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Somebody Else's Problem? Usability in Ship Bridge Design Seen from the Perspective of Different Maritime Actors

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ABSTRACT: Navigation is a complex interaction between human, organizational, environmental, and technological factors on the ship's bridge. Today, ships bridges include a broad suite of equipment with both digital and analogue interfaces, covering a range of functions and purposes. Suboptimal usability in equipment and interface design as well as layout of the ships bridge has been reported by researchers for decades. This paper aims to contribute to our understanding of why there has been limited progression in usability in ship bridge design over the last decades, by investigating the stakeholders' different perspectives of their influence, interest and responsibility for usability in ship bridge design. The study is based on interviews with seafarers, shipowners, equipment manufacturers, shipyard, insurance companies, classification societies and a flag state. Usability in navigational equipment and systems on a ship's bridge is required by the International Maritime Organization (IMO) SOLAS Regulation V/15. We find that this goal-based requirement is challenging to follow up both in design, development, and survey work. To achieve usability in maritime equipment and bridge systems ideally requires the actively involvement of end-users throughout the design and development process. We find that the seafarers, the direct end-users, do not have a clear voice in the ship bridge and bridge equipment design and the associated purchasing processes. The other stakeholders appear to recognize the existing shortcomings, and some do show interest in improvements, but the responsibility for usability seem to be fragmented, and they see the potential solutions as being somebody else's problem. We conclude by suggesting both long-term and a short-term way forward for improving usability in ship bridge design.

1 INTRODUCTION

According to the International Maritime Organization "Shipping is perhaps the most international of all the world's great industries - and one of the most dangerous" [1]. The high-risk nature of the shipping industry is confirmed by the European Maritime Safety Agency (EMSA) that registered 6921 persons being injured and 550 persons losing their lives at sea in the period 2014-2020 [2]. 43% of all casualty events in this time period was what EMSA categorise as navigational casualties which includes collisions, contacts and grounding/strandings [2].

Navigation is a complex interaction between human, organizational, environmental, and technological factors on the ship's bridge [3-5]. The ship's bridge can thus be characterised as a sociotechnical system [6, 7] where the design of technology interact with, and thus influence, other parts of the system [8, 9]. Since the general introduction of computerized equipment in the 1970s, there has been a steady increase in electronic and digital products for maritime use, and today, ships bridges include a broad suite of equipment with both digital and analogue interfaces, covering a range of functions and purposes. There is rarely any consistent user interface design across these systems [10] and suboptimal usability in equipment and interface design has been reported by researchers for decades [11-16].

There may be several factors contributing to the current situation on the ship's bridge. One factor is the challenge of designers and developers of technical systems to foresee how factors like time and resource constraints, management pressure or motivation will influence real use at a different time and in a different place [17]. As a result, it is often seen that the human component of sociotechnical systems do not behave as designers expect, or plan for [18]. Technology being designed without appropriate information about the user or context of use is a concern as, for instance, a systems designed-in safety features may not function as expected. For example, when of the bulk carrier Muros grounded in 2016 the accident investigation identified the use of some of the safety features in the Electronic Chart Display and Information System (ECDIS) as a contributing factor to the accident. The investigation report states that "The ECDIS on board Muros had not been used as expected by the regulators or equipment manufacturers." [19]. It thus seems there were limitations in the regulators and equipment manufacturers knowledge about the end-users and the context of use; knowledge that is however crucial when designing for usability [20].

The importance of considering human factors has been recognised by the International Maritime Organization (IMO) through its human element vision [21]. IMO has also addressed ship bridge design through the SOLAS (Safety of Life at Sea) convention regulation V/15. Regulation 15 requires that ship bridge equipment and procedures inter alia shall aim to "facilitating the tasks to be performed (...) making full appraisal of the situation and in navigating the ship safely under all operational conditions", "promoting effective and safe bridge resource management", "enabling (...) convenient and continuous access to essential information which is presented in a clear and unambiguous manner", "preventing or minimizing excessive or unnecessary work, "minimizing the risk of human error".

The IMO instrument also outlines specific requirements for the equipment that ships shall have installed through SOLAS regulation V/19. For all the equipment in V/19, there are also IMO Performance Standards, providing descriptions of high-level functionality required in a particular instrument, and much more detailed IEC Test Standards, where the individual test clauses must be fulfilled to obtain the required type-approval.

Despite the maritime stakeholders' commitment to regulatory compliance, suboptimal usability – which we claim is an indicator of a design which to some degree is unfit for the purpose it is intended for, and thus can be termed 'poor design', seems to be a persistent challenge in the maritime industry. In Reason [22], poor design is the terminology used to describe a latent condition that can be present for many years in a system before it combines with local circumstances and active failures that may result in a maritime accident [23-27]. In practice, the impact of poor design is often mitigated by the ability of users to find creative ways to make systems work [11, 18]. Seafarers are no exception, and they make the bridge system work through both adapting to design and making adaptations of design [3, 28]. Adaptations to design is occurring when seafarers adapt their work strategy to cooperate with the technology. This has also been described as integration work [3]. Adaptations of design can be very visible in the form of self-made covers for dimming screens, covering non-functioning buttons, pallets to stand on, lengthening of levers, written notes etc. [28]. Although seafarers apply strategies to handle their work environment, poor design have the potential to lead to design induced errors [29].

To mitigate, considerable design and development efforts aiming to improve usability in ship bridge design have been performed [10, 30-34], also attempting to increase the understanding of the fundamental issues underlying the present situation The persistence of suboptimal usability has been connected to the multiple stakeholders being involved in the ship building and ship bridge design processes [35]. There may be differences in the level of knowledge of human factors and human-centred design posited by different stakeholders [36]. The stakeholders may represent different interests that are difficult to align during the design process [37] and communication and cooperation between the stakeholders may be challenging [38, 39].

Yet another factor is the competitiveness of the maritime industry, in which many organizations work on very small profit margins and thus prioritize short-term economic gains [7, 16]. As new ship development is driven by economics, human-factor interventions need to be justified in terms of their likely benefits exceeding their anticipated cost [7, 40]. However, there is a lack of knowledge about, and especially methods for, measuring the financial effects of ergonomics which could enable maritime companies to make well-informed ergonomic prioritizations [41] – in other words, developing a convincing business-case based purely on objective data is difficult.

This paper aims to contribute to our understanding of why there has been limited progression in usability in ship bridge design by investigating the issue from the perspectives of a broad set of stakeholders in the maritime industry. The study is based on interviews with seafarers, shipowners, equipment manufacturers, shipyard, insurance companies, classification societies and a flag state. We seek to find factors influencing the low prioritisation of usability in the maritime industry by investigating the stakeholders' different perspectives of their influence, interest and responsibility for usability in ship bridge design. We also suggest a way forward.

The paper is structured as follows: The next section will provide the theoretical background as well as information concerning the ship operation and purchasing process and the maritime design regulations. Section 3 explains the methodological approach, followed by the presentation of the findings in Section 4. The findings are discussed in Section 5, and Section 6 concludes the study.

2 BACKGROUND

2.1 *Key concepts*

Design has been defined in multiple ways. For example, Herbert Simon viewed design as a problem-solving activity that concerns devising "courses of action aimed at changing existing situations into preferred ones" (Simon, 1969, p. 55). Design and development of products and systems in the maritime (or any other) industry must adhere to regulations and stakeholder- or customer requests which constrain or define what the 'preferred situation' may be. Design processes are also limited by factors like time and cost. Thus a more specific definition of design is used: "a specification of an object, manifested by some agent, intended to accomplish goals, in a particular environment, using a set of primitive components, satisfying a set of requirements, subject to some constraints" [42]. In this paper ship bridge design refers to the design of the physical bridge including the equipment, systems and layout of consoles.

