Chasing the end-user perspective in bridge design

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Abstract - **Navigators onboard maritime vessels often interact with several different electronic navigation systems from different equipment manufacturers, leading to a variety of user interfaces, panels and operating philosophies on the bridge. This may influence safety as it may lead to sub-optimal workflow and increased cognitive load. Rolls-Royce Marine (now Kongsberg Maritime CM) have developed a bridge environment aiming to unify the user experience by simplifying and standardising the different workstations on the bridge. The end-users were involved at several stages during the design process. This paper reports the findings from two field studies performed on two platform supply vessels with the Rolls-Royce Unified Bridge installed. Ethnographic inspired data collection was performed to reveal the navigator's opinions of this bridge environment. The main finding is that the they found this bridge to be overall user-friendly and well arranged. They also pointed at a few solutions that can be improved.**

Keywords
Bridge design, human-centred design, ethnography, evaluation.

INTRODUCTION

On June 8, 2009 the vessel *Big Orange XVIII* was en route to the 2/4-X-platform on the Ekofisk field to perform well stimulation (Kvitrud, 2011; Leonardsen, Jacobsen, & Hamre, 2009). At 04:00 the captain took over command on the bridge, the Ekofisk radar was contacted for permission to enter the 500-meter zone and the captain changed from autopilot to manual steering. After a couple of minutes, there was an incoming phone call to the bridge. The captain switched the steering back to autopilot and left the steering position to take the phone call in the radio room adjacent to the bridge. The conversation lasted for about 30 seconds. When he returned to the steering position he did not deactivate the autopilot again. At 04:11 *Big Orange XVIII* received permission to enter the 500-meter zone. The captain reduced the speed to make a turn and position the vessel alongside the installation. He then became aware that the vessel did not respond to manoeuvring attempts. The vessel managed to avoid collision with platforms 2/4-X and 2/4-C by passing under the bridge between them. Thinking there was a technical problem with the steering the captain did several attempts to manually manoeuvre the vessel to stay clear of the installations. The vessel passed very close to the jack-up flotel COSL Rigmar before it finally collided with the unmanned water injection platform Ekofisk 2/4-W at 04:17. There was no physical injury to personnel, but significant material damage to both the platform and the vessel. For one thing the production from Ekofisk 2/4-A had to be shut down. The investigation reports pointed at several underlying causes for the accident (Kvitrud, 2011), however the main direct cause being the captain did not realize that the autopilot was switched on during the entire approach.

Collisions between attendant vessels and offshore facilities are example of marine accidents that have a very high hazard potential. In addition to the risk for the personnel involved, damage to hydrocarbon pipes may cause severe oil spills and thus represents a threat to the environment. During the period 2001–2011, a total of 27 collisions were reported between attendant vessels and offshore facilities on the Norwegian continental shelf (Sandhåland, Oltedal, & Eid, 2015). Ibid found that "errors due to reduced vigilance and misconceptions of the technical automation systems emerged as the primary antecedents of collisions".

There are many factors that influence how a seafarer make sense of his/her environment, ranging from individual factors (human senses, perception, fatigue, workload and stress), communication and team work (roles, leadership), work environment (light, noise), to cultural aspects (safety culture, national culture) (Grech, Horberry, & Koester, 2008). Seafarers today are working in a technology dense environment on the bridge, interacting with highly advanced automated systems. The design of technology influences the way people work and how they perform. The *Big Orange XVIII* accident is for one thing an example of how fragile the human short-term

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memory is. But well-designed technology should support humans including human shortcomings like these. It seems that the Human-Machine Interface (HMI) on *Big Orange XVIII* did not convey a clear message to the captain regarding who was in control of the steering.

In addition to individual equipment not always having good interface design, many ship bridges consist of equipment delivered by multiple vendors. Nordby, Frydenberg & Fauske (2018) found that multivendor ship bridges may consist of up to 35 different types of equipment. The separate equipment units are usually installed in large work consoles leading to cluttered workplaces and suboptimal workflow for the navigators. Due to lack of standardization in the maritime industry, different companies have different user interface design. It requires cognitive workload to switch between different user interfaces, it also increases the need for familiarization and training.

