IAMU 2018 Research Project
(No. 20180201)

Developing optimal approaches for the implementation of S-Mode in MET
Theme Two
(The role of the human element in the improvement of maritime safety)

By
Australian Maritime College, University of Tasmania

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Abstract This project develops and evaluates the approaches that maritime education and training (MET) institutions can use to prepare their programs for the implementation of S-Mode. Using a two-stage research method design incorporating nine focus group interviews, the project first identified the challenges faced by MET, the necessary features of S-Mode from a training perspective, and possible measures that can be taken for MET to be better prepared for the implementation of S-Mode. The second stage refined and confirmed the findings through a Delphi study. The findings reveal that the current prevailing differences in on-bridge equipment has not only increased safety risks, but also placed significant pressure on MET to provide adequate training. It is agreed that the implementation of S-Mode may reduce some complexity in training by MET. Over reliance on S-Mode should be avoided. The findings show that there has been a lack of information about S-Mode development especially for MET. For MET to be better prepared, more stakeholder engagement is required. In addition, enough time is needed for MET to provide training to the trainers before such training can be provided to students.

Keyword: *S-Mode, standardisation, human-machine interface (HMI), maritime safety, maritime education and training (MET)*

Executive Summary

The prevailing differences in design, function, and interfaces among the same type of navigation devices and equipment on the bridge pose significant challenges to seafarers and pilots, because they have to familiarise themselves with all the devices and equipment within a very limited time when they board a different ship. In emergent situations, such differences may lead to wrong decisions or actions causing serious maritime incidents. Due to its significance to maritime safety, the International Maritime Organisation (IMO) chose the development of S-Mode as one of its top six priorities for e-Navigation and called for contributions from the wide maritime community for the development of guidelines for S-Mode. In the last ten years, the discussions of S-Mode development have occurred mainly among the representative bodies of seafarers and equipment manufacturers with little involvement from maritime education and training (MET). The S-Mode has obvious impacts on MET. It is likely that additional investment is required to set up new training programs including hardware, software, and training of instructors. There are also concerns among MET that over-emphasising 'standard' mode may result in inadequate education and training on essential knowledge and skills on which S-Mode is based. It is, therefore, critical to thoroughly understand the possible challenges of S-Mode implementation MET may face, and approaches MET may take to be better prepared for this significant new initiative. Therefore, this project aims to:

1) Identify the challenges that MET may face in providing appropriate education and training based on S-Mode;
2) Investigate, from the perspective of MET, the features that S-Mode should have for future-proofed solutions; and
3) Develop optimal approaches for MET to implement S-Mode.

This project conducted two phases of data collection using two methods i.e. focus group interviews and a Delphi study with participants from MET institutions. In the first phase, nine focus group interviews with teaching/training staff from nautical/applied science of MET institutions in China, the US, Canada and Australia were conducted. The purpose of the focus group interviews was to identify the challenges faced by MET based on S-Mode and to investigate the possible features of a future-proof S-Mode and approaches that MET institutions can take to prepare for the implementation of S-Mode. The outcomes of the focus group interviews were used to develop an instrument for a Delphi study. A total of 91 panel of experts from IAMU member institutions were selected for the Delphi study.

The participants in the focus group interviews, as well as the experts in the Delphi study, expressed the concern of having limited information about S-Mode even after 10 years of discussion. This may partly due to the reactive nature from the MET institutions. The little engagement of the MET in the consultation process of S-Mode reflects a disconnection among some key stakeholders within ship safety. This may result in some unwanted consequences when the S-Mode is to be implemented. Throughout the project, it was unclear to all participants as what the guidelines look like and what the timeframe is for implementation. Such a situation created uncertainty among the MET institutions which may negatively affect the ability of MET to be better prepared for providing required training on S-Mode. Based on the findings from the project, the following recommendations are made:

- Information on S-Mode is urgently needed for key stakeholders including MET institutions. Such information may include the guidelines on S-Mode, the process for implementation, and the timeframe for each step.
- As education and training providers, MET institutions should be more actively involved and engaged with initiatives where MET is affected or can play a role.
- The IAMU must play a greater role in S-Mode implementation. There is an urgent need for MET to develop relevant training package so that there is enough time for MET to train their own instructors. A collaborative approach led by IAMU may be more efficient and effective in creating quality resources for training programs.
- It is also suggested that a platform (or community of practice) containing S-Mode related information be developed. This platform can be used for sharing information, experience, and innovative ideas in teaching and training. It can also be used for collaborative research.

1. Introduction

The prevailing differences in design, function, and interfaces among the same type of bridge navigation devices and equipment pose significant challenges to seafarers and pilots, because they have to familiarise themselves with all the devices and equipment within very limited time when they board a different ship. In emergent situations, such differences may lead to wrong decisions or actions causing serious maritime incidents. Due to its significance to maritime safety, the International Maritime Organisation (IMO) chose the development of S-Mode as one of its top six priorities for e-Navigation and called for maritime industry-wide contributions for the development of guidelines for S-Mode. The origins of S-Mode can be traced back to 2006 when the IMO adopted e-Navigation to address the challenges of uncoordinated complex navigation systems. Over the last ten years, consultations have been carried out to develop guidelines for S-Mode. The discussions have involved seafarers on the one hand, as represented by maritime professional bodies, such as The Nautical Institute, to address the 'user needs' of S-Mode. On the other hand, associations of manufacturers of navigation devices and equipment, such as the Comite International Radio-Maritime (CIRM), have their own concept of S-Mode and have expressed their views and concerns on 'standardisation'. However, maritime education and training (MET) institutions have had less direct involvement in the discussion of S-Mode.

The core of S-Mode is to address the human errors that are caused by, or related to, human-machine interactions (HMI). The significance of human factors in the operational stability, performance, and safety of transportation systems, especially vehicle operations or navigating tasks has been extensively studied with the aviation industry being in the forefront of research in HMI. Compared to the aviation industry, the maritime industry is far behind. With the continuous and increasing adoption of advanced technologies by the shipping industry, there has been a clear concern that the intention of technology adoption by the shipping industry may not be achieved. There has been a rising concern about the increasing safety risk as the result of the complex and uncoordinated onboard navigational systems being introduced in the last 30 years. The implementation of S-Mode is an urgent response to properly address the HMI onboard.

This IAMU-funded project focuses on the challenges, needs, and approaches of MET institutions while facing the implementation of S-Mode. Through focus group interviews, the project investigated the challenges and opportunities faced by MET in providing effective education and training for on-bridge operations of device and equipment and identified the approaches that can be used to improve learning outcomes under the proposed implementation of S-Mode. The project also examined the features that S-Mode should have from the perspective of MET. The findings from the nine focus group interviews were analysed using NVivo. The outcomes of the analysis were used to develop an instrument for a Delphi study. The two-method design significantly strengthened the results of the project. The structure of this report is briefly explained here. The following section provides a comprehensive literature review on human factor, human-machine interface, e-Navigation and S-Mode, and the role of maritime education and maritime training. The methodologies of this project are then discussed in Section 3 including focus group interviews and the Delphi study. The findings of the focus group interviews are presented and discussed in Section 4, followed by the findings and discussions on the Delphi study. The findings are structured according to the proposed objectives of the project. Section 6 draws the conclusions and makes recommendations.

2. Literature Review

2.1. Human factor and shipping safety

Research shows that over 80 per cent of maritime incidents are related to human factors. Such reasons could be incompetency of personnel in communication or operating onboard equipment. In the general transport industry (road, rail, air, and water transport), research on human factor has always been an important focus for the improvement of safe operation of vehicles. While the role of human factor to accidents may differ across the transport sectors, there is a consensus on the significant role that human factor plays in ensuring transport safety. An analysis of 650 maritime incidents using Technique for the Retrospective and predictive Analysis of Cognitive Error (TRACEr) taxonomy suggests that incidents are often triggered by cognitive and psychological errors by the operator (van de Merwe et al., 2016). An EU-funded project, CyClaDes, found that 67 per cent of the analysed accidents involved issues with human-machine interface (van de Merwe et al., 2016), among which 50 per cent are associated with operations on the bridge (DNV, 2016).

2.2. Human-machine interface

Studies on human-machine interface (HMI) cover a broad spectrum of topics across many industries. Traditionally, HMI is considered relevant to the physical relation between the operator, machinery and equipment such as type and colour of alarms, automation, layout and ergonomics. In the shipping context, research on HMI generally deals with the working environment on board, both from the safety and effectiveness of human performance points of view (Cazzulo, 1996). The significance of human factors in the operational stability, performance, and safety of transportation systems, especially vehicle-operating or navigating tasks has attracted enormous attention of not only related industries but also regulatory bodies and educational and training institutions (Skalle et al., 2014, Burmeister et al., 2014). While the implementation of different technologies has provided much-improved control abilities of the crew or automatic mechanisms over vehicles, this development has also created challenges to training and the knowledge transfer between system designers and users. In the maritime domain, the difficulties in training with navigational systems are amplified by the complication of the whole shipboard systems as well as the discrepancies between training programs and real-world conditions (Ali, 2006, Eleye-Datubo et al., 2008). A review of the factors is presented in the studies of Eleye-Datubo et al. (2008), Soares and Teixeira (2001) or Boring and Gertman (2004).