The human factors discipline is concerned with achieving two related outcomes of sociotechnical systems: human well-being and overall system performance [43]. It requires a conscious approach of applying human factors theory, principles, data, and methods to the design process to achieve these two outcomes [44]. An essential characteristic of a well-designed system or product is its usability. The ISO standard 9241:210 defines usability as "the extent to which a system, product or service can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use" [20]. To achieve a goal with effectiveness refers to the accuracy and completeness with which users achieve the specified goals while efficiency refers to the resources used, which may be time, human effort, costs, materials, in relation to the results achieved. In this paper, the user is the people who operate the system and make use of the output of the system.

One approach to achieve usability – i.e., what we have chosen to define as 'good design' versus 'poor design', as discussed above - is the Human-centred design (HCD) process. The HCD process as outlined in the ISO standard 9241:210 "aims to make systems usable and useful by focusing on the users, their needs and requirements, and applying human factors/ergonomics, and usability knowledge and techniques" [20].The ISO standard outlines a framework for an iterative design process where the major activities are

- Understanding and specifying the context of use
- Specifying the user requirements
- Producing design solutions
- Evaluating the design

A key success-factor in human-centred design is the actively involvement of users throughout the design and development process [20, 45], recognizing that it is only the users that can provide a profound understanding of their needs and the context of use in which the design object is to function. The users can be involved in all the activities outlined in the HCD process, they are an important source for relevant data obtained through methods like for example observation, interviews, task analysis, the users can participate in design activities, or they can evaluate and test prototypes and design solutions.

In general, the benefits of usable systems are increased productivity, reduced errors, reduced training and support, improved user acceptance and enhanced reputation [20, 46]. Research in the maritime industry has found that usable systems benefit seafarers in terms of improved physical, psychological, and social well-being, higher motivation and job satisfaction, as well as improved performance [13, 43, 46, 47]. Cost-benefit trade-offs are in general a key consideration for adopting HCD methods [45]. Hence, it is important to note that usability may also benefit the shipowners through a safety gain arguably achieved through good design, as well as improved operational performance in terms of productivity, efficiency, quality, a better reputation for hiring and retaining personnel, reduced training and operating costs [46, 47].

2.2 *Maritime stakeholders*

Stakeholders may be individuals, groups or organizations "who have an interest (stake) and the potential to influence the actions and aims of an organization, project or policy direction" [48]. The stakeholders are thus identified in relation to a specific issue or project. The relation to the issue can also be described as "those who are affected by or who can affect a particular decision or actions" [49]. The purpose of collecting and analysing data about stakeholders is to develop an understanding of how decisions are taken in a particular context and to possibly identify opportunities for influencing the decision-making processes [48]. Maguire [46] recommends identifying a broad set of stakeholders as part of the HCD process, including recipients of output from the system, marketing staff, and purchasers, and to this end, Dul [43] identified four main stakeholder groups of system design:

- System actors: i.e., employees, product users, who are part of the system and who are directly or indirectly affected by its design and who, directly or indirectly, affect its performance.
- System experts: i.e., professionals such as engineers who contribute to the design of the system based on their specific professional backgrounds.
- System decision makers: i.e., decision makers (e.g., managers) about the (requirements for) the system design, the purchasing of the system, its implementation and use.
- System influencers: i.e., media, governments, standardisation organisations, regulators.

Seeing this in the maritime context, this industry comprise numerous actors that are either directly involved in the transport of goods or people, or in supporting areas of activities, inter alia: ship operators, shipowners, the crews, shipbuilders, design firms, equipment suppliers, brokers, agents, repairers, the IMO, flag states, coastal states, classification societies, insurance companies, , education/training providers, financiers, cargo owners as well as port/terminals [50].

2.3 *Maritime design considerations*

In the ship design process, different stakeholders can represent vastly different interests and their expectations towards the design solution may for such reasons not be aligned. Indeed, a lack of relevant information, ineffective collaboration, conflicts and trade-offs may result in an excessive addition of features to satisfy the expectations of all stakeholders as the design process unfolds [37] but such additional capabilities may not cause a premium on the charter rate that can justify the added cost and thus negatively affect business outcome [37]. Of particular interest to maritime design is the issue of system design where authority is distributed within and among several organisations with design decisions spread over time, has been described as "sequential attention to goals" [51]. The sequential attention leads to decisions to be taken without being aware of how they influence other decisions. Gernez [52] differentiate between two stakeholder groups involved in ship design: designers (ship designer, sub-contractors, shipyard) and the end-users (ship owner, ship manager, operator, and crew). The difficulties of sharing information between the technical expertise of the designers and the operational experience of the end-users, is a factor that may contribute to suboptimal or unsafe ship design solutions [52]. Part of this picture is that designers and developers tend to assume that their experiences are similar to the users' experiences so they can see themselves as fair representatives of the users they design for [53]. Both the interest in, and the power to influence human factors in the maritime industry is greatly differentiated between stakeholders [54], and to illustrate this issue, the human factors community have stronger relationships with system actors than with systems experts and decision makers, i.e., the stakeholders that have the power to influence system design [43]. Also, the competitive nature of the industry entails the relation between usability and profitability is perceived as a trade-off rather than synergy [55].

2.4 *Ship operation and purchasing process*

The shipping industry is international and "a ship can be owned in one country, operated from another country, and registered by a third country, and crew can hail from any country" [50]. The industry consists of different business sectors depending on the type of cargo being carried (bulk, tank, container or specialized cargo, to mention a few), whether it is providing services like port tugs and bunker ships, services running on fixed schedules like container lines, passenger and cruise ships, or whether it is organized as tramp. The different sectors may have differently organized economic models or organizational structures to compete for business. What the sectors do have in common is the highly competitive terms of its business [56]. An essential activity in shipping is thus to match the capacity to carry cargo or perform given services with the needs of customers, shippers or charterers. "This includes not only providing the right service at the right price, but also the buying, building, chartering-in and chartering-out of ships in anticipation of international, but also local and regional, market conditions."[56].

The shipping companies has access to a global labour force as the IMO International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW) ensures basic requirements on an international level, and the STCW certificates of competence are internationally accepted. Crewing management can thus be outsourced, and shipowners have the possibility to optimize cost structures through replacing the crew, or parts of the crew, with workers from a different nationality. The recruitment period for seafarers may be limited to a single voyage or a contract for up to a year. Seafarers employed through a crewing agency mainly interact with the crewing agency despite that their contract of employment may be with the shipowner. (Walters & Bailey, 2013).

Shipowners can decide to expand their fleet by investing in second-hand ships or new ships, as well as through the use of outsourcing and chartering, which occurs frequently and makes a distinction between ownership and the operation of a ship [56]. Investing in a new ship can be done through buying a standard ship type developed and 'mass' produced by a yard. In this case the shipowner has little or no influence on choice of equipment on board. An alternative approach is to initialize a ship design process based on the shipowner specific needs in terms of market, cargo type, expected area of operation, and possible equipment preferences and hull or machinery constructional feature preferences. Shipowners may approach shipyards with a preliminary specification and general arrangement plan prepared by a ship design bureau, or shipyards may have their own in-house naval architect departments that can provide both design and, subsequently to an agreement between the parties, the production specifications and drawings of a ship, usually also including the 'maker's list'. In some detail, the maker's list is a list of suppliers negotiated and approved for delivery of equipment, machinery or services to a particular (series of) ship to be built, which forms an important part of the contract between the shipowner and the shipyard, considering that it sets a certain agreed standard and limits the potential purchasing choices for the shipyard. The main participants contributing to the ship design process are the shipowner, the shipyard, and the ship designer [57]. The suppliers of materials and equipment are selected through negotiations and the number of suppliers for a single ship may add up to 350 [57].