Rolls-Royce Marine (now Kongsberg Maritime CM) is a commercial actor that have incorporated Human-centred design (HCD) in the development of maritime equipment. They set out to develop an integrated bridge based on research and knowledge about the actual work context and performed a complete redesign of the ship bridge environment, including consoles, levers and software interfaces (Bjørneseth, 2014). One of the objectives was to achieve consistency across applications concerning the graphical user interface (Bjørneseth, Dunlop, & Hornecker, 2012). The end-users were involved at several stages throughout the design process.

This paper reports the findings from two field studies performed on two platform supply vessels (PSV) with the Rolls Royce Unified Bridge installed. Ethnographic inspired data collection was performed to reveal the navigator's opinions of this particular bridge environment. The work aimed at performing a user-centred evaluation after long-term use which can provide input for improvements for future versions of the product.

BACKGROUND

Safety through design

The maritime industry is a high-risk industry as accidents may have severe consequences for human lives, the environment or the economy. The cause of accidents in this sector are often attributed to "human error", e.g. Dhillon (2007) reported that over 80 percent of marine accidents are caused of influenced by human and organizational factors. According to AGCS (2017), 75-96% of marine accidents can be attributed to "human error" as "a number of incidents have occurred where crews have relied too much on technology, particularly involving electronic navigation tools." (AGCS, 2017). As pointed out in the AGCS report, it is often problematic for humans to interact with technology. A maritime system, like the bridge on a vessel, is a system where human, technological and organizational factors influence each other. How humans interact with other system components are predetermined in design (Lützhöft and Vu, 2018). Faulty design may make the interaction between humans and the other system components difficult which may lead "human error". Lützhöft and Vu (2018) states that "it is faulty design, not 'human error', that is the primary, or latent, reason behind accidents in the maritime industry". Design has also been reported as a significant contributor to accidents in other domains, like aviation, railway and nuclear (Kinnersley & Roelen, 2007). Hence, it is a safety issue that design can accommodate the needs, capabilities and limitations of the humans.

Human factors can be defined as "the scientific discipline concerned with the understanding of the 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" (Salvendy, 2012). It has been suggested that within the human factors discipline the sensemaking perspective (Weick, 1995) may be a useful concept for understanding human behaviour on the bridge (Danielsen, 2018). Sensemaking concerns the cognitive processes through which people work to understand issues or events, by extracting cues from the environment and through cycles of interpretation and action create meaning to these events (Maitlis & Christianson, 2014). Scholars have described sensemaking as a factor influencing resilience (Takeda et al., 2017, Grøtan and van der Vorm, 2015).

Considering human factors knowledge in design has been implemented in maritime regulations, as seen in SOLAS (Safety of Life at Sea) regulation V/15 regarding the design of ship bridges, bridge equipment and procedures. SOLAS V/15 has formulations like "allowing for expeditious, continuous and effective information processing and decision-making by the bridge team and the pilot" which promotes human-centred design that accommodates sensemaking. The International Organisation for Standardisation defines human-centred design as "an approach to interactive systems development that aims to make systems usable and useful by focusing on the users, their needs and requirements, and by applying human factors/ergonomics, and usability knowledge and techniques." (International Organisation for Standardisation, 2010). Human-centred design implies a throrough understanding of the user and the work context and involves iterative activities like data collection, analysis and producing design solutions. To develop a proper understanding of the work context in the maritime sector Lurås & Nordby (2015) stress the importance of field work to develop a “designers sea sense”.

Human-centred design has been reported to have an added-value in the maritime sector, benefitting the seafarers in terms of physical cognitive, psychosocial and organizational improvements as well as having certain benefits for the ship-owners, such as reduction of costs (Costa & Lützhöft, 2014).