There is a general belief that the realization and understanding of causal and systematic relationships between system interface, human errors, and accidents leads to improved platform designs for such interactions (Rasmussen and Vicente, 1989). It is with this belief that there have been large numbers of studies devoted to a better understanding of issues related to human-machine interface (HMI) using various methods. For example, the interactions between human and autonomous machines were modelled by Heymann and Degani (2002) using Formal Abstraction to include four elements: machine model, operational tasks, user-machine interface, and user model. The interface provides the user with a simplified view of the machine. However, not all the events of the machine are known to the user, and the information displayed is only a part of the actual behaviour of the machine. A method proposed by Ukawa et al. (2004) categorizes the unexpected situation of HMI into three states: 1) mode confusion, where the machine is at a different mode than expected by the user; 2) refusal state, where the machine is not responsive to human inputs; and 3) blocking state, where the interface changes unexpectedly due to internal events. Such unexpected states may pose significant safety risks to both the vehicle and the operator. Improvements on HMI designs have brought more 'cooperation' between human and machine allowing freedom for both sides for a more resilient approach (Hoc, 2000). In the broad transport industry, the aviation industry has been leading the way in the study of HMI and its implications on safety. Due to very large number of vehicles involved, the road transport industry has also made significant investment into the research of HMI with an aim to reduce road accidents related to HMI. The maritime transport has attracted much less attention compared with its other transport counterparts. Literature of HMI related to air, road and maritime transport is reviewed in the following.

Air transport

Compared to the maritime industry, the aviation industry has gone much farther than its in terms of improving HMI design for improved safety and efficiency through research and innovations. Early research shows that computerised automation used in modern aircraft induces high cognitive workload and specific types of errors (Sarter and Woods, 1994). Hoc (2000) categorised the failures in the human-machine relationship into four types: 1) loss of expertise due to continuously reliance on automation; 2) complacency due to over-confidence in automation; 3) inconsistency of utilizing automation due to trust and self-confidence; and 4) loss of adaptability and situation awareness. Lintern (2000) argued that embedding within more advanced technologies has had a considerable increase in accidents that have resulted from a breakdown of information management. Accidents have occurred because the aircrew could not find or remember, did not notice, or misinterpreted critical information because critical information is hidden, or its meaning is obscure, or the aircrew is distracted by the obscure meaning of competing information that is consuming their attention. Technological developments have led to more problems than they have resolved (Lintern, 2000). Lintern (2000, p. 68) commented that:

> *Human–machine interface design has typically been a theoretical activity or, at best, one in which the more popular information-processing views have been used to justify design solutions without shaping them in any substantive way. A consistent theme recognizes that users can exploit the information made available at an interface by perceptual forms and changes in those forms (i.e., events), but that theme does not recognize any link between the nature of the information and the nature of the control requirements. As a result, interface design is a fragmented endeavour in which design solutions lack any substantive coherence within or across work domains*

For the design of information displays, the dynamic response of the system must be analysed to identify the information and the way that should be presented at the interface, e.g. in collision-avoidance, it can be time-to-contact information (thus the time to response to avoid collision) or distance-to-contact information (thus the distance to act to avoid collision) (Lintern, 2000).

Current HMI is considered static and does not take into consideration the dynamic variations in cognitive task loads (Spitzer et al., 2014). As reported in the US Air Force 2010, cited in (Liu et al., 2016), technology advancement continues its pace, so natural human capacities and advanced technologies have become increasingly mismatched and humans will be the weakest component in the generalised processes and systems by 2030. Therefore, a dynamic sharing of tasks between human pilots and avionics systems through advanced HMI will be required to achieve better overall performance. An architecture for single pilot operations which has been proposed are based on adaptive human-machine interface (Liu et al., 2016), in which two important features are proposed to address the possible weaknesses of high level of automation. *Dynamic task allocation* is capable of adjusting the level of automation to optimise task allocation between the automation systems and human operations (Liu et al., 2016). For example, the automation can be increased if a spike in mental workload of the pilot is predicated. On the other hand, if the pilot is predicted to lose situational awareness due to high levels of automation support, the level of automation can be adjusted to a lower level to keep the pilot mentally engaged. The second feature is *Adaptive alerting*. As explained by Liu et al. (2016), traditional alerting is normally in fixed forms using either visual, auditory cues or a combination thereof. Such alerting may become ineffective due to human limitations, such as in the case of perceptual tunnelling, a phenomenon in which an individual under high stress becomes focused on one stimulus and neglects to attend to other important information or tasks [(Wickens et al., 1998) cited in (Liu et al., 2016)]. Adaptive alerting can be designed to prevent such occurrences, e.g. haptic cues. In addition, innovative cockpit HMI design has been proposed for aircraft vehicles, where the display of specific information could be magnified or manipulate by gesture of the pilots instead of the traditional way, where switches or knobs are preferred. This design also allow adaptive display solutions and training effectiveness since a single simulation system could be designed to mimic different cockpit designs (NLR, 2013, Suijkerbuijk et al., 2017). A complete review of HMI evolutions in aviation, both military and civil could be found in the study of Lim et al. (2018).

Road transport

The impact of the human-machine interface (HMI) on the behaviour patterns of vehicle operators has been examined extensively, for example, Vaezipour et al. (2019), Muñoz et al. (2016), and Wu et al. (2011). In civil road transportation, where the operating systems are not as complicated and the life cycle of the vehicles are not as long, different approaches have been used for HMI such as haptic feedbacks, tactile or gestures (Pickering, 2005, Van Erp and Van Veen, 2004, Chun et al., 2012, Mulder et al., 2010, Pickering et al., 2007, Weir, 2010). Higher or relatively more intrusive approaches such as electromyogram, electrooculogram, electroencephalogram are also considered (Neto et al., 2006, Lim et al., 2015, Zander and Kothe, 2011). Another trend is redirecting and manipulate displaying information with the operating conditions. For example, reducing mental workload for drivers by an adaptive man-machine interface (Piechulla et al., 2003, Panou et al., 2005, Amditis et al., 2005) or heads up display (HUD) (Charissis and Papanastasiou, 2010, Jakus et al., 2015) is proved as effective in enhancing driving safety. Solutions are also proposed with a future proof factors such as robotic automobile (Bünte et al., 2011). HMI is evaluated mainly through two methods of evaluation including: a) HMI checklist, which is preferred by funded or regulated bodies since it could provide a more decision-making oriented view (pass or fail); or b) task-based assessment, which is more valued by researcher, and developer by providing more insightful and realistic data (Ross and Burnett, 2001). Recommendations are also provided for aspects of evaluation such as contexts, techniques, measurements, evaluators (Ross and Burnett, 2001, Weir, 2010). In addition, an observed simulation-based training obstacle in the road transportation sector is indicated by Vaezipour et al. (2019), Fisher et al. (2011) as psychological effects of electronic or digital simulation systems such as motion sickness, dizziness and nausea are well-acknowledged .

Maritime transport

In the maritime industry, many studies and discussions on HMI have been undertaken under the theme of human factor or human element with reference to shipping safety. Technology has been used to automate many tasks to dramatically reduce crew numbers onboard and to increase operation efficiency (Kahveci, 1999). However, technology developed without reference to key human factor principles has the potential to be counter-productive, not least in safety-critical industries such as shipping or aviation, where mistakes can lead to disastrous consequences. Allen (2009) contended that while the role of humans has changed from navigator/engineer to operator, at times going further down to just a monitor, evidence suggests that rather than freeing up resources, new vigilance demands are introduced, which may be extremely taxing. Complex new automated systems resulted from continuous adoption of new technologies may therefore give the illusion of reducing workload and introducing redundancy. This may not necessarily be the case in reality. Also, the task of controlling multiple remote systems may require high levels of cognitive ability and skill. There is also evidence that introducing new electronic systems onboard may reduce levels of communication on the bridge (Gould et al. 2009), which may become a safety concern.

Twenty years ago, May (1999) identified six HMI problems on the bridge: (1) the irrelevance of displayed information; (2) inefficiency of interaction mechanism; (3) inadequacy in operational support; (4) fragmentation of implemented hardware; (5) inconsistency in information presentation; and (6) incoherence in its situational support. To a great extent, these six problems are still relevant today. Ten years after May's publication, Jacobson and Lützhöft (2008) investigated the needs for standardisation from users' perspective to improve HMI on bridge. There has been continuous adoption of new technologies in ship design and construction with an aim to improve shipping efficiency and safety. However, research has shown that high system complexity, interdependency and automation may increase mental workload which could result in more human errors (Asyali, 2014, Hahn and Lüdtke, 2013, Man et al., 2018). For example, Asyali (2014) examined the impacts of new technologies on the on-board crew. The first impact relates to the changing relationship between operators and machines where the conventional direct relationship between the two has become more indirect. New technologies also bring a generation of new complex tasks that require mental cognitive problem solving and system interdependency understanding. Furthermore, since new technologies enable programs to control machines, under operating contingencies, operators are still required to have the skills to perform tasks with old technologies. Finally, new technologies require re-skills as a result of significant reductions of the number of complex tasks carried manually. Asyali's (2014) study also indicated that the increase of system complexity and interdependency as well as the increase of automation lead to increase of mental workload. Man et al. (2018) tested a ship-shore HMI to test the ability of operators in interpreting and controlling navigation tasks and situations. The result indicates that there is possibility that matured technologies on-board could cause "human errors" as the operators are not kept in the loop and therefore cannot accumulate enough information for reliable decision-making. The simulation approach developed by Hahn and Lüdtke (2013) is able to assess the risks for HMIs in e-Navigation systems. Better design of HMI as well as the interior design of the vessel is critical to support the human element.