2.5 *Maritime design regulations*

The global nature of the shipping industry has led to regulations mainly being developed internationally through the International Maritime Organization (IMO). The international Convention for the Safety of Life at Sea (SOLAS) was incorporated by IMO when it was founded in 1958, and this convention continues to be the most important international maritime safety mechanism [58]. The SOLAS convention governs safety through 14 chapters that specify minimum standards for the construction, equipment and safe and secure operation of ships [59]. Chapter V, Safety of Navigation, identifies a number of navigation safety services which should be provided by Contracting Governments and include subjects like maintenance of meteorological services for ships, the ice patrol service, search and rescue services and routeing of ships.

However, SOLAS Chapter V also relates to equipment onboard ships conforming with the convention, which counts almost all ships in the global trading fleet. As such, SOLAS Chapter V Regulation 15 (V/15) sets forth "Principles relating to bridge design, design and arrangement of navigational systems and equipment and bridge procedures" [60]. Important in the present context, these seven principles require a series of usability considerations to be considered in bridge design, bridge equipment and procedures. Regulation V/15 is a goal-based regulation (also referred to as function-based regulations) that sets forth objectives which the designed product or system shall achieve, however without offering a detailed description of how to achieve them. Detailed guidelines for physical ergonomic criteria for bridge equipment and layout is made available in the IMO MSC/Circular 982 [61].

The principles in Regulation V/15 are applicable for decisions made for the purpose of applying the requirements of several other regulations in Chapter V, including Regulation V/19 "Carriage requirements for shipborne navigational systems and equipment". Regulation V/19 outlines specific requirements for the equipment that ships shall have installed, for example compass, charts, ECDIS, radar, automatic identification system (AIS), echo sounder, speed measuring devices, track and heading control. For each of such instruments, and underlying /supporting Chapter V/19, IMO has issued Performance Standards for the devices in question. One-by-one, the Performance Standards outline, usually in rather high-level language, the functionalities, and qualities of the particular instruments, and thus serves the purpose of ensuring that seafarers are provided with the equipment and tools deemed needed to perform a particular task, independently of the manufacturer of the devices. However, due to the brevity and nature of the IMO Performance Standards, they are less usable as test standards to prove conformance, and for this purpose, the International Electrotechnical Committee (IEC) develops highly detailed test standards matching the IMO performance standards. In other words, the practice is so that manufacturers relate to the IEC Test Standards when they develop their instruments, and the IEC Test Standards in turn form the base for the issuing of Type Approval certificates of navigational instruments. This goes for any kind of requirements, i.e., also including requirements to ergonomics of equipment, where the combined requirements contained in the appropriate IEC Test Standard and the over-arching ergonomics requirements contained in IEC 60945 [62] and IEC 62288 [63] are to be fulfilled in entirety.

Ships flying the flag of a European Union (EU) country, or one of the European Free Trade Association (EFTA) countries, are further constrained to only install marine equipment marked with the EU Marine Equipment Directive (MED) mark of conformity, also known as the "wheel mark". The "wheel mark" is issued by notified bodies that verify the equipment is in compliance with all applicable standards for design and production, including the IEC Test Standards IEC60945 and IEC 62288, all together specifying the minimum performance requirements, methods of testing and required test results of particular devices.

There are several test methods outlined in IEC62288 that can be applied for validating the equipment's compliance: inspection of documented evidence, measurement, observation, and analytical evaluation. Of particular relevance for this paper, it is noted that this standard describes how testing according to the requirements of 'analytical evaluations' are to be performed:

"Analytical evaluations may be made by a relevant expert with the necessary education, skills and/or experience to make an informed and reliable judgement concerning the presentation of information, its appropriateness and usability. It is used for the evaluation of properties which can be judged only in the context of other information or knowledge which requires the tester to make an informed assessment of the likely performance of a typical user of the presentation." [63]. The appointment of "a relevant expert" is at the discretion of the notified body.

The flag state is responsible for national enforcement of the international maritime regulations. The Norwegian legislation directly addressing ship bridge design is found within Regulation 1157 2014-09-05 [64] where SOLAS Chapter V/15 is implemented. The flag state administrations are responsible for surveying and issuing certificates that confirm ships are designed, constructed, maintained, and managed in compliance with the IMO regulations for ships flying their flag, a task which the flag state administrations at their own discretion may delegate either to surveyors nominated for the purpose or to recognized organizations (ROs), to perform the inspections and surveys required to validate conformance.

3 METHODS

The empirical foundation for this paper consists of interviews with seafarers, shipowners, a shipyard, equipment manufacturers, a flag state, classification societies and insurance companies. In total, 42 informants have been interviewed in the period 2018-2021. An overview of the informants is presented in Table 1. The maritime sector consists of a vast array of possible stakeholders in ship bridge design. The stakeholders in this study were selected using a snowball sampling approach, initiated through the interviews with the end-users - the seafarers - and further developed through the subsequent interviews with informants from other stakeholder groups.

All seafarers, except one, worked as captains or deck officers in Norwegian companies at the time of the interviews. One seafarer was a lecturer in nautical studies with previous sailing experience as a captain. Semi-structured interviews were performed during field trips on board three passenger ships and two offshore supply vessels. The onboard visits allowed for observations that complement the interview data. In addition, a focus group interview with six high-speed coastal vessel deck officers was performed at a Norwegian education facility.

Table 1. Overview of informants in the study.

Stakeholder group	Job titles	No. of persons
Seafarers (working on passenger ships, high-speed coastal vessels, offshore supply vessels)	Deck officer/Captain	21
5 Shipowner companies (with fleets consisting of bulk-carriers, oil- and gas-tankers, cruise ships, offshore support vessels	Head of HSEQ & Human Factors/ Electro Automation Engineer/Marine and HSEQ Manager/Vice president newbuilding/ Senior Marine Advisor	5
3 Equipment manufacturer companies	Vice President R&D/Senior Designer/ Principal engineer HF and maritime HMI/ Service engineer and Project Manager/Salesperson	5
2 Classification societies	Head of Section/HF Consultant	4
1 Flag state (The Norwegian Maritime Administration)	Senior engineer/Senior Advisor	3
2 Marine insurance companies	Senior Loss Prevention Executive/ Loss Prevention Director/Vice President	3
1 Shipyard	Naval Architect	1
Total number of informants		42

Table 2. The findings from each stakeholder group in this study.