A human centred design process should also include evaluation at several stages during project development. According to the standard ISO 9241:210 user centred evaluation (evaluation based on users’ perspective) is a required activity in human-centred design (International Organisation for Standardisation, 2010). User-centred evaluation is considered useful in all stages of in the project from the early concept of the design to its long-term use. Within research it has also been suggested that in order to “observe change due to the introduction of technology, we should be there a) immediately when it is introduced, b) when it is in use, and c) when users have adapted to it.” (Lützhöft, 2004 p20). It is argued that certain types of problems or tailoring will be visible at certain time periods after introduction of technology.

The Rolls-Royce Unified Bridge

Rolls-Royce Unified Bridge started as a conceptual innovation project to define the next generation ship bridge. The goal of the project was to increase operational safety in demanding maritime operations through redesigning the ship bridge environment, including consoles, levers and software user interfaces utilizing a human-centred design process. The human factor and physical ergonomics were the basis of development in order to introduce a more comfortable and safe working environment for the operators on-board, making it user centric and flexible. Above all, it should unify the user experience in one single concept – the Unified Bridge.

To think holistically on the complete operation, from the human perspective, the involved functions, systems and equipment, the complete interactions on the ship bridge (the control centre) was important to gain enough insight to coordinate the different initiatives and produce a physical design on consoles, levers and graphical user interfaces for software applications. The Unified Bridge philosophies including unified alert handling (silencing alerts from one location), unified look and feel on all software applications (including symbols, navigation patterns etc.) and unified dimming of lights on the bridge from a remote-control application (described below), are vital parts of the innovation concept. Following the unveiling of an initial design concept at a leading maritime exhibition, development work began based on the four design principles:

- Safety
- Performance
- Proximity
- Simplicity

The development process included collection of qualitative data through interviewing ship operators; carry out studies in the field to view functional designs and doing observation and usability studies, including a thorough mapping of any relevant rules and regulations. On a detailed level, prototypes (lo and hi – fidelity) of all physical devices (consoles, levers and chairs) were developed and thoroughly tested involving users throughout the process from drawing to final concept. Verification methods such as hierarchical task analysis, functional task analysis and eye-tracking equipment were also used to assess frequency of equipment usage, important tasks/functions and optimize placement of monitors, levers and operational equipment.

The project proceeded in close co-operation with industrial designers. The Rolls-Royce Unified Bridge project proceeded in two parallel runs where one part of the project was the development project, developing new technical solutions, graphical user interfaces, consoles, operator chairs, levers etc. The other part of the project was a research project supported by the Norwegian Research council, doing testing and evaluations of the concept. With this project composition, it was possible to feed the research results directly into the development project for instant implementation.

To optimize the traditional over-equipped work surfaces to set focus on the operation-critical equipment, a number of individual sets of equipment from third party suppliers were replaced with a new integrated product that could remote control equipment that was important for the vessels operation, however not vital for the actual operation that was carried out. Lantern, searchlight, bridge light and window viper control are a small collection of the equipment remote controlled from the bridge station through a touch-screen computer solution. In traditional ship bridges, the above-mentioned equipment are independent systems, that on their own has large single panels that occupy important space close to the operator. By moving such equipment to a bridge equipment station further away from the operational zones, the original panels are still available to the operators, but with the possibility of remote control. This leaves the operation-critical equipment in closer proximity to the operator.

Initially the concept was developed for platform supply vessels but has been extended to a range of different vessel types, such as cruise, tug, ro-pax, construction, double-ended ferries, mega yachts, service- and fishing vessels. The expansion of the Unified Bridge concept to other vessel types has shown that the philosophy behind the concept with focus on the holistic operational environment and user experience is generalizable to most vessel types. As an example, the Unified Bridge cruise concept, installed on the new *MS Roald Amundsen* owned by Hurtigruten, has the same holistic philosophy as the specialized supply vessels, but the consoles have been adapted to suit the operational pattern for exploration cruise vessels. The bridge wing on these vessels are of more importance than the bridge wing on supply vessels. Mainly because the vessels arrive at many different ports during their journey and the bridge crew needs full overview of the ship side when porting. Also, tender operations when tourists go exploring in smaller RIB boats that are boarded at sea requires good overview of the ship side. Another example is fishing vessels where the Unified Bridge concept has been adapted to suit the typical operational patterns when fishing. Fish searching equipment and a videowall is vital when looking for suitable locations for fishing. Depending on the type of fishing vessel, the aft bridge or the bridge wing has important functions that much be taken into consideration.