The human-machine interface has also attracted significant attention in the development of unmanned vessels. In such studies, the interactions between vessels and the on-shore navigation centres are the focus and considered as the crucial factors in the reliability and safety of vessel operations. For example, Burmeister et al. (2014), Rødseth and Burmeister (2015) revealed the lack of sufficient human-machine interface for reliable remote operations, which is mainly relied on factors such as, a) harmonized presentation of the situational awareness of the ship; b) standardized and automated reporting of information; and c) integration and presentation of the information received via communication equipment in graphical displays. HMI is also considered by various studies as a major factor in the safe navigation of unmanned vessels with problems such as reliability, visibility, aiding ability (Thieme et al., 2018).

Improving HMI outcomes

While research in HMI is widespread and findings vary across industries and contexts, there is consensus that HMI has significant implications on operation safety. There is a dynamic relationship between the operator and the equipment or machine being operated. A driving purpose for HMI research has been to improve the efficiency and safety of operations. Hoc (2000) proposed solutions to address four types of failure resulting from poor HMI design and implementation. Debernard et al. (2016) developed a set of 12 principles for transparency in HMI. Weir (2010) investigated the importance of simulation system design and operation in testing and evaluating HMI. In aviation, Thomson (2015) identified four key elements for HMI design: 1) HMI should provide clear, unambiguous information; 2) alarms should be designed to attract attentions, but not distractions; 3) operators should be kept in the loop; and 4) the possibility of making unintended irrational control input of the operator should be anticipated. Regarding the structure of the HMI, different studies were conducted to investigate the trade-off relationship between the depth and breadth of the hierarchical menu structure. It is concluded in studies by Kiger (1984), Jacko and Salvendy (1996) and Burnett et al. (2013) that breadth is preferred over depth by automobile users. However, no such studies have been conducted in the maritime domain.

In a broad view, a modern operator-bridge interface comprises three key aspects, organisational, personal, and ergonomic (Goulielmos and Tzannatos, 1997). Physical ergonomic aspects refer to the optimisation of the environment including factors such as illumination, temperature, noise and vibration. It also covers the design of controls, equipment, systems, and workstations based on an analysis of anthropometric measures. Organisational aspect refers to the allocation, sequencing and scheduling of tasks, work and shift cycles and the organisational attitude towards safety performance. Personal aspect includes both mental and physical conditions as well as the compatibility with the environment. The relationship of the three aspects are illustrated in Figure 1. While the organisational aspect may not be obviously present in the environment, it has significant direct and indirect influence on the personal and ergonomic aspects. As explained by Goulielmos and Tzannatos (1997), the modern operator-bridge interface combines the functional characteristics of a human consisting of displays, receptors, central nerve systems and effectors and an electronic based component consisting of sensors, input interface, transfer function unit and output interface. The operator-bridge interface is a control loop where a function may be performed by either component or both. As a principle, to enhance shipping safety, the bridge of a ship must be designed and maintained in such a way so that the hardware (machines and equipment), software (procedures and instructions) and liveware (operators) complement each other to produce a harmonious entity.

2.3. e-Navigation and S-Mode

e-Navigation was first introduced to IMO in 2006 in its 81st session of the Maritime Safety Committee to address the "*compelling need to equip shipboard users and those ashore responsible for the safety of shipping with modern, proven tools that are optimised for good decision making in order to make maritime navigation and communications more reliable and user friendly*". This initiative was developed at a time when increasing technologies, especially information and communication technologies were introduced to the shipping industry through manufacturers' adoption of these technologies into their shipping-related products. Innovations and technologies advances from equipment manufacturers have every intention to improve the safety of ship operations. However, there are considerable concerns that uncoordinated development and adoption of technologies may hamper the future development of marine navigation systems due to a lack of standardisation on board and ashore, incompatibility between vessels and an increased and unnecessary level of complexity. e-Navigation is therefore defined as *"the harmonised collection, integration, exchange, presentation and analysis of maritime information onboard and ashore by electronic means to enhance berth to berth navigation and related services, for safety and security at sea and protection of the marine environment"*. e-Navigation has a clear dedication to 'user needs' and consideration for the human element.

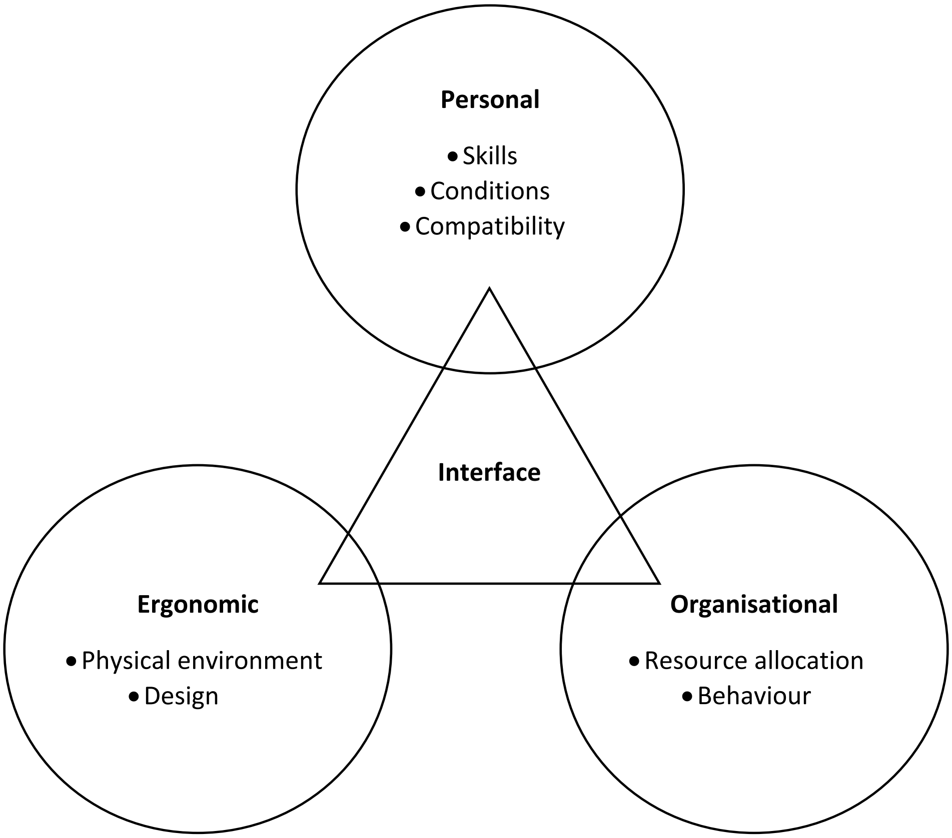

Figure 1 An operator-bridge interface (Authors)

To support the e-Navigation initiative, six priorities were identified and supported by the IMO, of which the S-Mode was to be developed to address the requirement for 'harmonised presentation' of maritime information under e-Navigation. Specifically, S-Mode supports two of the core objectives of e-Navigation (NAV 53/WP.8): 1) integrate and present information on board and ashore through a human-machine interface which maximises navigational safety benefits and minimises any risks of confusion or misinterpretation on the part of the user; and 2) to manage the workload of users while also motivating and engaging users and supporting decision making. Since NAV 53, there has been increasing discussions and studies around the development of S-Mode amongst the key stakeholders through their respective representative bodies.

S-Mode

The S-Mode concept was first proposed in 2008 (Nautical Institute, 2008) through a joint submission by The Nautical Institute (NI) and the International Federation of Shipmasters' Associations (IFSMA) to raise the serious concerns about the increasing complexity and uncoordinated nature of shipboard navigational equipment. For example, there are over 30 different manufactures of ECDIS (Electronic Chart Display and Information System) in the market with a much larger number of models. For GMDSS (Global Maritime Distress and Safety System) communication equipment, the number of main manufacturers may be small. However, the number of models produced by these manufacturers is enormous (refer to Appendix 1). The prevailing differences in design, function, and interface among the same type of navigation devices and equipment on bridge pose significant challenges to seafarers and pilots alike since they have to familiarise themselves with all the devices and equipment within very limited time when they board a different ship. In emergent situations, such differences may lead to wrong decisions or actions causing serious maritime incidents. Recognising its significant implications to maritime safety and its role in e-Navigation, the development of S-Mode was then accepted by IMO's Maritime Safety Committee as one of its priorities for the four-year work program on developing practical solutions to implement e-Navigation.

In 2016, a proposal on how best to develop guidelines for greater standardisation in the use and operation of onboard navigational equipment was discussed during IMO's sub-committee on Navigation, Communications and Search and Rescue (NCSR 3). The proposal was co-sponsored by the Comité International Radio-Maritime (CIRM) and the International Electrotechnical Commission (IEC), as well as the NI and IFSMA, and jointly submitted by Australia and South Korea. The proposal partly addressed the equipment manufacturers' concerns over S-Mode about the difficulties for them to meet different user needs and preferences, since the proposal stated that S-Mode should not limit a manufacturer's ability to innovate.