Stakeholder group	Influence & Interest
Seafarers	Design issues Takes responsibility for handling suboptimal usability through adaptations No/low design influence, high interest
Shipowners	Low interest, perceived influence varies from low to high Responsibility for usability sits somewhere else Profitability prioritised
Equipment manufacturers	High interest in involving end-users through HF methods Influence through design and development, however HCD processes are challenging (cost (profitability), regulations, customer requirements, barriers to including end-users)
Shipyard	Have influence but low interest (due to lack of awareness about HF and usability) Prioritize completing project within time/budget/contract specs (profitability)
Classification societies	SOLAS V/15 a «dormant» requirement HF not part of standard packet class Market competition forces minimum notations (profitability) High interest but influence through voluntary notations (chosen by shipowner)
Flag state	Interest and influence on conventional ship building is medium SOLAS V/15 not followed up through supervisory work No national requirements beyond international due to risk of ships flagging out (economic considerations) Industry have responsibility for challenging regulations
Insurance	Not responsible, low interest, low influence Work on behalf of shipowner Indirect influence through awareness campaigns (towards seafarers)

The interview with the other stakeholder groups took place in the informant's workplace or remotely using a web conferencing tool. The shipowner informants had different roles in company management, they were all decision-makers concerning ship bridge design and equipment. They were employed in shipowner companies with international operations, four which have their main office in Norway and one in UK. The shipyard informant was a naval architect that had worked for several years in a shipyard in Asia. The equipment manufacturer informants worked as designers or engineers in Norwegian companies or in a Norwegian department of an international company. The Flag state informants worked in relevant departments in the Norwegian Maritime Authority. The informants from the classification societies worked at either the company head office in Norway or in the head office in UK. The insurance companies operate internationally, and the informants worked either in the company head office in UK or in Norway.

All interviews were semi-structured [65], lasted for about one hour and were conducted by one or two researchers. In the interviews, we asked the informants about their role, their interest in and influence on ship bridge design and usability, and how they perceived other maritime actors' role, equipment preferences and priorities, and design related to performance and safety. The interviews consisted of open questions focusing on the informants' experiences and opinions and allowed the informants to talk freely about different aspects of the topics we introduced.

The data material consisted of field notes and audio-recorded interviews that were transcribed verbatim. The transcriptions are the source of the quotes in Section 4.

3.1 *Analysis*

Thematic analysis (Braun and Clark 2008) was initially used to analyse the data in this study. This method allows for identification of themes across the data in a systematic manner. The data material for each stakeholder group was first analysed separately. Initially the data from the three stakeholder groups seafarers, equipment manufacturers and shipowners were subjected to open coding, which broke down the material to smaller sections before comparing, refining, and clustering codes into themes. This work was published in[28, 55]. The topic of stakeholders' influence and interest in ship bridge design was then further developed through performing additional interviews with a shipyard, a flag state, classification societies and insurance companies. The additional data allowed for a re-analysis and comparison of findings across the seven stakeholder groups. The findings concerning interest and influence on ship bridge design for each stakeholder group are shown in Table 2.

The approach of generating knowledge about stakeholders' behaviour, inter-relations, interest and influence on a particular process or decision-making is known from the stakeholder analysis literature [48, 66]. This knowledge can be used to develop strategies for managing stakeholders of projects or organisation in order to facilitate the implementation of specific decisions or organisational objectives [48], however, in the present case, the knowledge generated focused on the informants perceived influence and interest in ship bridge design, with the ultimate aim of shredding light on existing factors that may hamper progress in this direction. Moreover, the resulting insights were used to suggest possible ways forward.

3.2 *Scientific quality*

Several measures have been applied to ensure the trustworthiness [67, 68] of the current study. The initial coding was performed by the first author. In addition to the authors of the current paper, five researchers with extensive experience from research within the maritime sector, human factors and safety, have been involved in both the data collection, analysis, and writing during the course of the research, which strengthens the credibility of the study. When performing interviews, one cannot be sure whether the informants are providing an accurate account of their experiences and thoughts or if their accounts are adjusted to what they think the researcher is interested in, or what others, like company management, would like to hear. However, the topics raised in this study were not of a personal or sensitive nature. The informants seemed to find the topic interesting and willingly shared their experiences and opinions. In addition, serving as a kind of triangulation, information obtained from previous interviews and observations was continuously discussed during subsequent interviews.

There are some factors relevant for the transferability to other contexts of the study. First, the data sample does not include all sectors within the maritime industry. The authors acknowledge that there is an extensive network of actors and stakeholders in the maritime industry in addition to the stakeholder groups included in this study. There is also a limited number of informants from each stakeholder group. However, the richness of the data collected has allowed for an analysis that identified patterns across the stakeholder groups concerning their perceived interest, influence and responsibility for usability in ship bridge equipment design. Second, the majority of informants in the study are Norwegian and the findings may first and foremost reflect a situation specific for the Norwegian and/or European maritime sector. Considering the international nature of the maritime industry where the stakeholders operate, compete, and are regulated internationally, the conclusions drawn may still have broad relevance. The results provide descriptions from which readers can make judgements relating to the transferability of results to other, specific contexts. Further research is needed to establish the relevance of the findings for specific maritime sectors, geographic areas, or the maritime industry in general.

4 RESULTS

In this section the findings from the interviews with the stakeholder groups seafarers, shipowners, shipyard, equipment manufacturer, flag state, classification societies and insurance companies are presented.

4.1 *Seafarers*

The navigators are the stakeholder that has the most obvious interest in ship bridge design. Navigating a ship requires management and interaction with many pieces of equipment. The function and design of individual equipment as well as how the equipment is physically organized to constitute the overall work environment have direct impact on seafarers' work tasks and work performance. In our fieldwork and interviews with seafarers we found many examples of suboptimal usability in ship bridge design and equipment. The frequent existence of suboptimal usability was also confirmed by the other stakeholder groups.

One example of equipment not fit for the context-of-use is the lack of possibility to dim screens during night-time, an issue that frequently came up during the interviews and field trips:

"That screen, you have it in front of you all the time, it cannot be dimmed properly so you lose your night vision while you are steering the ship. We used to cover it with a patch. In return we could not see the alarms from the propulsion system, we heard the alarm and had to lift the patch. When you are in a narrow fairway and a pilot is shouting at you, it starts beeping and you have to lift the patch and in addition lose your night vision"

The seafarers expressed frustration over systems and equipment that do not accommodate their tasks and the context. Still, they manage to do their job through creative ways of adapting to less successful designs, as also described in [28].

All in all, the seafarers describe they have little or no influence on ship bridge design. The seafarer's involvement in ship bridge design in a newbuilding is usually restricted to a captain being part of a site team or being allowed to give his opinion during the final assembly e.g., regarding placement of certain items in the consoles. The seafarers would like to have more influence, however finding ways to give feedback can be challenging. In our study we did not find any systematic feedback system in place and the seafarers may find it difficult to be heard, as this quote exemplifies:

"I have tried but got the message: 'thanks for the input but we have already paid for this solution'. Then designers, engineers and sales have related to classification, regulations, and authorities, then they deliver the order to

the yard, and on top is the owner that has paid for the solution already. When you as the end-user express what you would like to have the message is 'Sorry, you are half a year to late"

This quote also sums up who the seafarers think have influence on ship bridge design, designers, engineers, sales, class, regulations, authorities, shipyard and shipowner. Several seafarers pointed to the fact that many actors and competitors are involved, as contributing to the lack of usability.

4.2 *Shipowners*

Shipowners can be organized in different ways, it can be a company, a person or an investment fund owning ships. Shipowner companies can range from small family-run companies owning one or a few ships to multinational companies owning hundreds of ships. The different functions like ship management, technical management, purchasing, insurance and human resources may be departments within the company, or it may be outsourced to a third-party company.