In general, field studies, interviews and gathering insight within the field of interest, has been an important step for Rolls-Royce Marine (now Kongsberg Maritime CM) when new products are to be developed, or when revitalizing already established products. The insight gathered from the investigations has been used as the foundation for development. The user has been involved throughout the development process from idea to finished product being released into the market. Throughout the products' lifecycle, the users are still involved by returning insight of product utilisation to the product owner for them to include in new improved versions of the products.

METHOD

Sample

Fieldwork was conducted on board two offshore supply vessel owned by a Norwegian shipping company. The vessels, built in 2014 and 2016, were equipped with the Rolls Royce Unified Bridge. Figure 1 illustrate the overall layout of the bridges.

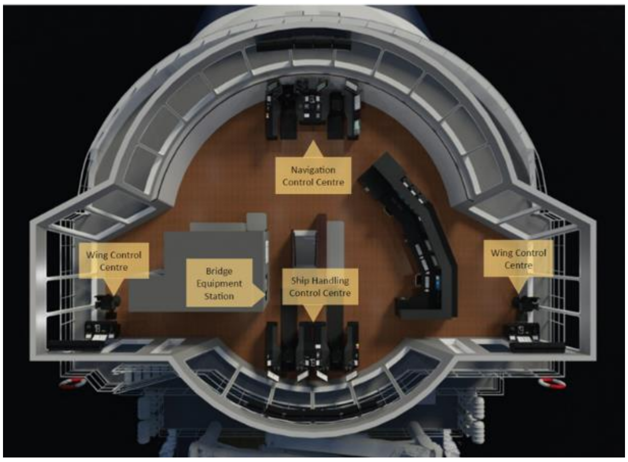

Figure 1. Illustration of the Unified Bridge arrangement on the PSV bridges.

Both vessels had four Norwegian officers on-board that participated in the study. They had all trained at Norwegian maritime educational institutions and had worked on these particular vessels from 1-4 years. Their shift rotation was 4 weeks on board and 4 weeks off. On board each ship the four officers were divided in two shifts that for 24 hours had 7 hours work, 5 hours rest, 5 hours work and 7 hours rest. The current study is part of a research project that has been notified with NSD – Norwegian Centre for Research Data, to make sure any personal data collected is managed in compliance with Norwegian legislation. The study was approved by the shipping company and all officers signed participant consent forms.

Data Collection

The fieldwork was performed by the first author and lasted for a three and a four-day period while each vessel was operating on the Norwegian continental shelf. As the time spent in the field was relatively short, it was not possible to perform ethnography in the traditional sense. Hence, selected aspects in this context were studied, also known as Micro-Ethnography (Bryman, 2016) focusing on the officer's work processes and interaction with the equipment on the bridge. Observation on the bridge was performed around 12 hours a day (with short breaks) and included semi-structured interviews while the officers were working, taking care not to disturb operations. The questions asked were general, open questions regarding the officer's thoughts about the Unified Bridge in general, positive and negative aspects of integrating bridge equipment and how this bridge environment was perceived compared to other bridge environments they had worked with. In addition, more specific questions about the available equipment were asked, e.g. what they thought about the thruster levers, the chair, placement of screens, alarm management and so on. The field notes were written in between the observation periods when the observer withdrew to the cabin, as the conversations with the officers was experienced to flow more naturally when the notebook was not visible. Hence, the quotations in this paper are translated from Norwegian to English and as remembered by the observer. Pictures that were taken during observations and conversations with crew turned out to be a good aid for remembering what had been discussed when writing field notes.