According to the Nautical Institute's proposal, S-Mode should include three features:

1) A default display presented at the press of a button;
2) A standard menu structure on this display, where all essential tasks can be operated in the same way across all manufacturers; and
3) A standard interface device (mouse, trackpad, joysticks, etc.).

In order to determine what are considered essential tasks, what a default HMI should look like, and how an interface should be standardised, The Nautical Institute insisted that the widest possible input from the estimated 400,000 navigating officers in the global fleet was essential. This feedback should then result in a small number of possible solutions that will be subject to thorough tests in simulation for effectiveness before a final decision is made. A large survey was launched in 2017 through The Nautical Institute's Navigator magazine to call all seafarers around the world to provide input to the development of guidelines for S-Mode. The report of the survey was submitted to the Sub-Committee on Navigation, Communications, and Search Rescue (NCSR). The 5th Session of the NCSR established a Correspondence Group on the development of the draft Guidelines on S-Mode, coordinated by Australia (IMO, 2018). By the time of writing this final report, the 6th Session of the NCSR has considered the report submitted by the Correspondence Group (IMO, 2019). The report (IMO, 2019) contained the draft guidelines for standardisation of user interface design for navigation equipment, amended guidelines for the presentation of navigation-related symbols and performance standards for the presentation of navigation-related information on shipboard navigational displays, which were subsequently approved after deliberation in Working Group 1 of the 6th NCSR.

The seemingly unlimited advancement of technologies and their fast adoption into the maritime industry in a very much uncoordinated and varying way may achieve the opposite intentions of implementation. As Bhardwaj (2013) commented, the potential for error-causing behaviour related to automated systems has not been addressed adequately by the maritime industry, and there have been little or no unifying efforts to integrate human element into engineering design through cognitive ergonomics. Lützhöft (2004) argued that the design of equipment on vessels often contradicts the seafarers' conception of how things should function. Designing equipment that is considered universally intuitive is a challenging task. Amongst other potential variables, evidence suggests that culture can have a significant impact on successful interface design (Shen et al., 2006). The human-factor engineering concept may help the integration of human characteristics into the definition, design, development, and evaluation of the ship to optimise human-machine performance under specified conditions. The incorporation of S-mode in e-Navigation process engineering recognises the need for cognitive ergonomics and human factors in the conceptualization, design, and development of human systems integrated technological systems (Bhardwaj, 2013).

2.4. Maritime training and education

The introduction of new technologies on ships is often influenced by the drive for profit seeking through the reduction of crewmembers in order to reduce labour costs. The industry's continuous efforts to reduce cost has led to a shift from labour to technically intensive ships. It has been suggested that there is a lag between the introduction of new technology and the provision of training to operate them (Committee on Advances in Navigation and Piloting 1994), with many seafarers only receiving training 'on the job' (Lützhöft 2004). The inability of many educational programs and training schemes to catch up with the rapidly growing complexity of shipboard technology has presented challenges for HMI considerations (Goulielmos and Tzannatos, 1997). In a questionnaire survey of 819 officers, better training of crew to use ship technology was identified as one of the most important factors for seafarers to confidently embrace new ship technologies (Allen, 2009).

The training and related maritime educational affairs on this topic also received considerable attention. Problems have been identified in current maritime training systems such as unsuitable education and training objectives (Roth and Emad, 2008), inappropriate skill assessment techniques (Gekara et al., 2011), and shortage of instructors who are well-trained and up-to-date in educational technologies (Hanzu-Pazara et al., 2010). The role of the instructor as the intermediate in the process of knowledge transfer and the need of new methods in the training of skills related to new technologies are emphasized by Ali (2008). The lack of standardization in both the training processes and the real vessel technical system has also been discussed in literature. For example, on-board training programs were identified by Chauvin et al. (2009) as crucial to complex situational decision-making capacity. Sandhåland et al. (2015) further examined the emerging errors related to insufficient training due to the "incomplete mental models related to the vessel technical systems" despite the existence of the on-board training program. Schmidt (2015) investigated different solutions for education and training using simulators with a focus on navigation operations such as bridge, radio, cargo handling, ballast handling as well as safety and security operations. The importance of simulation-based and realistic training has also been stressed by Sellberg (2016), Sellberg et al. (2018). The advances in immersive technology and virtual reality provide more options for training programs to be more engaging where navigating operators can execute tasks through using a game controller (Sheehan et al., 2018).

In the last ten years, the discussions of S-Mode development have occurred mainly among the representative bodies of seafarers and equipment manufacturers with little involvement from MET. The S-Mode has obvious impacts on MET. On the one hand, S-Mode may reduce training burdens and enable greater standardisation of training since the primary objective of S-Mode is to facilitate equipment familiarisation. As discussed earlier, there are large number of bridge equipment manufacturers making many models resulting that it is impossible for any training institutions to develop training labs for every system. The standardisation would allow simplification of shoreside training programs. On the other hand, there has been very limited information available to MET about S-Mode and how S-Mode may affect education and training. It is likely that additional investment is required to set up new training programs including hardware, software, and training of instructors. There are also concerns among MET that over-emphasising 'standard' mode may result in inadequate education and training on essential knowledge and skills on which S-Mode is based. It is, therefore, critical to understand the challenges of S-Mode implementation MET may face, and approaches MET may take to be better prepared for this significant new initiative. This report is timely as it responds to the urgent need of MET institutions for understanding the implications of S-Mode on their current training programs and being more actively involved in the S-Mode development and implementation. Against the above background, the objectives of this project are to:

1) Identify the challenges that MET may face in providing appropriate education and training based on S-Mode;
2) Investigate, from the perspective of MET, the features that S-Mode should have for future-proofed solutions; and
3) Develop optimal approaches for MET to implement S-Mode.

3. Methodology

Since little information was available on how MET should respond to, and prepare for, S-Mode, the project employed two data collection methods, focus group interviews and a Delphi study with participants from MET institutions. In the first phase, focus group interviews with teaching/training staff from nautical/applied science of MET institutions were conducted. The instrument for the focus group interviews was developed based on a thorough literature review discussed earlier. The nine-question interview is provided in Appendix 2. The purpose of the focus group interviews was to identify the challenges faced by MET based on S-Mode and to investigate the possible features of a future-proofed S-Mode and approaches for the implementation of S-Mode in MET settings. The outcomes of the focus group interviews were analysed using NVivo (NVIVO, 2019). Based on the findings from the focus group interviews an instrument for a Delphi study was developed. This two-method approach was considered innovative and appropriate for this project, where there was little reference on the topic. The information collected from the wider education and training community provided the foundation to develop a proper instrument for the Delphi study. The selected panel of experts from IAMU member institutions in the Delphi study strengthened and refined the approaches and strategies that this project endeavours to develop for the implementation of S-Mode in MET institutions.

3.1. Focus group interviews

In total, nine focus group interviews were conducted, of which five in China (Dalian, Qingdao, Shanghai and Guangzhou), one in Australia, one in Canada, and two in the United States

(Maine and Massachusetts). Figure 2 shows the locations of the nine focus group interviews. Only one focus group interview was planned for the United States. However, due to the timing and availability of the participants, the planned interview had to be carried out separately in two small groups with two and three participants respectively. The remaining seven group interviews consist of 5-6 participants. The demographic profiles of the participants are presented in Table 1. Given the topics of S-Mode, it was decided that the invited participants would need adequate seafaring and maritime and training experience. Of the 41 participants, 37 are Master Mariners (Unlimited) representing over 90% of the participants with remaining holding other certificates of competency. The years of sea time range from 6 to 28 years with a majority (56.1%) having 10-20 years of seafaring experience, and over one third (34.1%) more than 20 years and less than 10% sailing for less than 10 years. For teaching and training experience, over sixty-three per cent of participants have been teaching or training for 10 to 20 years. About a fifth of the participants (8) have taught for over 20 years, and the remaining (7) have been in the maritime training and education for less than 10 years. The extensive experience of participants in both seafaring and maritime training provides the confidence on the quality of the discussions in the interviews and thus the information collected from the focus group study.

The length of interviews ranged between 63 minutes to 116 minutes with most interviews (6 groups) being completed within 70 minutes. In total, 664 minutes of discussion were recorded. The recordings were sent to two professional transcription service providers, one for the interviews in English and the other in Chinese. The 664 minutes of recording resulted in 132,785 words in transcripts (Table 2). The Chinese version of the transcripts was translated into English before all transcripts were analysed using NVivo (Version 11). The outcomes of the analysis were used to develop the statements for the Delphi study.