The shipowners in our study span from describing their interest and influence in ship bridge design from being high to low. In the high end of this scale, the offshore support vessel company expressed an explicit interest in ship bridge design, not only to ensure safety and production but as part of ensuring crew well-being. During the ship building processes they described following up both on the equipment manufacturers and the yards closely to make sure the bridge design had the intended standard. Their own judgement was that they spent more resources than most shipowner companies on ship bridge design, but that it paid off in the form of good working conditions for the crew:

"I think we gain on that. We have spent resources on this, but throughout the ship's lifetime the everyday life of people on board is much better, that way it is worth it."

The other four companies in our study, ranged both their interest and perceived influence on usability in ship bridge design to be medium to low. They all emphasize that building a ship is a considerable investment, and shipowner management is focusing on big picture issues of a ship's construction and specifications, such as cargo carrying capacity, the number of passengers, speed, efficiency, i.e., the factors that are important for a profitable investment. For these owners it is important to keep the costs to a minimum and usability on the ships bridge is not worth an additional investment. The large bulk and oil tanker companies described buying ships more or less off-the-shelf. They also prefer buying several ships in a series with standard design as they find this decreasing investment cost and crew training cost.

One of the informants from these companies did think that they have some influence on bridge equipment through what they choose to buy and how much they are willing to invest:

"We do have some power, we build maybe 10 boats per year, and we are buying them, so we have the possibility to make requirements and invest more money if we want to. If we get in early, we can request to redesign the whole bridge without additional costs. So, the owners have a lot of power in this, we can drive things forward, but in almost all shipowner companies they now use equipment made in Asia"

Although this shipowner found they have some influence, the shipowner informants pointed to the regulators, shipyards and equipment manufacturers as the stakeholders with the main influence on ship bridge design. The informants expressed that safety of navigation is ensured by complying to regulations:

"…as long as you follow the rules and requirements you are safe"

The belief that safety is ensured by regulations may have influenced their interest in safety and ship bridge design. This was currently not a topic of specific interest for these shipowners:

"Of course, safety is always an important thing, but that is not where you feel it is urgent right now, after all, we do have relatively safe equipment already"

It was also emphasized that if there is a need to change anything it should be done through regulations as both equipment manufacturers and shipowners are forced to prioritize compliance:

"I think the easiest way to make changes is through regulations, because they will be followed by both the equipment manufacturers and shipowners"

When the shipowner signs a contract for the whole ship, the shipyard has the design responsibility. The shipyard chooses equipment suppliers depending on their negotiations and agreements with suppliers and if the shipowner would like a different supplier it will come with an additional cost, as explained by one informant:

"We had in the contract what they call a makers list, so you had to have at least three possible suppliers for the bridge equipment that the ship yard could choose and then we would get the specifications for the supply and either approve it, but if you wanted an alternative supply we had to pay the difference in the cost between the supplier we wanted and the supplier that the ship yard had chosen. (…) then we would say 'I'm sorry we are not going to pay the extra'"

Usability was perceived to be the responsibility of equipment manufactures and the equipment manufacturers should also bear the cost for developing usable equipment. The competitiveness of the maritime industry was emphasized, and one informant described themselves as 'the weak link in the food chain', thus other actors must take responsibility for the equipment on the bridge:

"Everybody is always turning towards the shipowners to pay more, but financially it must be very critical for the shipowners to do more. The shipowners might think that the equipment manufacturers have the responsibility to deliver safe equipment that is easy to use and of course the maritime institutions have a responsibility to educate people, so they are capable of handling the equipment"

In other words, as this quote additionally illustrates, the shipowners also pointed to the seafarers' training, competence and their responsibility for being able to handle the available equipment.

4.3 *Shipyard*

The shipyard is where new ships are being constructed or where service and maintenance repairs or conversions, modifications or upgrades of ships are performed. Most shipyards have a design department and an engineering department. Naval architects are important professionals in this context as they work with ship design at the conceptual and construction levels, as well as often being involved in project management.

The building time which consists of both the design phase and the building phase, is an important cost parameter for a shipyard. Depending on the market situation, ships like tankers and bulk carriers are increasingly built in larger series from a standard design to increase the production efficiency of the shipyard. After the first vessels in a series have been built and construction bugs have been ironed out, there is seldom much more to be done by the design and engineering departments, leading to a per-ship cost reduction and shortened delivery time. Shipping companies do not need to be involved during this type of building process. Neither is it usually being considered in any detail what particular kind of operations the ship will be used for, where should the ship sail, what kind of crew will operate it etc.; designs of this nature are aimed a world-wide, unrestricted trading.

Naval architecture is an engineering-based profession and according to our informant, ship operations or the human-factors needs of end-users are not part of their professional focus. The informant describes the ship design process being about going into the ship design spiral and try to complete the design fulfilling all main requirements within the given time. An alternative approach, experientially very often used as a starting point for a new design, is to use the drawings from an already approved (sister) ship.

Concerning the ships bridge, the naval architect designs the outline of the bridge and can also be involved during the detailed design at the shipyard. The equipment manufacturers may deliver finished consoles, or consoles can be designed and produced by the shipyard and their sub-suppliers, in which case the equipment suppliers deliver components and drawings. Bridge equipment may be bought as individual sub-systems or components, resulting in equipment coming from perhaps 5-10 different equipment manufacturers, which all may have different operating philosophies.

The informant is of the impression that usability and implementation of human factors considerations into design differs considerably between equipment manufacturers. However, the informant emphasize that a naval architect will not start a discussion with stakeholders regarding human-factors related end user needs. As long as there are no compulsory requirements regarding usability or human factors this is not on a naval architect's agenda. According to the informant, although being aware of guidelines for implementing human factors in design, both from classification societies and standardization organizations, it is not clear who should be responsible for using them.

4.4 *Equipment manufacturers*

Equipment manufacturers are companies that make maritime equipment for ships, including specialist hardware, software, diesel and electrical propulsion systems, bridge equipment or DP systems. The equipment manufacturers in our study were either delivering a few specific pieces of bridge equipment or a whole range of bridge equipment, including consoles and integrated bridge solutions.

All equipment manufacturer informants in our study expressed high interest in usability and in involving seafarers in their design and development processes. However, there is a trade-off between this interest and time and cost considerations in the development processes. The price of their product is an all-important factor when competing in the maritime market.

Their influence is considerable in the sense that they design and develop the equipment and systems to be used on board. However, the informants depict several factors that limit this influence. Regulations are an important factor. The intention of regulations, to ensure a certain standard that contributes to safety, are perceived as positive. However, they also experience regulations, i.e., the IMO Performance Standards and the IEC equipment test standards described above, as being a hinder for innovation and restricting design solutions towards lower usability. As an example, one of the equipment manufacturers has ECDIS as the main part of their portfolio and ECDIS, like all other mandatory bridge systems required by SOLAS Regulation V/19, must comply with detailed regulations. In their opinion some of the requirements lead to solutions that create unnecessary challenges for the users:

"We would like to see that the experiences we have from being close to the user group would be taken into account. We see so many times that the standards have things that works directly opposite of the intention, it reduces safety although the intention has been the opposite"

Another factor limiting equipment manufacturer influence is the customer requirements. The customer is either representing the shipowner or the shipyard, not the end-user directly. The equipment manufactures experienced that shipowners can have their own subjective opinions regarding the bridge which may lead to altering the design in ways that designers think makes the bridge less usable.

"In the end the owner decides, not the people using it. He (the owner) overruled it even though all the users wanted the ergonomic solutions."