Methodological challenges

The observer in this study was inexperienced both in the maritime sector and as an observer. The observer initially set out to collect data on how seafarers make sense of their environment, particularly how the electronic navigation equipment could support their sensemaking. By being inexperienced in the field the observer may have misunderstood what the information or data meant to the informants or may have missed or misunderstood situations that occurred or the content when the officers discussed with each other. However, the advantage of being an "outsider," is asking what may possibly be perceived as naïve or simple questions, making the informants thoroughly explain equipment functions and work processes, that insiders might take for granted.

In addition to the main focus which was the officer's interaction with the equipment on the bridge, the observer also initiated discussion on topics like professional culture or how the informants experienced being away from their family for long periods of time. As qualitative research is about understanding and interpreting the meaning of informants, discussing additional topics may have been beneficial for the analysis. Still, the findings in this paper is mainly based on what the officers explicitly expressed regarding the bridge equipment.

Although ethnography is context specific, the findings may be transferable and of interest for designers and engineers involved in development of integrated ship bridges or HMI in general for use in the maritime sector.

As described in the findings section, the officers often used the term "getting used to" when they described interaction with equipment. An effect of evaluation at this stage, after the bridge system has been in use for several years, is that it may not reveal problematic issues as the humans have adapted to their work environment. The findings could be strengthened by further work where including a combination of methods, like quantitative measurements or the use of a domain expert or a human factors expert.

FINDINGS AND DISCUSSION

In this section the findings from the field studies are presented and discussed. First the findings from the bridge environment in general is discussed, followed by the findings from the main pieces of equipment that were redesigned as part of the Unified Bridge concept; the consoles, Graphical User Interfaces, levers, chairs and alarm philosophy. The last section describes crew concerns regarding integrated bridge systems. For overview a summary of the main findings is presented in Table 1.

Table 1. A summary of the main findings from this study, presented as design success or design issue.

Item	Design success	Design issues
The overall bridge design	Users found it "user-friendly" and "well arranged".	None
Consoles	Equipment needed for navigation and DP-operations readily available from main working position. Touchscreen with integrated functions found "practical" and "time-saving". Open front of console accommodate view outside.	Small windows obstruct view in fore steering position. Extra laptop needed on aft console during cargo operations. Blue light by lever base obstruct night vision.
Graphical User Interface	Well-functioning.	An overview display of tanks required 180-degree mental rotation. Colour contrast issue, users found black text on a grey background hard to read.
Levers	Satisfied with size, feedback and scale on thruster levers. Satisfied with three-in-one function of DP joystick, as well as placement of buttons on top and at base.	One lever obstructed view to part of radar-screen. Rudder lever has opposite function to thruster-levers, not used due to fear of confusion.
Chair	Easy to get in/out of. Positive that can be moved back/forward.	Did not accommodate comfortable seating for a seven-hour shift. Backrest broke in high sea-sate and had to be fortified.
Alarm philosophy	Satisfied with unified alarm handling for most alarms on one screen.	Not all alarms were integrated and had to be managed from mid console.

The Bridge Environment

The overall impression of the bridge environment in both vessels was tidy, clutter-free and with very few local adaptations. Local adaptations like marking levers or buttons, adding extra computer mice or cover screens with fabric to dim them can often be found on ship bridges. When the HMI is sub-optimally designed, crew often find workarounds and tailor the HMI to be able to get their job done. In this respect the absence of tailoring and adaptations may in itself indicate that the bridge equipment supports the officers work task in an adequate manner.