Figure 2 Locations of focus group interviews

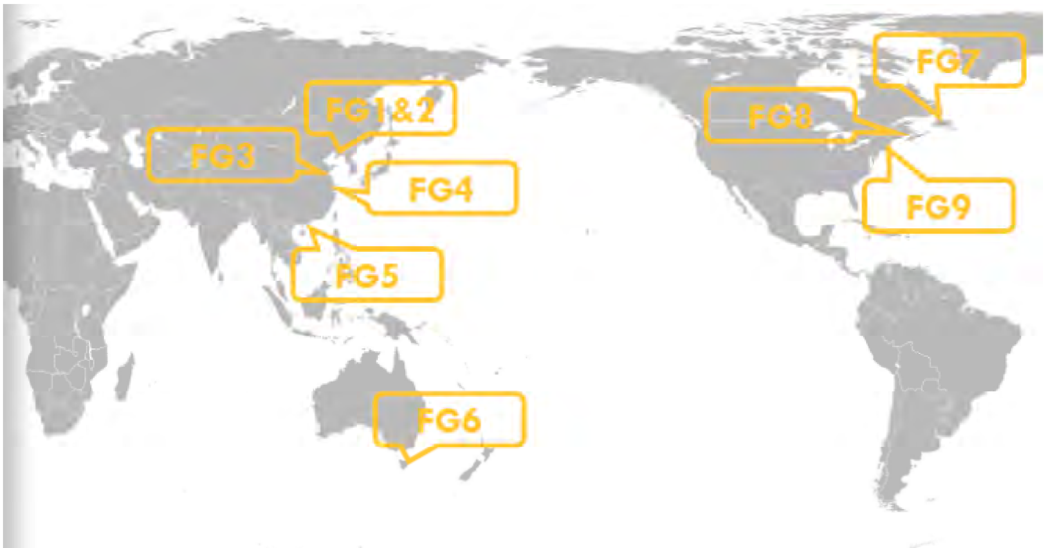

Table 1 The profile of participants in the focus group interviews

	Seafaring experience	Teaching/training experience
Master Mariners	37 (90.2%)	
Other CoCs	4 (9.8%)	
Over 20 years	14 (34.1%)	8 (19.5%)
10-20 years	23 (56.1%)	26 (63.4%)
Less than 10 years	4 (9.8%)	7 (17.1%)

Table 2 Focus group interviews (participant number and length)

Group	Participants	Length (minutes)	Transcript (words)
1 (AU)	5	67	10,168
2 (CA)	5	76	12,091
3 (US1)	3	66	7,706
4 (US2)	2	68	10,897
5 (DL1)	5	63	18,440
6 (DL2)	5	116	25,517
7 (QD)	5	65	14,716
8 (SH)	6	75	17,646
9 (GZ)	5	68	15,604
Total	41	664	132,785

3.2. Delphi study

Delphi is widely used in social science for different purposes (e.g., forecasting and assessing) in different contexts including business, economics, politics, and engineering (Landeta, 2006). The method systematically and interactively utilises the deliberative power of multiple experts (expert panel) based on the principle that the outputs of a structured group are more accurate than those of unstructured groups or individuals. Due to a lack of information on S-Mode, this method is considered appropriate to use the collective knowledge of the experts to explore a relatively new topic. A facilitator was introduced to the Delphi study process to ensure interactions between experts occur in unbiased way. Direct interactions, such as focus group discussions, may unleash the effects of social deficiencies caused by different personalities, levels of authority, or reputation, which may result in intimidation, dominance, or manipulation by participants with greater power or authority or strong personality. A Delphi study, while encouraging interactions, such interactions are facilitated through an intermediate so that the panel of experts remain anonymous. The participants, therefore, can freely express their ideas and opinions as well as critiques to establish a cross-checking mechanism to reject false information while keeping a common ground of knowledge.

Delphi is characterized by the repetition of the interactions among experts to actively seeking the convergence toward consensuses. The outputs of experts in a specific iteration are collected by the facilitator, checked for satisfaction of the stopping criteria before making the decision for continuing the next iteration or stopping. The iteration of Delphi should stop if the derived outputs satisfy the definition of the consensus and continue if it does not. In cases where the knowledge base is not sufficient for the experts to continue revising their assessments, the Delphi process should also stop.

The nine focus group interviews conducted in the first stage of this project produced large amount of qualitative data. After qualitative analysis using NVivo (Version 11), statements around the three project objectives were then constructed. The Delphi study consists of five sections with the first section being demographic information and the last one about general statements on S-Mode. Sections 2-4 are to address the three project objectives with a total of 65 statements. A copy of the Delphi study is included in Appendix 3. A 7-point Likert Scale (from strongly agree to strongly disagree) was used to indicate the extent of experts' agreement on each statement. A consensus was considered reached when all experts chose 'agree / strongly agree', or 'disagree / strong disagree' toward a statement.

The aim of conducting the Delphi was to seek agreement among all experts from MET institutions on the statements. To ensure a wide coverage of experts, a thorough search of experts was carried out among the IAMU member institutions. In total, 91 experts were identified covering countries from Europe, North America, Asia, and Oceania. A list was compiled with email contacts for sending invitation. Of the 91 experts, 70 were Master Mariners accounting for 77%, 9 Chief Officers (10%) and the remaining being 2nd and 3rd Officers.

Due to the geographical obstacles, the Delphi study was carried out on an online platform. *Calibrum* was chosen because of its diversified support for flexible deployment of Delphi. This platform also yields reliability with previous adoption in projects of the European Commission (EC) and the United Nations Development Programme (UNDP). An invitation for participation was sent out through the platform to all identified experts. To help the experts complete the study, brief information and instructions about the project and the Delphi study were provided on the landing page of the Delphi study.

4. Findings and Discussions on focus group interviews

The findings were reported following the three project objectives and around the nine interview questions developed based on the literature review.

4. 1. Current challenges of MET

During the focus group interviews, a large number of issues were raised and discussed. Some of these are common across all MET institutions while others specific to individual institutions. Differences are also observed between countries. The analysis of the discussions resulted in four topics related to current challenges of MET.

- Organisation of training
- Current systems used in training
- Challenges in maritime training and education programs/activities
- Challenges in practical training

4.1.1. Organization of training

The topics on organisation of training range from policy level such as governance of education programs and curriculum structure, to day-to-day operations of training activities. Among the participating institutions, the levels of program offerings vary with some institutions providing bachelor's degree programs only, others offering certificates and/or diplomas (and advanced diploma), and some offering a very wide spectrum of programs from Cert I to PhD level and everything in between. For STCW (International Convention on Standards of Training, Certification and Watchkeeping for Seafarers) related maritime education and training programs, the governance structure may have multiple layers depending on the offerings. In addition to meeting the general regulatory requirements for higher education (e.g. the Tertiary Education Quality and Standards Agency – TEQSA in Australia) (Australian Government, 2019c) or vocational education and training (VET) (e.g. Australian Skills Quality Authority – ASQA) (Australian Government, 2019b), all STCW related programs must comply with the requirements set by the maritime safety administration or authority of the respective country. For the United States, it is the Maritime Administration (MARAD) (United States Department of Transportation, 2019), for China, China Maritime Safety Administration (MSA) (Chinese Government, 2019), and Australian Maritime Safety Authority (AMSA) (Australian Government, 2019a) for Australia. While the STCW provides the minimum requirements on education and training of seafarers, the actual administration may differ with some having little intervention in program delivery while others being more involved.

The role of the national or state maritime safety administration may significantly affect the way training is organised and delivered. For example, several participants explained that maritime education and training in China strictly follows the syllabus developed and provided by the MSA, based on requirements set by the STCW. MET institutions of all levels have little authority to develop or modify the programs. As one participant commented, *"...if it is theoretical training, the whole is subject to the training outline of the Maritime Safety Administration, so basically our entire training is in accordance with these requirements."*

It is a common composition that the MET consists of three main components, theory, practice, and internship, although the terms used in the institutions vary. The structure of the three components is, however, different. This mainly relates to the sequence of the activities, the emphasis placed on them, and the allocation of training time. In addition, there is a clear distinction between higher education and vocational education in terms of focus and time allocation. The time allocated for practical classes in vocational education is about 50%. "*The proportion of practical operations required by the Maritime Safety Administration is very large, and it may be up to 60% according to the requirements. The curriculum is divided between practice and theory, so VET reduces a lot of theory for practical training.*" The emphasis on practical classes is also partly due to "*the low scores of VET students achieved in the National College Entrance Examination (NCEE), which makes it difficult for students to comprehend too many theories*". In the higher education sector, the requirements on understanding fundamental theories are much higher. "*If we follow the requirements of the Maritime Safety Administration to do 60% of practical exercises, there are fewer things for teaching theory. The theoretical knowledge of navigation cannot be effectively passed down*".

The class size was also a point of discussion. Generally, for classes explaining theories and basic principles of navigational systems, the average size ranges from 20 to 40 students. For training on simulator or real machines, the classes are divided into much smaller groups. The actual size and the time allowed for each student still varies depending on the available space, number of simulators, and equipment. In addition, some institutions also provide onboarding training. Such training could be a short visit to a training vessel in port, or a real sailing experience for a few hours. As commented by a participant, "*...we also do some on-board training. We have some vessels that put out into the harbour. We have another vessel that puts out into the bay for two- to four-hour voyages. We have a training ship that both sides diesel 500-foot-long length overall training ship that transits the North Atlantic Ocean during the summer months and they have practical experiences operating equipment there.*".

It was noted that due to resource constraints, some VET institutions may not be able to provide the same opportunity for onboard training. "*Because we have training ships, we can provide training for the juniors on board. During the training, our Second Mate will give students lectures about the actual equipment on the bridge. We ask students to read equipment manuals in advance to make them familiar with the main equipment like radar and electronic charts before they operate. After the ship starts sailing, students watch and learn ship manoeuvring alongside with the duty officer. Towards the end of the training, we allow students to operate on-bridge equipment when it is safe to do so.*" "*For VET institutions, the training ships are often unavailable, and the training can only be completed through the placement offered by shipping companies after graduation*".