It may be difficult to get a position in the market based on selling the concept of usability. The maritime market is focused on cost effectiveness and equipment developed through user-centered design process does not mainly compete on price, but in addition on intangible benefits like increased safety, efficiency, effectiveness and user satisfaction, which are difficult to quantify in a business case or purchase decision.

In addition, it may be a challenge to get access to seafarers and ships and none of the equipment manufacturers had any systematic way of collecting feedback from operations. The informants also described tensions within their company regarding time and cost spent on design and development processes:

"We would like to be more out (in the field) but it is challenging to achieve (…) we have technical personnel that does it, in a way we who have the user-centred design part we do not have any tasks or system to fix, at least not something that everybody sees. We do see the need for it."

4.5 *The Flag State*

The flag state is responsible for the enforcement of national and international maritime regulations on ships flying their flag. The Norwegian Maritime Authority (NMA) is subordinate to the Ministry of Trade, Industry and Fisheries and the Ministry of Climate and Environment. The Norwegian legislation directly addressing ship bridge design is found within Regulation 1157 2014-09-05 Navigation and navigational aids for ships and mobile offshore units, where SOLAS Chapter V and the IMO MSC circular 982 is implemented. However, the focus on regulation V/15 through supervisions seem to be limited:

"The intention to include it in the regulations, regulation 15 states the considerations that must be taken when designing and placing equipment on a bridge. The guideline (MSC circular 982) addresses these considerations but from there to being good at actually using it in our supervisory work is to go a bit far"

Concerning ships being built within existing regulations the flag state informants considered NMA's interest and influence to be medium. The influence is essentially through providing the framework conditions through regulations, including supervision and auditing to ensure compliance with legislation. The informants express being comfortable with having general regulations with minimum requirements, as that provide the same conditions of competition in some areas. The informants are of the opinion that prescriptive regulations may limit innovation; however, goal-based regulations are difficult to follow up:

"The issue with goal-based and function-based, the problem is its all good but when you have to measure something and set an acceptance criterion or standard for what should be allowed, you need to have some known factors to measure up against, so that everything does not become completely abstract"

The NMA is aware of existing challenges regarding design of ship bridges and bridge equipment. They point to the lack of standardisation considering a holistic view on the bridge work environment guiding how the different pieces of equipment should be placed together. Currently it is up to equipment manufacturers, yards, and shipowners to decide how this is done and the practice varies between ship types and within different segments in the industry. In general, the informants have the impression that HMI and human factors developments is not fully exploited in maritime sector, which can be connected to the strong focus on profitability. Still, it is important for the NMA that Norwegian requirements do not go beyond IMO regulations, due to the goal of ensuring predictable conditions for the industry and to reduce the risk of ships flagging out.

The NMA is responsible for bringing issues to the IMO, however, the NMA is of the opinion that the industry also has a responsibility for pushing regulations forward.

"I would like to see the industry challenge the regulations. As new equipment becomes available or new research that says something about which resolutions and colors are best, I would like to see that automatically forwarded. I am unsure if this is the case, you do get the impression that they are most concerned with staying within the regulations when building a vessel. I understand that they do, but someone has to take the fight."

4.6 *Classification Societies*

Classification societies are non-governmental business organizations that establish technical standards for the construction of ships. Based on plan approval and onboard inspections during the building period of a ship, they issue classification certificates that verify that the construction of a vessel complies with their standards; certificates that are maintained throughout the lifetime of the ship through renewed surveys. The class certificate is necessary for the shipowner to register the ship in a flag state and obtain marine insurance. The certificate of class will include class notations that signify which rule requirements are applicable for the assignment and retention of class. While the basic class notation is mandatory, other descriptive class notations are optional and can cover different aspects, for instance ship type, special structural or engine standards, or, depending on the ship type and the wishes of the owner, there are also notations regarding navigation and manoeuvring. In addition to delivering their own services, classification societies can also have a role as Recognised Organisation (RO), meaning the flag state has delegated the responsibility for inspection and supervision of the flag state rules to the classification society.

Bridge and bridge equipment is not part of classification unless the shipowner wants a specific, navigation-related voluntary notation. Following up SOLAS V/15 is not a priority for class societies:

"Regulation 15 says something about bridge design, but it is almost a dormant requirement in relation to SOLAS ships. There are not many requirements for it in relation to normal standard class or SOLAS ships, but some flags i.e., Germany and Norway have said that IMO circular 982 applies, that they are minimum requirements. So, when you build a main class ship according to SOLAS, the 982 also applies and then it is quite significant, however the follow-up I do not want to say much about"

The informants experience from the role as RO is that it is common for the flag to give exemptions from this part of the regulations. The informants think that traditionally class societies have focused on the technical solutions and not been concerned with operations. Also, the majority of surveyors from class societies have technical background and human factors knowledge is not part of their training. The class surveyors follow guidelines and checklists concerning technical systems and equipment and they often work under considerable time pressure.

All mandatory equipment required by SOLAS Chapter V/19 has type approval, and according to the informants, installation and placement are equipment manufacturer and shipowner responsibility. From class point of view the shipowner has the main influence on ship bridge design, illustrated by the following quote:

"We think it is entirely driven by the owner/operator. Every other player in the industry is just selling stuff or providing services. (…) the only ones putting money in in the end, either by buying stuff or by running stuff, is the owner/operators. Everyone else are passengers. (…) if the owner/operator is not interested and does not provide sufficient information and requirements, nothing is ever going to happen. That is a big problem, because increasingly owners are banks"

Class considers their interest in ensuring safety through bridge design as being high. However, their influence on ship bridge design is through selling and developing the optional navigation and maneuvering notations. These are adapted to different ship types and may include requirements for different working positions, what kind of equipment should be there, placement, visibility etc. The sales argument being put forward is that navigation notations will give lower insurance, meaning that although investment in design is higher cost is saved on lower insurance. One of the informants emphasize that through developing these notations they contribute to push the industry forward. If the shipowner chooses a high navigation notation their influence through this notation is high. However, this classification society recently had to develop a new notation that only have minimum requirements in addition to SOLAS. This notation was described as necessary due to the demand in the market for a simple notation that requires minimum investments. Providing such as notation is part of the competition with other classification societies that provide these types of notations.

4.7 *Insurance*

Insurance is the shipowner's protection against financial loss due to accidents and incidents. Marine insurance has two main areas: 1) hull and machinery that cover the risk of property damage and 2) Protection and Indemnity (P&I) insurance that cover open-ended risks, like third party liability for cargo, injuries to people or environmental damage. (The loss associated to not operating is still with the owner).

Insurance companies are impacted by ship bridge design in terms of claims due to navigational incidents and accidents. According to the insurance companies, although the ship accident rate is declining every year, the risk remains the same as the consequences are higher, the ships are larger, systems are more complex, and claims are larger. However, collisions and groundings do not lead to the largest claims:

"Pollution claims are high cost as you can imagine but not very frequent (…) but what we get they are very expensive so in terms like that collision claims, groundings, in real terms are not a huge problem, they are acceptable within insurance terms anyway."

The insurance company informants state that both their interest and influence in ship bridge design is low. They have no direct influence on shipowners regarding ship design or choice of bridge equipment. Especially the P&I club emphasized that they are working on the shipowner's behalf, they are brought in by the shipowner to protect him/her from the unexpected and interfering with the design of ships is not part of their responsibility.