When discussing the bridge environment in general, the officers described it as being “very well arranged” and “a very user-friendly system”. The underlying reasoning for this opinion was mainly that the equipment was well adapted to their needs. Most of the officers had experience from working with other more conventional bridges and compared the Unified Bridge concept to their previous experience. One of them claimed that “none of us would like to go back to working with a conventional bridge with all the buttons on the consoles”. The same officer continued with reflecting on that what he preferred to work with also had do with what he “was used to”. When he started working with this bridge he found it a bit cumbersome because he was used to finding things elsewhere. Still he claimed when looking back and comparing the different bridges he had worked with, he preferred the Unified Bridge. Another officer also explained that it took some time for him to get used to this bridge system, especially the touch screen. He came from an old boat with more analogue systems and although “some of the buttons there were very small and hard to find in the dark”, he “was used to it”. However, after getting used to the touch screens he now preferred this system because “you have everything you need easily available”. This passage illustrate not only that they appreciate that equipment has been arranged in a manner that accommodate their work, there is also an element of the officers adapting to the work environment. When looking back on working with ship bridges with poor design, it didn’t seem to bother them at the time as they “were used to it”. It has been described as part of the seafarer culture to be able to ‘handle anything’ and adapt to the circumstances at hand (Lützhöft and Nyce 2008). This brought some uncertainty as to whether the expressed positive opinion could be somehow biased due to adaptation. Hence it would strengthen an evaluation to both observe the users immediately when the new technology was introduced in addition to when users have adapted to it. Still, the main finding regarding the overall bridge environment was that the users were positive and content with how their working environment was designed.

The data collection did not reveal any differences between officers due to their experience with this system (whether they had one- vs four-year experience). However, one of the officers had participated in the final stages of the design process where he amongst other things influenced placement of equipment in the consoles. Other officers had also had close contact with engineers from the manufacturer in the first period after the ship was launched where some start-up problems had to be solved. These officers were particularly positive to the bridge system. They had thorough knowledge about the different parts of the technical system and the reasoning behind placement of equipment. Employee participation was also one of the factors identified by Österman, Rose, & Osvalder (2010) as influencing achievement of a good working environment and safety onboard. They found that employee participation could make the crew feel appreciated and heard and positively influence business operations.

Console design

The forward steering position was used when sailing to and from port and offshore facilities as well as between offshore facilities (Figure 2). According to the officers the main task when sailing to/from port with autopilot engaged was looking out of the window to monitor weather and traffic, as well as looking at screens inside to monitor vessel status, the ECDIS- and radar-screens where most frequently used.

Both the fore and aft workstations were open in front and as such not obstructing the view ahead of working position. This solution gave a good view of the deck from the aft steering position where the windows almost covered the entire bulkhead surface. However, in front of the fore bridge the windows were positioned only on upper half of the bulkhead and the officers mentioned that larger windows would have given a better view outside also on the fore bridge. Hence, it is important to include end-user preferences not only in bridge equipment design, but also when designing the vessel itself.

Figure 2. Officer in forward steering position.

As seen in figure 2 the main screens displaying ECDIS and radar were placed in front of the main working position, accommodating the frequent use of these. Other displays e.g. conning display were placed in the overhead and the officers did not express any strong opinion of the positioning of these.

The touch screen placed in the mid console was especially appreciated by the informants (Figure 3). This screen was an integrated product where the navigator could choose what information to go on which screen, they could remotely control equipment like lantern, searchlight, window vipers and dimming of all screens. This screen was described as «very practical» and «timesaving» as they didn’t have to spend time «to run around looking for switches». This solution seemed to accommodate what the officers found practical and necessary for performing their main tasks. Activities like “running around looking for switches” were perceived unnecessary and taking up attention from more important tasks.

Being able to dim computer screens are important for the seafarer’s night vision. The authors have experienced bridges where all screens had to be dimmed individually or screens not having dimming functions at all where the crew covered them with fabric not to obstruct night vision. In both PSVs the only home-made dimming functions that were observed were on the phone display as well as the blue light by some of the lever bases. The red light by the lever bases was not covered, indicating that choice of colour is important for how much it affects night vision.

The stern steering position was used for Dynamic Positioning (DP) operations when the vessel was positioned alongside the offshore facilities (Figure 3). During DP operations one of the officers was responsible for monitoring the DP system while the other oversaw loading and offloading operations, including communication with people on deck and on the offshore installation. Both officers followed the activity on deck, the loading and offloading of cargo as well as communication with the different stakeholders. The DP system control could be switched between the two positions, a function they at times used when one of the officers had to leave his chair.