4.1.2. Current systems used in training

Systems used for training include simulators and real machines. For simulation systems, all participants reported that 'mainstream' brands and equipment are used. It is observed that a Transas simulation system is used in USA with the newest version of Navi-Sailor and Navi-Planner 4000/4100 for ECDIS simulation. Canada, China and Australia, on the other hand, mainly use Kongsberg with Polaris and K-Scene bridge simulation. Both systems are considered satisfying the needs for training purposes, with acceptable update frequency. The USA group enjoys the commonality of the Transas system and the update frequency of around once a year. The Australia and Canada group stated that the Kongsberg system has been recently updated, the frequency is also once a year and it is adequate in meeting training and teaching needs. Some institutions also develop their own simulation programs or source from providers other than those 'mainstream' manufacturers. For some VET institutions, updating the main simulation program could be a significant financial burden. Consequently, the update may not be updated at an optimal level. "*Ever since I joined the institute, we have been using the Norwegian Kongsberg simulator. The version was 4.0 when I came, then it was 5.6 after intermediate upgrade, then the current version is probably 7.2. But we have had a relatively slow upgrade and recently planned to upgrade it again.*".

Unlike simulation systems, real machines have very large numbers in varieties, brands, models with some being relatively new and others being up to 60 years old. "*Our school has been established for decades, and some of the old equipment in the 1960s is still there. There are also new ones and more models.*". Many of the equipment was donated by shipping companies when their ships were scraped. The equipment then becomes a part of the collection in the laboratory to be used for students on-machine learning. The benefit is that students have opportunities to learn from both simulation and a real machine. *"MET in the higher education sector tries hard to provide real machines of mainstream equipment for the students to practice. Because the basic function of equipment from different manufacturers is similar, but the way they operate is different. We make the students learn as much as possible about the operations. For example, when teach students on electronic charts, there are two systems, one from a shipping company, the other from Kongsberg, and their operation is completely different.*"

4.1.3. Challenges in maritime training and education programs/activities

The most prominent challenge in maritime training and education on bridge equipment operation is the vast number of onboard equipment and the diversity of models. While the basic functions of the same equipment remain the same across brands and models, the way they are operated may be significantly different. Given the time and resource constraints, MET institutions can only use 'mainstream' equipment for teaching demonstration and practical training. As one participant commented, "*for example, electronic charts, the electronic chart installed on ship must be trained by the manufacturer. For colleges and* *universities, you cannot install so many different electronic charts. You can choose one or two at most. It does not make much sense if one-sided emphasis is placed on the use of the actual equipment. How many real equipment can you provide? The cost of a set of actual equipment varies from hundreds of thousands to millions, and thus how much investment do we need?*". The associated issue with the diversity is the pressure on MET to expose students to different equipment types as much as possible. However, this may bring more confusion to students. "*For example, the operation method of route charting is completely different on equipment made by different manufacturers. Students practised route charting on Kongsberg equipment. Later they get confused when they work with a different brand in a shipping company. The function is the same, but operation methods are different. Because they have learned about two kinds of equipment at the same time, they may get confused with the two. I think this confusion may raise safety concern on ships*".

The increasing complexity of on-bridge equipment is another challenge. An expert in USA expressed: "*It's a bit of a bad case of synergy .... I'm thinking about it could be AIS and ECDIS or ARPA and AIS, and then we can look at the AIS on the ECDIS too. I think that there are three and four levels and the GPS coming in. I think that's where this tremendous complexity, confusion, loss of situation awareness seems to enter for me*." And "*Yes, even the manufacturers try actually to be innovative for the market, so they bring in new things and it adds to more confusion of the students.*". With the fast adoption of advanced technologies onboard ships, the demand for skills on seafarers has been increasing. This has placed significant pressure on MET. "*Both our college and the training institution feel that the pressure is very high. In case something is missed and not taught to the students, we could be liable for accidents caused later because more and more things are regulated by law in much more detail*.".

All the groups were concerned about the differences between the implemented training systems and the actual systems onboard the vessels in the real world. "*We do the Kongsberg series here, and we have some issues with students and even me going to other vessels, using a different system, like Transas you know, something like that. And it's a good course, but you know, unless you go on a vessel that's got the Kongsberg system on, it's really just a basic course to let you know what's there. And then when they go on the vessel, they have to do their own in-house training for that particular system on that vessel, right?". "But again, this is the problem with us right now. The kids are trained on Transas which is pretty easy. It's much easier. It's much more like their iPhones. They're pretty cosy with Transas in a lot of ways. And then we go to the Raytheon model on the ship, and they're a little bit lost because they're punching, they're looking for cards, they're looking for menus that are not as obvious."*. "*A simple thing like route laying even, the Transas way of doing it is different to the Kongsberg way of doing it. I'm talking about a very simple task. So, you can imagine if you go into the more complex menus.".*

Another group even went further for the ecological validity of the shore-based simulation. "*I do not think it (simulation) is real enough, it is very different from the reality. When teaching on the simulator, assuming that a 100,000-ton tanker is given to me, with the given ship data, I don't want tugboats because I can operate it without them. But how can it be possible in reality? There is a big difference in the manoeuvrability of the ship in simulation and reality*." "*There is also difference in the simulation environment including the virtual environment it presents and the kind of environment and pressure that we, as operators perceive*." "*Although we keep telling students that as soon as you step into the room, you just pretend as if you were on board, the students wouldn't think that they are on board. They would think they just entered a playroom, and it does not matter if there is collision*." The pressure imposed by simulator operations, or the degree of attention required of the students is hardly 'simulated' to the level of authenticity close to real world scenarios. "*This has also constituted a problem for our teaching and training when it comes to a debate on whether simulation can replace real on-machine operations in the real world.*" However, simulation has also its strength. "*The scenarios and content of onboard training is limited due to the training conditions while with simulation systems, far more complicated and extreme scenarios are possible*.".

Another challenge is about the quality of students enrolled in the nautical programs versus the amount and level of theoretical teaching in MET. It is commonly accepted among several groups that the quality of students coming to the nautical programs has been declining over the years due to competition from other industries offering much better salaries or working conditions. "*I think the real problem is that the quality our students has become increasing low. How can students be admitted to the program with a score slightly over 200 points while the normal minimum for admission is 400? How can you train them into good pilots? I provide three trainings every year for people wanting to be a captain. I can see that the overall quality of the crew has worsened a lot, and it is impossible for them not to have accidents at sea. Some of them should never become captains. How can crew with such quality command a ship? But in the end, they all become captains. This is the real problem. I don't think other things such as equipment and instruments cause any problem.*". The consequence of lower quality students results in compromises in teaching fundamental theories. "*Given the quality of our students, it is impossible for them to learn all of it. In my opinion, it's not bad if they can just master the main content.*" The compromise in reducing teaching of theories is somehow justified by the misalignment of competency assessments and sometimes, the irrelevance of the teaching contents. "*The theories are too much and complicated to the students. Also, much of the theories cannot be used on real ships. This leads to stress and lack of motivation from students*." In addition, "*students will forget all within one year on board if they do not use it in reality, no matter how well they have learned.*" "*Another point is that the tests from the Bureau of Maritime Safety only assess some key points, and this kind of can be reasonably predicted. So what's the motivation?*" One participant echoed, "*that thing (theory) is not practical after boarding a ship, right? So why bother?*" Another added, "*theories should be simplified so that students can understand the simplified theories and master the actual operations*."

From a slightly different perspective, the North American groups expressed similar concerns about inadequate education background of some students obstructing their ability to learn as much as others can. "*One of the problems is we have maritime academies here in the United States and these young kids probably, like the rest of the world, they're college educated kids and they're smart. But there are some people that come from a little bit of a struggle down in like the Gulf area and they're great on deck, but they just haven't been in the classroom as some of the other kids. So, when you get someone that's just trying to pass the coast guard exam and just trying to know what's on the test, when you put that person and they're good enough just to get a third mate license.*". In a similar way, new technologies and increasing complexity in navigational systems have become challenging to some senior students. "*The younger generation are fairly quick because they've been brought up on computers. They can get everything fired up within five to ten minutes. However, some seniors may struggle.*"

Due to the limited time and resources, MET can only provide training with what is available and to the extent it meets the STCW. The variety and complexity of navigation systems requires on-going training or self-learning to be competent on what they operate. This is not always possible. The USA group revealed that there have been obstacles in continuous training of their students after they have finished the training courses. "*They go out too, they learn to use ECDIS. It's modern, there is redundant ECDIS on board the ships. They're treated like young adults and they're trained very well. And then we get kids going out on the* *lakes and some other places, and they come back, and they tell me that they weren't even allowed to touch anything and have been told that's no good. It's poor mentoring on the part of the ship's crew.*"

The Canada and USA groups expressed the challenge for MET to keep up with the industry as more and more technologies and applications are being adopted. This problem is associated with both human resources (trainers, simulation operators) and system updates. "*Well, one of the issues we have is the radar that's built into the Transas simulator. It doesn't really function as according to the latest marine radar performance standards…. For example, if you turn on target history and then change scales, then the target history resets. Whereas according to the performance standards it's not supposed to do that. So, that's one of the issues I have, is the way that works.*". "*I think I paid €325 to do Safe bridge training on how to do the Raytheon on ships because it was different from the Transas. And it took me a couple of days to work my way through it, but it was quite adequate actually, to be honest.*".