According to the insurance companies it is a misconception in the industry that insurance premium can be influenced by the choice of ship bridge equipment. The insurance premium is calculated in a conservative way based on the historical number of claims. The reward in the form of lower insurance premium will only occur when no claims have been shown over time:

"Insurance is just gambling you know, insurance gamble that you are not going to have a claim and proceeds the premium (…) answer to the underwriters is: well if you do this claims will go down so you will clearly get less premium, but at the end of the day insurance is a market place, it's all down to if you have a lot of claims that you have to pay a lot of premium, that's the system."

One of the insurance companies stated that they would like to have more impact on safety and ship bridge design, especially the opportunity to connect insurance premium level to class notations but they claim that will not be agreed to by the underwriters.

The insurance companies do regard they have indirect influence through the awareness campaigns run by their loss prevention departments towards seafarers:

"We have had lots of awareness presentations on what we see in navigation accidents, including the use of systems, understanding of positioning. It is based on the requirements we see, to try to avoid seafarers making the same mistakes (…) and the problem is that our audience is the seafarers, the navigators and not the superintendent or the technical personnel in the shipping company".

5 DISCUSSION

5.1 *SOLAS V/15 – a 'dormant' requirement*

SOLAS V/15 requires that human factors' considerations are the basis for all decisions "which affect bridge design, the design and arrangement of navigational systems and equipment on the bridge", i.e., in our interpretation, that the navigational equipment and systems must be usable; must be good design. Achieving usability requires however requires active involvement of end users throughout the design and development process [20, 45, 46]. In this study we find that the core regulation underpinning this demand, SOLAS V/15, is neither applied systematically in the design and development processes, nor is it having a significant position and impact during the ship design and purchasing processes, and nor is it an explicit, or even implicit, part of the survey work by the regulators.

The seafarers in our study have high interest in usability in ship bridge and equipment design as they are directly affected by it [49] through their daily work. However, they experience having little or no influence on ship bridge design or the selection of equipment, whether it is the design and development process or the purchasing process. With the widespread use of crewing agencies and short employment contracts [56] there are few possibilities for seafarers to interact with the shipowners or other stakeholders to give feedback from the use of ship bridge equipment. Even in organizations where owners' representatives – superintendents – are recruited among seafarers, and thus understand the end-user needs from their own practice, there is little impact to be observed. Speculatively, the underlying cause for this paradox could be that their freedom of action is tuned to the same agenda as most other members of a ship owning organization: ensuring compliance to rules, cost-neutrality (or cost-reduction), and timely delivery of the ship so that a return of investment can commence.

Seen from the perspective of the other stakeholders there are differing reasons for not involving seafarers in design and purchasing decisions. The equipment manufacturers in our sample expressed high interest in usability and in involving seafarers in the design and development process. However, they experienced that their access to ships and seafarers is limited. To involve seafarers arguably also adds time and cost to a development project which reduces the profitability margin, and since there does not seem to be an explicit market demand for usability, 'going the extra mile' could be considered as a luxury.

The purchasing process is another opportunity for involving seafarers in bridge design decisions and equipment selection, where seafarers' experience would be able to influence the choice of equipment towards instruments with superior usability. The ship purchasing process is however usually a negotiation between the shipyard and the owner/buyer, and these negotiations often revolves around the main characteristics of a newbuilt ship like speed, fuel consumption, capacity, delivery time, and cost. Usability is not on the table, apart from the implicit assumption that compliance to the IEC test standards provides usable systems. This was emphasized by some of the shipowner informants, that believed as long as you comply with regulations, the level of safety is good enough, and there is no reason to invest more time and money.

Based on the maritime actors focus on cost efficiency it would seem like a viable idea to connect insurance premium to the choice of ship bridge equipment. However, according to the insurance companies' informants, the insurance premium is conservatively calculated based on the historical number of claims. Despite running awareness campaigns directed towards seafarers on how to use equipment on the bridge, the state that they are in general neither interested nor involved in ship design processes.

Regulators can ensure compliance through their plan approvals and subsequent survey work. However, they seem to have conflicting relationships between balancing safety and economic considerations. The class societies express high interest in usability in ship bridge design but their only possibility to influence design is through voluntary navigation notations. Class societies are also part of the competitive maritime market and must provide 'cheap' notations that require minimum investments to compete for business. As such, they are in the main no driver for usability in the industry. One class society informant described SOLAS V/15 as a 'dormant requirement' not followed up by anyone in the industry: "It says something about bridge design in regulation 15, but it is almost a dormant requirement in relation to SOLAS ships".

The flag state is, as described, responsible for enforcing the international regulations on ships flying their flag. One example is Norway, where it is important for the NMA to ensure a level playing field also on a world-wide scale, i.e., predictable competitive and reasonable conditions for the shipping industry, and thus avoiding any additional national requirements that can enhance the risk of ships flagging out. SOLAS Regulation V/15 is, it transpires, not actively followed up within the NMAs supervisory work, and moreover, one of the flag state informants brought up the challenge of following up goal-based regulations: "you need to have some known factors to measure up against, so that everything does not become completely abstract". As opposed to the chain of prescriptive regulations and standard tests underpinning the implementation of SOLAS V/19 – IMO performance standards and IEC test standards, the goal-based requirements in SOLAS Regulation V/15 requires both specialized human factors and seafaring knowledge, as well as an out-of-the-ordinary effort from designers and surveyors to be implemented. So, while the benefit of goal-based regulations is the freedom in developing technical solutions to meet the goals, there seem to be a need for providing the required knowledge to follow up SOLAS Regulation V/15 in a form that can be understood and applied by the relevant actors.

5.2 *Usability – somebody else's problem?*

The stakeholders in our study varies in the expressed interest in ship bridge design, and represents a continuum that spans from 'high' when it comes to the seafaring end-users, all the way to 'low' when it comes to the shared tacit understanding by other stakeholders that is agreeable to consider SOLAS V/15 as dormant and settle for compliance to SOLAS V/19. The perceived possibility to influence ship bridge design was often seen in the context of responsibility for design and design processes. One common pattern is that stakeholders refer to the shipowners as responsible for the equipment on board their ships. Another pattern is the stakeholders referred to the regulators, or the regulations, as responsible for ensuring safety and as a major influence on usability. Maritime stakeholders are in general committed to regulatory compliance, as it is necessary to be allowed to operate. We wholeheartedly agree to the impact of maritime regulation and see the IMO instruments as essential for the safety of shipping. However, we do not immediately support that IMO is lacking behind when it comes to the institutionalization of maritime usability. On the contrary, we suggest that the IMO in this case have made the necessary provisions through SOLAS V/15; however, and much to be considered, what appears to be the less-than-vigilant enforcement of this regulation leaves usability up to the different maritime actors. The resulting fragmentation of responsibility for usability is evident, as the actors suggest – think - that the responsibility for usability sits somewhere else, as illustrated in Figure 1. The figure illustrates the fragmentation of perceived responsibility but also that the distribution of arrows is not symmetric, most arrows points towards shipowners. Most shipowners meant usability is the responsibility of shipyards, equipment manufacturers and regulations. They also pointed out the seafarers' responsibility for being able to handle the equipment. On the other hand, seafarers, equipment manufacturers, class societies, flag state and insurance companies are of the opinion that the shipowners are responsible for ensuring usability in ship bridge design. It is also interesting to note that the insurance informants believed shipowners are responsible for usability while their awareness campaigns are directed at seafarers and their use of equipment. In other words, the stakeholders believe responsibility for usability sits somewhere else - it is somebody else's problem.