Figure 3. Officer in stern steering position. A thruster-lever and the DP joystick can be seen in front of the screen ahead. The touch-panel with integrated functions is facing toward the officer on his right-hand side.

The officers described the DP system in these vessels “the DP system is very good in this vessel” or “this DP system is a lot better than other DP systems I have used”. The statements were substantiated by that the displays had shortcuts and there was no need for searching for what they needed in lengthy menus. Another feature that was emphasized was that all information going into the DP checklist could be found on one page, there was no need for looking up information in different locations. This was another example of a very concrete accommodation of user needs that they found very practical. The DP checklist must be completed before entering the 500-meter zone around the installations and are often performed several times a day.

One adaptation was observed on the aft console. The officers in charge of cargo operations added a laptop on the console to use an internet software solution for cargo logistics. The console did not accommodate equipment like this, hence the laptop interfered with the touch screen and the power line was obstructing free passage from the console. There is a continuous development in technology and applications used on the bridge, although challenging, the bridge should be designed in a way to accommodate future changes.

In general, the officers expressed they had everything they needed within reach both in fore and stern steering positions. They very rarely had to move from their working position to perform tasks related to navigation. Some of them even mentioned they felt they were sitting too much during their work hours, especially during DP operations that can last for several hours. Still, the observer's impression was that although sitting their arousal was not so low that it weakened performance according to the Yerkes-Dodson law (1908). During DP operations the officers was continuously engaged in monitoring and coordinating and communicating with the different stakeholders involved in cargo operations.

Graphical user interfaces

The graphical user interfaces (GUI) were not discussed in detail with the officers. They found the GUI in general to be working well. However, they pointed at a couple of points that could be improved in future versions. One was a display that gave an overview of pumps and tanks and their placement in the boat. The overview was displayed in a manner that required 180-degree mental rotation to comprehend the placement in the vessel. As this information was important for proper ballasting of the vessel, one officer expressed concern that errors could be made due to the mismatch between display and vessel directions. One other concern regarding displays came up, and it had to do with colour contrast, where they found black text on a grey background hard to read.

Levers

The officers were positive regarding the thruster levers (Figure 4), they especially emphasized that they were big enough to give good grip and that they gave clear feedback concerning position. The scale on the levers was also well received however, one of the officers explained that he never looked at the scale as «you get a feeling for how much to give when you get to know the boat». Human-centred designed equipment should be generally usable to all types of seafarers. A less experienced navigator may appreciate the possibility of having a scale, although with experience a ship-sense (Prison, 2013) is developed resulting in a more intuitive feeling of how to operate the equipment.

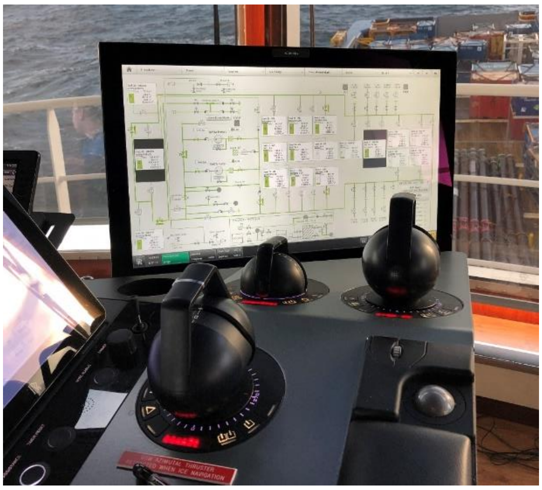

Figure 4. The thruster levers position in the console.

One officer mentioned that the lever placed on the angled front end of the consoles could obstruct the view of information on the lower part of the screens in front of the consoles.

The rudder lever had a different shape than the thruster levers and was also readily available from the steering position. The rudder lever was not used. As opposed to the thruster levers, when turning the rudder lever to starboard the vessel moves to starboard. One of the officers pointed out that he did not want to use it since the function was opposite of the thruster levers and he was afraid that it might lead to making a mistake.