4.1.4. Challenges on operating onboard equipment

All groups raised the concerns about the complexity and fragmented adoption of onboard systems both across different ships in general, and on the same individual ships specifically. This issue can hamper the decision-making ability of both students and seafarers alike leading to serious safety concerns. "*I run exercise with the electronic charts where I get them to run the exercise for half an hour and then I switch the GPS off and they're happily navigating still because there is, they just see only a warning. They don't know what that warning is. And then they see for themselves the ship navigating on land on the electronic charts but with the radar it shows it is on water.*" "*The students are confounded by the reality of the real world when they realise that not everything operates like a Transas simulator."* The complexity of the onboard system is also obstructing the possibility of the operators in using the full potential of the system. "*Especially when you join a ship and you are brand new. You can use always basic tools, range and bearing and if we are an experience mariner, you'll use it. But can't use to the full potential of the equipment.*"

The continuous introduction of new functions and abilities into the already complicated system further amplifies its complexity. "*This (the complexity) is becoming a problem after the introduction of ECDIS. Before that, radar was relatively a simple tool. There can be different designs, different display and different options, but functions are limited. So, it's easy to switch from one brand to another. But up to the introduction to ECDIS, everything becomes more and more complicated and there are totally different manufacturers. They have different versions and they are updating their own equipment yearly*." The increasing complexity requires the operators to have a thorough understanding of the equipment under operation in order not to miss any important information. "*So when you go to interrogate a lighthouse, if you don't have certain things turned on in charts for example, like text or buoys, you're not going to see it on the actual screen when you customise it if you don't click certain boxes in charts. And I don't want to run on and on. But the point I'm trying to make is it's very sensitive now. So, you really have to know what you're doing basically, know the steps.*". Participants also expressed the concerns about possible over- reliance and emphasis on electronic equipment at the expense of experience. "*More complex system with more information is given, the importance of experience becomes of less relevance and importance and this worries me*."

The reliability of electronic devices on the bridge is another concern. "*And the charts were all right, you know. It was all right until the screen went blank. Then there was a bit of a panic, right? But there was no back up, no redundancy. Nobody really knew how to use the ENC or the laptop and get it back course, because it had always been on. And then an alarm went off,* *and they were trying to figure out what the alarm was.*". A North American group raised another issue of the ECDIS system when the zoom scale is changed. "*And people were in shock. These are some of the best sailors in the world, how could this humanly happen with the zoom? When you zoom in you'll get all your depths and numerous other information. But once you go past a certain scale that you should pick up because you'll get a red flag, but there's just so many things on the ECDIS that people become oblivious to. What happened is they were on the wrong scale and the wrecks weren't showing and they ran aground. And I see that all the time with the students. A lot of the mistakes when you read like the doomsday scenarios and ECDIS around the world, so many of them are scale oriented.*" The reliability may be related to the performance standards of the electronic devices, which could be a problem as the speed of introducing new equipment may be faster than the updates on performance standards. One participant raised the concern. "*Another issue I see coming that hasn't really raised its head yet, is performance standards for ECDIS are now 12 years old. I kind of feel that there's going to be a change coming soon. So, it's kind of like the new alarm regime that they introduced two years ago that we're just now getting on top of. I can see some more changes coming in the near future that confuse me even more.*"

The current onboard alarm systems attracted considerable attention and discussions among all groups. The first issue is the inconsistent meanings attributed to alarms with various visual or audial signals in different volume levels, frequency, and tone. "*I've observed through the years just the students looking at an integrated bridge control panel and not being able to determine, we've all realised this, not being able to determine where the alarm is coming from, what the tone of the alarm is, the electronic beeping signal and all, we're familiar with the problems associated with that.*" This was confirmed by another participant. "*The sound varies according to different models, the collection or judgement of information also varies greatly, and this can be very distracting and sometimes dangerous.*". "*There are too many alarms, and people simply become very insensitive. Few years ago, a ship ran into a pontoon and stranded in the Malacca Straits. There was an alarm when the ship approaching the shallow water. However, because there were so many alarms, people did not notice it, and paid no attention. That was it!*" The extent of the problem may depend on the experience of the person in concern. "*It may be easy to tell for an experienced pilot. The newcomers may be confused about it.*" "*Unless you can do a much better job on board, I was un able to tell the sound when I first worked on board. It took me two or three months to get used to the alarms including AIS, VDR, C station, radar, fire and sewage. There are many alarms you can tell and may know where to find them after a while.*"

Furthermore, the pitch, volume, and frequency of alarms sometimes can be very distracting and annoying. "*The echo sounder up on the ship simulator is exceedingly loud, hideously annoying and very persistent and it causes them to jump. Whenever the echo sounder goes off, when the transducer crosses into shallow water and they literally jump. And they all, including me, officer in charge of the watch, we'll all jump on the console trying to silence that echo sounder.*" This intuitive reaction demonstrates a potential risk that a warning may not be timely and appropriately investigated and acted upon, which may lead to the eventual accident. This was elaborated by another comment. "*It is very mechanical anyway. There is an alarm when the ship encounters a change in water depth, crosses a bathymetric contour, or something else that may have nothing to do with our navigation safety. But the alarms keep the on-bridge crew constantly on the run. They may be very nervous at the beginning, but as an old Chinese saying goes, they no longer brother if the alarms are too frequent. What are they going to do if they no longer bother? Some may turn it off which may cause significant risks*".

The reliability of the alarm system itself can be a weak point. "*Because the sensor is faulty the whole night alarms are ringing*." Faulty alarms may result in insignificant attitude of crew on bridge toward all alarms without discrimination. "*And I'd really get on the mate sometimes because they just hear the ECDIS alarm, they hear the GMD assess alarm and it's just like, that's just another alarm.*" In some cases, extreme measures may be used to 'silence' a faulty alarm. "*And we couldn't isolate it (the alarm), we couldn't turn it off, until the electricians actually cut the wire.*". These actions and reactions toward alarms may potentially pose serious safety risks.

Moreover, the complexity and uncoordinated nature of alarms on bridge brings further issues. "*Alarm management is becoming a big issue, I think, and the thing about that is you join a vessel and its alarm system is different than the previous one. And our latest, the last version of ECDIS has a very complicated alarm system. Maybe there are, you've seen all 16 different options. So, it is difficult to distinguish which one is which. So, it's very difficult to identify which one is more important or less important.*" To make it even worse, manufacturers from time to time add more alarms to their equipment. "*I mean we've already got the bridge management, the bridge watch alarm system. It just seems like every time we have an issue, we throw more alarms at it. And it's getting to the point in my opinion it's becoming counter-productive. There're too many alarms.*"

Finally, some electronic devices onboard cause light pollution on the bridge due to the inability to adjust the brightness. This includes some of the visual alarms. "*The ECDIS is the worst, the brightest, you have to go around the panel, put your face in the window to see anything… Lost your night vision, yes… And you couldn't see anything. We had side-by-side chairs. It was not a supply boat, but... Until you got it around the console, you were almost blind looking ahead. And it was the ECDIS. You'd hang over the ECDIS to see.*"

4.1.5. Challenges of MET for the implementation of S-Mode

It was a consensus among all focus groups that information on S-Mode was scarce, be it the S-Mode itself, or its development. Consequently, the discussion on this topic was very limited. Most of the comments were about the absence of information on S-Mode and how this may affect their preparation for the implementation. As commented, "a*ctually I believe it is difficult to say without many things before seeing the S-mode*.". Equally, it is difficult to identify the possible challenges for training on S-Mode. "*If we can somehow be a party or to update and what's going on and what's being decided on and what they're thinking about putting in S-Mode, then it won't be just sprung on us at the last minute*." This was echoed by another participant. "*Well we need to find time to prepare. That's always a concern of mine, it's one thing to say we're going to do this. Time is money, money is time. We're all full, our schedules are full as teachers. Our students' time is full, so that's a concern. But we need a very concerted co-ordinated top-down directive, guidelines for moving ahead in this area.*"

In addition to the concern about the lack of information on S-Mode, some groups expressed the concern about the potential cost associated with the implementation of S-Mode. "*You can have a great system or a piece of equipment. We can have a wonderful simulator and if the person behind the exercise, there's always a person, and if that person messes it up and can destroy the training for the students. So, whatever we spend or whatever we think about, it comes down to money.*" "*With the S-Mode I guess the challenge for the Maritime Education and Training Institutions is more, like, how does that happen? What kind of capital expenditure is required to flip the switch, and now you've got, what existing equipment you have turns into S-Mode equipment.*"

Some groups raised a broad issue about the potential resistance to the implementation of S-Mode. Standardisation, if not managed properly, may impede the motivation for innovation and continuous investment in research and development. Another concern is the protection of intellectual property where mandatory standardisation may deprive the intellectual properties of some products. It was observed that the resistance may be from the manufacturers. "*The greatest resistance may come from the manufacturers. Profits and intellectual property protection are the main sources of resistance.*" "*The problem now is that manufacturers may not have much profit. No one will do something without profits. If standardisation does not bring profits, it hardly motivates the manufacturers*."

