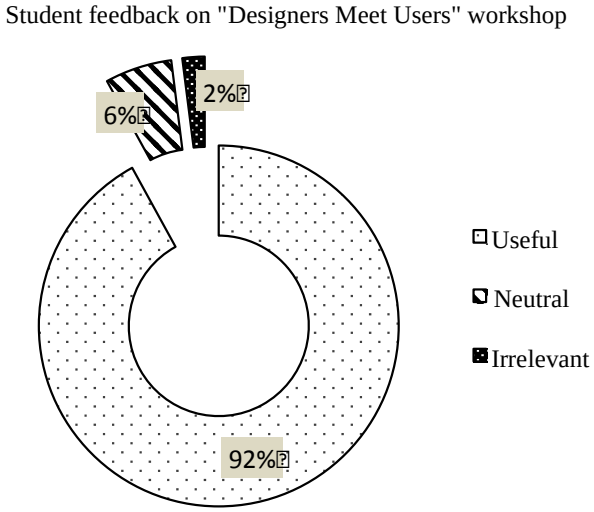


Figure 2. Student feedback on "Designers Meet Users" workshop.

3.2.2 Student suggestions and feedback on the workshop

The responses given to the open-ended question were listed, assigned an explanation and then categorised. A majority of the students provided positive feedback on the workshop as illustrated by a sample of statements listed below, however, 24% did not provide any feedback.

"I think the "designers meet users workshop" was very beneficial, really good to get fresh, experienced eyes, because we don't have that experience though we are designers. This is getting us to think about HCD"
"Constructive feedback was given and advices from users are much appreciated. Gave us insight on stuffs that we may never thought about"
"Consultation time with seafarers was exceptionally valuable. This is the most valuable 60 minutes we spend during this design project period"
"Talking to experts from industry allowed us to visualise potential problems"

Furthermore the majority of students recognised the significance of "post-design" contact with those who work onboard the ships to obtain and maintain a clear understanding about the working conditions, operational issues, physical environment, tasks, work flow and potential hazards on board ships. In addition they identified the importance of end user participation and end user feedback in the maritime design process to provide important information about how ships, their

components and services are used, i.e. information that can assist with improving design, operation and usability aspects. Furthermore 88% of students requested to arrange similar workshops again and more often during their design project period. Some of them requested to arrange this workshop in the early stage of the design process, in the first semester of the final year of their studies as illustrated by a few statements listed below.

"We would very much like to have more meetings with users so that designers have a better overview of what users are experiencing with good design and bad designs and we can design based on the user needs"
"Can we have "designers meet user" workshop more often? really helpful. Any possibility to line up meetings with experienced users/experts throughout first semester?"

Some of the students suggested attaching an experienced seafarer as end user representative to each group from the initial stage of the design process as illustrated by a sample of statement below.

"Can we have one end user representative attach to each design team throughout the design process? That will be a great value to us"

Another request from the students was to have slightly longer meetings, for example two hours of Designers Meet User sessions. Three students requested to provide notice of the workshop at least a few weeks prior to allow them to prepare some questions and a short presentation.

4. Discussion

The enthusiasm displayed by of most of the students, and their appreciation of the effort taken to setting up a common stage for seafarers and future designers to meet, so as to incorporate an HCD approach into ship design process, is seen as a clear and positive finding of this study. Most of the teams were well prepared to meet the field experts with their design drawings, specifications and 3D models. This shows the students' interest to discuss their designs with the end users, and thus to obtain their feedback to modify their designs. Since this was the first such workshop arranged at AMC, it was a novelty, and students not only appreciated the opportunity, but also requested to repeat such an event more frequently. Furthermore, the field experts acknowledged the questions raised by the students to clarify the operational aspects onboard the ship and saw them as showing that the students were very motivated to stimulate their knowledge on the operational issues, ships' crew face during their sea time. This feedback and suggestions did help students to learn about good features to be continued and developed, the failures and weaknesses, potential risks and even ideas about how to improve them. In addition, the field expert team highlighted the possible design alterations within the general arrangement and other layout drawing to make the designs more user friendly than its original, indicating that the students had little or no HF knowledge or experience. Thus it is needed to integrate HF/HCD knowledge into maritime design engineering education system in a more targeted engineering-oriented fashion.

However a few teams were not prepared for the workshop session, and some of them requested to be informed about the workshop schedule a few weeks prior to it. In preparation for the next workshop, this will be considered. Furthermore some of the students requested to arrange the workshop in the starting stage of the design project. This has to be considered in future work of this ongoing research study. As students requested, during next design project unit, it will be possible to arrange longer workshops and an end user representative for each project throughout the year. Students could use this approach as an inspiration, to continue this practice during their career, in order to apply an HCD approach during their designs.

The two teams who focused more on luxury for guests were reluctant to rearrange the general arrangement on crew's perspective based on field expert team suggestions because they recognised that modification as a painful process. However the experts showed them the difficulties that crew may face while working onboard the vessel. This finding shows that some designers may be reluctant to apply this HCD approach. Thus it will be necessary to discuss more examples on HCD applications and benefits of HCD approach with future cohorts of maritime design engineering students. In addition it will be needed to arrange more onboard visits to show them the design issues that crew are facing onboard ships. This is supported by the fact that most of the team members were not confident on their design solutions. They posed the question to the field expert team and requested whether their designs satisfy the user and operational requirements. This has to be expected from inexperienced undergraduate students who are doing their first design project and therefore the discussion with the field expert team was a good opportunity for them to gain a worthy experience prior to the start of their career.