Ideally, the knowledge from research and design efforts already undertaken would lead maritime stakeholders involved in ship bridge equipment design to understand the value of ergonomics and prioritize it, regardless of whether it is supported by mandatory rules and regulations. However, as usability arguably is associated with cost, we find it is unlikely that improved usability of bridge systems and equipment is something that will appear by itself within the world fleet, unless practice is changed, and – everything else equal – a more subjective drive for safer and cleaner oceans becomes a part of the decision-making fabric. This unfortunate notion also springs from the consideration of the difficulty of constructing a credible business case in favour of good bridge system usability, unless the cost of potential accidents is included – accidents, which however, in the eyes of the insurance companies, are 'not a huge problem, they are acceptable within insurance terms anyway'.

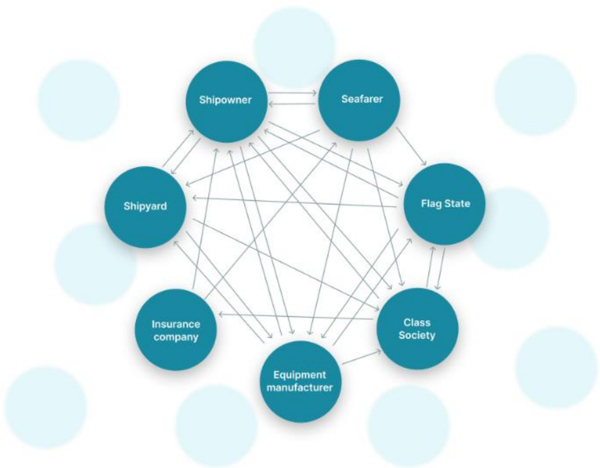

Figure 1. The allocation of responsibility for usability in ship bridge design, as perceived by the different stakeholders. The arrows pointing towards seafarers is about their responsibility for handling the equipment. The background circles indicate the existence of additional stakeholders, who may also have influence on usability in ship bridge design.

5.3 *A way forward?*

One could believe the closing statement above to be a kind of stalemate, at least unless a workable shortcut could be found. In the foregoing, the present situation arguably resulting in poor usability of bridge systems and equipment has been outlined. Stakeholders appear to recognize these shortcomings, appear to show an interest in improvements, but see a potential solution, or solutions, as somebody else's problem. Moreover, in spite of the provisions of SOLAS Regulation V/15, expectations apparently are that a change of rules is needed to make usability requirements more explicit than they already are, also considering IEC 60945 and IEC 62288, and from our data it seems that the industry is waiting for the IMO to initiate such a process.

Pursuing this line of thinking, it seems relatively clear to the authors that usability considerations relating to bridge design and the design of bridge equipment could be made more explicit, and that the provisions of SOLAS Regulation V/15 could be made more operational through descriptions of usability inspection methods, and the transfer of generic human factors knowledge to more technically-oriented stakeholders, i.e. tuned to the typical audience of maritime design engineers, marine superintendents, surveyors and plan approvers. We suggest that actions towards such a change are initiated, towards what we see as long-term improvements of maritime safety through improved usability and the associated reduction of errors and mishaps that often are attributed to humans. On the other hand, we also recognize that such actions, as well as the corresponding cultural adaptation that rather likely is also a component necessary for success of such a scheme, is a very far reaching, serious and time-consuming venture, ignores the need of a here-and-now return-of-investment (ROI), and all in all, such a scheme is possibly to the timescale of decades, rather than years.

With this in mind, our thinking keeps reverting to the position that the present regulations actually do seem to state what appears to be needed in way of usability requirements, especially considering the powerful wording of SOLAS Regulation V/15, but also the wording and the test regime included in IEC 60945, IEC 62288 and the individual equipment test standards which could suffice in many respects. On that basis, we ask ourselves, could there be a short-cut, a simpler, more expedite and less complicated way forward, without a major revision of rules, and a massive change of culture in the maritime industry? We have arrived at the conclusion that there could be such a solution. Our suggestion is that a shorter-term, potentially immediately effective approach, could possibly be brought about if end-users were to be much more clearly represented in the process of plan approval, system assessment and type approval of maritime instruments. As mentioned above, the present test methods often call for expert evaluation, but leaves the definition of experts open – but, if the norm for the definition of 'expert' was to include current seagoing experience and a relevant seafaring career, many of the 'pass' criteria in the various standards would not need explicit explanations. The term 'intuitive', which is seen in both IMO Performance Standards and IEC Test Standards would, for instance, take on a much more real meaning when evaluated by an experienced seafarer, as would – again as an example – the term 'logical grouping', which is also a usability heuristic that is used in the present rules and test standards. Considering that the relevant, present-day IEC Test

Standards call for the assessment of navigational instrument features and functions according to such terms, the evaluation of seafaring experts would probably be more to the point and several degrees more relevant for fellow seafarers than similar assessment made by any other discipline.

Taking a change of practice towards giving the seafarers a louder and clearer voice during type approval, plan approval and potentially onboard surveys, could possibly, and possibly even in a rather short time span, help building up a more comprehensive understanding of the actual context-of-use and perspective of the end-users, thus aiding bridge design and bridge equipment development. In the slightly longer run, such a pool of knowledge could also become a resource that design engineering could tap into to improve their products and services.

6 CONCLUSION

To achieve improved usability in maritime equipment and bridge systems ideally requires the actively involvement of end-users throughout the design and development process. Usability in navigational equipment and systems on a ship's bridge is required by the IMO SOLAS Regulation V/15 regulation. However, this is a goal-based requirement that is challenging to follow up both in design, development, and survey work, considering that the surveyors overwhelmingly have a technical background not having been trained in human factors, and – perhaps for this reason - the regulation is seen as a 'dormant requirement' by the maritime stakeholders. In this study, the usability in ship bridge design and bridge equipment is investigated from the perspective of different stakeholders in the maritime industry: seafarers, shipowners, equipment manufacturers, shipyard, insurance companies, classification societies and a flag state. From these sources, we find that the seafarers, the direct end-users, do not have a clear voice in the ship bridge and bridge equipment design and the associated purchasing processes. In other words, the stakeholder with highest interest in usability have what seems to be a low, or even the lowest, influence. Indeed, the other stakeholders appear to recognize these shortcomings, and some do show interest in improvements, but the responsibility for usability is fragmented, and they see the potential solutions as being somebody else's problem.

In our understanding of the wider picture, there seems to be a lack of incitement for prioritizing usability, since it is not strictly followed up through certification of bridge and bridge equipment designs, and neither is it perceived as cost-effective as usable equipment, which conceivably may have a higher investment cost, does not seem to result in lower insurance premiums or other tangible economic benefits. We suggest long-term improvements of usability can be made through making the usability considerations relating to bridge design and the design of bridge equipment in current regulations more visible and subject to more focused validation. In addition, we recommend that the transfer of generic human factors knowledge to more technically oriented stakeholders become a best practice, highlighting the importance of catering for end-user needs. We also argue that small steps to improve usability within a shorter time span can be taken, and to this end, we suggest that seafarers are included as 'experts' when 'expert evaluation' is required in the process of plan approval, system assessment and type-approval of maritime equipment. Such a practice can potentially be effective within a very short time span and within the current structure of the maritime sector and the present regulations governing the usability of bridge equipment and bridge design. From our vantage point, we believe that the perspective of the end-users, and an immediate and direct understanding of the context-of-use, can almost immediately be brought into the ship bridge design and equipment manufacturing processes without any change of rules, regulations or other practices.

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