The DP joystick was also described as "very good" and "user-friendly". One officers even described it as "genius" that the joystick had a three-in-one function as opposed to other DP systems he had previous experience from. Other features of the PD joystick they appreciated were the buttons both on top of the joystick and at the base, they functioned very well. They also emphasized the possibility of resting the hand at the base without accidentally pushing the buttons there, as some of them had previous experience on unwanted incidents due to resting the hand on base buttons.

Chair

The operators chair (seen in Figure 2) was the single piece of equipment the officers were most critical towards. It was easy to get in and out of the chair and the possibility to move the chair forward and backwards were often used. However, they basically found it uncomfortable to sit in. Some of the officers described it as too hard while others as too soft, especially the support under the knees. Some found the seat being too short to support the knee. One officer described the chair as being ok in the beginning of the shift but impossible to sit in for seven hours. Another officer mentioned he did not like the headrest as it didn't support the head properly. There were deviating opinions regarding having the armrests attached to the consoles and not the chair. Some thought that these armrests did not give good enough grip in high sea states when you need something to hold on to. Others thought the armrests were functioning well. On both vessels the backrest had to be fortified as they broke during high sea state, an event that influenced how the officers perceived the overall quality of the chair.

Alarm philosophy

The unified alert handling, meaning that alarms could be silenced from one location was another system feature the officers described in positive terms. The alarms were presented on one screen that gave «good overview», "it is easy to detect where the alarms are coming from». As one of the officers explained: "on other vessels you might have to go to the console, read a code and then look up in a manual to figure out what the code means». Handling and prioritizing alarms may in a direct way impact safety. There are examples where crew has disabled audible alarms that could have alerted the crew and maybe prevented an accident (MAIB, 2017). However, not all equipment was possible to integrate in the Unified Bridge system, e.g. the Inmarsat alarm had to be silenced on the console placed in the centre of the bridge.

Integrated Bridge systems and vessel autonomy

Although the integrated bridge system was mainly described in positive terms by the crew, supporting their work tasks in appropriately, integration may affect their job in other ways. The crew were concerned about a development towards vendors controlling more from shore. E.g. troubleshooting or maintenance that previously was done on board now have to be performed remotely by experts on shore. One example was if they saw the need for an additional bridge light, a simple piece of equipment, the onboard electrician could not install it (and immediately solve a problem). It would need reprogramming into the integrated system, this takes time and money, often resulting in that it is not done. Seafarers have previously been found to be sceptical towards organizations on shore (with staff without sailing experience) making decisions concerning the vessels (Antonsen, 2009). The digitalisation of maritime sector will possibly lead to more tasks and responsibilities being performed by the onshore organizations. It might be wise to make an assessment in collaboration with seafarers of how future tasks and responsibilities should be shared between onshore organization and the crew onboard in order to find an arrangement that can work for both parties.

CONCLUSION AND FUTURE WORK

This paper reported the findings from two field trips on board platform supply vessels with the Rolls-Royce Unified Bridge installed. Ethnographic inspired fieldwork was conducted to find the opinions regarding this bridge system from the seafarer's perspective. Overall the officers were very positive, describing the bridge system as being "very well arranged" and "a very user-friendly system". The human-centred design process behind the development of this bridge system seem to have been able to accommodate many of the end-user needs. The design makes sense to the seafarers when it is in line with their work practices. The officers pointed at some points for improvement that is valuable input for future development of the system. They also expressed some concerns regarding the crew's autonomy as integrated bridges may increase supervision and control from shore.

The Unified Bridge has now been in the market for five years and has continuously been improved based on the feedback from the two vessels visited in this study. The results from this particular study is important to the product organisation for two reasons. First, to provide insight to further improve the concept and address the flaws pointed out. Second, to underline the importance of continuing to invest in science-based product development and product improvement, and to confirm that the concept development process incorporating human factors and a user centric process has been a success.

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