5. Conclusion

A "Designers Meet Users" workshop was conducted with Bachelor of Engineering students at Australian Maritime College. A team of seven maritime field experts were present as the end user representatives, to provide HF feedback on final year 'Design Projects'. Students facilitated a walkthrough in their designs to the field experts in order to obtain such feedback and suggestions for improvements. The session was analysed using researchers' observations, student feedback and closed debriefing session with experts. The analysis findings indicate that the students had little or no HF/HCD knowledge or experience, based on the designs they presented. Thus it is necessary to integrate HF/HCD knowledge into maritime design engineering education system.

Based on student feedback, 92% of them acknowledged the value of having such workshops to improve their knowledge by meeting with field experts, and 88% of them requested to repeat it. Also they identified the importance of having discussions with end users during the design stage. It shows that such practical sessions are recognised by the students to improve their knowledge gained through theoretical sessions. Therefore, it is recommended to introduce "Designers Meet Users" workshops for all maritime engineering undergraduate courses. In addition the field expert team appreciated the effort taken by the researchers to provide input to future designers. As the future work, it is intended to arrange such workshops at the different stages of students' final year design projects to maintain the consideration on user needs, through the direct and continuous involvement of end users. This will support future maritime designers to stimulate their knowledge on workplace processes, tasks, equipment, potential risks, and operational issues onboard ships and to establish a clear understanding of the situation in which the design will be used. In addition this effort will encourage future maritime designers to continue this practice during their career, in order to design a happy ship.

Acknowledgements

Authors would like to acknowledge the support given by the AMC lecture David Harte and the maritime field expert team. The Tasmania Human Ethics Research committee (HREC) approved the project under the approval number H00014771.

References

Abeysiriwardhane, A., Lutzhoft, M., and Enshaei, H. (2014). *Human factors for ship design; exploring the bottom rung*. Transactions of the Royal Institution of Naval Architects Part C: International Journal of Marine Design, **156**(C1): p. 153-159.

Abeysiriwardhane, A., Lutzhoft, M., Petersen, E.S., and Enshaei, H. (2015). *Future ship designers and context of use; setting the stage for human centred design.* Paper presented at the *International Conference on Marine Design 2015*, London,UK.

Alert! (2004). *Ergonomics: An ergonomic nightmare*. The International Maritime Human Element Bulletin, (3), 8. Retrieved from Alert! website: http://www.he-alert.org

Alert! (2010). *Design, build, maintain*. The International Maritime Human Element Bulletin, (24), 8. Retrieved from Alert! website: http://www.he-alert.org

Calhoun, S.R., and Stevens, S.C. (2003). *Human factors in ship design*. In T. Lamb (Ed.), Ship design and construction (1 ed., Vol. (2), p. 1-27): Society of Naval Architects and Marine Engineers.

Costa, N.A., and Lützhöft, M. (2014). *The values of ergonomics in ship design and operation*. Paper presented at the *Human Factors in Ship Design and Operation, Royal Institute of Naval Architects*, London, UK.

Dobbins, T., Rowley, I., and Campbell, L. (2008). *High speed craft human factors engineering design guide*: Human Sciences & Engineering Ltd.

Ellis, N. (2009). *Vessel design and the well-being of seafarers.* Paper presented at the *Seafarers International Research Centre Symposium Proceedings*, Cardiff, UK.

Hemmen, H.F.V. (2003). *The need for additional human factors considerations in ship operations*. Paper presented at the *Second International Symposium on Ship Operations,Management & Economics*, Athens,Greece.

IMO. (2001). *Guidance on fatigue mitigation and management* (MSC/Circ.1014). London, UK: International Maritime Organization.

ISO. (2010). *Ergonomics of human - system interaction - part 210: Human - centred design for interactive system (iso 9241-210:2010)*: International Organization for Standardization.

Kannings, A. (2014). *Gautama buddha: Life & words* (Vol. 1).

Kuo, C., and Houison-Craufurd, S. (2000). *Managing human error in maritime activities*. Paper presented at the *Human Factors in Ship Design and Operation, Royal Institute of Naval Architects*, London, UK.

Launis, M. (2006). *Participation and collaboration in workplace design*. In W. Karwowski (Ed.), International encyclopedia of ergonomics and human factors (Vol. (2), p. 1274-1277): CRC Press.

Lloyd's Register. (2008). *The human element - an introduction*: Lloyd's Register Group.

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

Petersen, E.S. (2012). *Engineering usability.* (Doctor of Philosophy), Chalmers University of Technology, Gothenburg,Sweden.

Petersen, E.S., Dittmann, K., and Lützhöft, M. (2011). *Making the phantom real: A case of applied maritime human factors.* Paper presented at the *3rd International Symposium on Ship Operations, Management and Economics*.

Squire, D. (2014). *Human element competencies for the maritime industry*. Paper presented at the *Human Factors in Ship Design and Operation, Royal Institute of Naval Architects*, London, UK.

The Nautical Institute. (1998). *Improving ship operational design* (1 ed.). England: O'Sullivan Printing Corporation.

Thomas, G., Harte, D., and Pointing, D. (2013). *Developing student skills through industry-aligned and team-focussed design projects*. Paper presented at the *Education and Professional Development of Engineers in the Maritime Industry*, Singapore.

Thomas, G., Lawrence, N., and Furness, P. (2006). *Learning through industry-focussed and team-based ship design projects*. Paper presented at the *Australasian Association for Engineering Education Conference*, Auckland, New Zealand.

Walker, O. (2011). *The human element competency required for design appraisal*. Paper presented at the *Human Factors in Ship Design and Operation, Royal Institute of Naval Architects*, London, UK.