4. 2. Suggested features of S-Mode from the MET perspective

While guidelines on S-Mode have been developed based on wide survey on seafarers and discussions with equipment manufacturers, as an important stakeholder of seafarer training, MET institutions have had little involvement in the last ten years in the formation and development of S-Mode. This project objective was to seek the viewpoints from the education and training personnel on features that should be included in S-Mode. These viewpoints may be served as a comparison with the actual guidelines approved by IMO and will be released late this year. The proposed features may also be used as input for the continuous improvement of the guidelines for S-Mode. A wide range of topics were covered during the focus group interviews. A number of key themes were identified after the qualitative data analysis and will be reported in the following sections.

4.2.1. General suggestion on S-Mode

The discussion of possible features for S-Mode started from the purposes of developing S-Mode, based on which the structure, function, and management may be developed. "*First of all, what is the purpose of using S-mode? It is to solve the problems we may face with unfamiliar equipment when we move on to a different ship. If after you have worked on the ship for two months and you still are not familiar with the equipment, you will have to always use this standard mode. These standard functions may not affect your daily duty most of the times. If you feel comfortable with it, you shall keep on working in future, and also learn personalised information or be trained by your company before you work on board. But I believe the S-mode is not the solution for daily use, is it right*?"

For others, standardisation should be more on the consistency of the layout, terms, symbols, and menu structure across different brands, models, even different equipment. "*What I suggest is S-mode should be related to the layout, names, the menus, interfaces, symbols but they should not be related to the preferred setting. Because I can prefer, for instance let's say a north-up setting, but this will not be achievable in some situations. So, I don't think that there is one perfect setting which will fit all different types of situations that we can face with.*" One group suggested that the standardisation should focus on the interface and the information presented. Another one commented, "*Standard display was helpful, but it missed the mark a little bit. I think that standard display is the embryonic version of what we're trying to get with S-Mode, if you will. It was a good idea and they had the right idea, but we've got to move a little beyond that at this point. You would like to just be able to look, see what chart you're on, say your safety depth and safety contour, have certain settings pop up right then and there. You do not have to dig around for the real basic stuff, not have to dig around for it.*" It seems that S-Mode should make operating equipment easy and intuitive.

4.2.2. Structure

The current navigational system is considered too complicated with many functions being never used. The development of S-Mode is considered an opportunity to simplify the interface and function in addition to 'standardisation'. As a North American participant commented, "*I keep thinking about menus and sub-menus and positioning of controls.*" And: "*The interface that has to be simplified if you want standardisation. So, if it is like for example, GPS, let's have one button which will give you the function put your waypoints in. It's not having to dive into submenus to select your waypoints.*" In another group, one participant commented, "*there are too many things and too complex indeed. The excessive functions and information are overload for the officer on watch. Sometimes these are burdens and do nothing good to the safety.*" Another participant added, "*The software should be simplified into fewer items. Just like the computer or smart phone, it is too slow when the software or applications are too many and too complicated. The most common and essential functions should be included. Others can be referred through manual instructions*." "*For example, I usually use the basic target tracking of navigation surveillance and fix position in radar, many other functions are never used.*" "*It is not necessary to put some unused functions into the standard mode. The less items in the main menu, the better for crew. I only use a small number of functions all the time.*"

It was suggested that there should be a pre-defined structure in S-Mode so that functions in all devices are presented in a structured menu system. "*We should try to list the main function and their order and then simplify the interface. Just put the most important and common functions in the first menu layer on the landing page so that key functions can be operated directly without needing to dig around. Other functions that are not particularly important or common can be shown on the next level in the menu.*" A simplified structure will facilitate the duty transfer when personnel replacement occurs. It will also speed up the process of the replacing officer to get familiar with the new on-bridge navigational system. "*For duty transfer on the bridge, because only a few functions and buttons you use, what the replacing office will ask is the main functions, and the rest will be learned later, and it won't affect safety.*" "*If the main menu is standard, the submenu should allow personalisation. It is the same as using a mobile phone, right? You can move the APPs as you like. For example, I'll put WeChat on the first page of the screen. If you think that something is frequently used, the button of which can be shifted to the right position on the screen (for easy operation). For an electronic chart with a touch screen, the commonly used buttons are moved to the position near the hand, and other uncommonly used ones are placed at corners. There are only a few buttons that are commonly used. It is good to have this function of moving buttons on a touch screen*."

4.2.3. Personalisation

All groups suggested that there should be a function in S-Mode to allow personalised setting to be saved on the machine or in an external device, e.g. USB. The saved settings can then be uploaded to the next navigational system when the person moves to another ship or reassumes watch duties. "*Like I said when you make up these routes, if you could just save it in that customised setting like a voyage plan instead of having to, when you reboot it you always have to, when you make any type of plan, you have to do it in custom. You have to go through the whole process again. When you sit and make up a voyage plan and save that route, too bad you couldn't save it in that customised route.*" "*A function to allow people to actually make adjustment using their preference and then record it as this. And the next person can do exactly the same thing. So, you exit and the next one can come in and there. Use their code or whatever. The way they want. It's the same concept of the mobile phone. People use their mobile phones differently. But it's a standard set of keys there*." One participant moved the idea of saving personalised settings even further. "*Would that be again, be nice if we have some things there around merchant and navy, around the world, we have a cloud-based* *system where all the seafarers would be able to save their preferences in the system. So wherever, whichever ship they go, they just use their ID and bring up their setting*."

4.2.4. Priorities for standardisation

Given the complexity of the onboard navigational systems, participants were asked the priorities of standardisation in S-Mode. The electronic chart display information system (ECDIS) was the most discussed equipment among all groups. "*All the manufacturers have widely different method of doing a manual fix on the ECDIS and I think that's a critically important feature that a mariner needs to learn and be able to use confidently early on. So, I'd like to see a little bit of a move towards standardisation in that also*." With ECDIS, target tracking was the most frequently discussed function for standardisation. "*Target-tracking information that should be standardised similar to the way that the IMO navigation symbology has now been standardised. I think that would be a huge step. Standardising the information about the status of the samplers providing input would make it a lot easier for the watch officer to verify that their inputs are valid or at least that their inputs are still coming to the ECDIS or the radar as they're required to. I think that would be an important piece too*." Another area of concern in ECDIS is the setting. "*When you set your safety depth and safety contour, everything that you needed, not a cluttered screen. But everything that you needed, isolated dangers without turning on spots, everything popped up. And your track line came up with specified parameters that you could count on. Now that could be way over simplifying it. It's going to be a battle over what gets picked.*" Route design in ECDIS was also a function that requires standardisation.

Radar, as one of the most used equipment onboard, attracted much discussion on standardisation. "*For example, safety related, motion pattern settings of Radar, can be standardized. However, those personalised functions can vary, such as the function of tuning and gain, pattern of true motion and relative motion*." "*The most important thing we use radar is the movement information of ship. Therefore, the most basic function is the position and speed display of my ship, the position, speed and course of other ships, which can be used to determine directly the risk of collision*." Another participant added, "*motion vector and Bow-Up display in the radar, are the most basic information, and then the tail track, the target track and acquisition. Display of the information of CPA, TCPA, and so on, are the essential functions. Rain and snow suppression are basically involved in Radar adjustment. Standardisation is better and more convenient for crew to adjust in the same way*."

The automatic identification system (AIS) was also an area of discussion for standardisation. "*At least, I can change the setting status in AIS when the ship is berthed in the port. Essential functions must be obvious ad upfront. Like now, menu usually comes out, because the next step is still set the status of ship, and you have to return to the previous menu. It is best to display the content in the screen according to the priority level*." "*Can you list the most important things in order, define what is the most important and what is the second most important? I think this list is particularly important.*" "*In terms of AIS, list in order by distance and degree of danger, for example, there are so many ships in Singapore, but only 200 of these ships are displayed on the screen. Other ships are never displayed at all. There is a good chance the No. 201 ship could be more dangerous than the machine thought*."

4.2.5. Alarm system

Since it attracted considerable attention during the interviews among all groups, the discussions on the onboard alarm system is presented in a separate section. As discussed earlier in this report, there were many concerns about the onboard alarm systems including the number of alarms, inconsistent meanings attributed to alarms, the excessive and sometimes very disturbing frequency and noise levels. Many suggestions were given during the focus group interviews.

Number of alarms

A North American participant expressed, "*There're too many alarms. At some point we have to rely on the mariner's expertise and knowledge to gather the information on their own rather than be automatically alerted about everything. Yes, a lot of things are important enough to require, to demand an automated alarm system but a lot of this other informational level stuff you can let the mariner figure that out for themselves*." Another participant commented, "*If we developed the protocol, would it help? And it is possible that that would help, but not if you've got gazillions of nuisance alarms.*"

Protocol

All groups suggested a protocol on the alarm system is needed. "*So, alarm management is important. And I think it's becoming more and more difficult on S-mode*." And "*Actually I believe that whatever it is, it can be audible, visual or sound, that should be a standard. Because now the manufacturers are creating these standards in the market. It is good actually just to improve the technology but on the other side, users or operators suffer a lot. It's changing very quickly, so that should be a standard. Mariners should be feeling comfortable whatever the brand name is, at least he will hear the same thing, he will see the same thing*."

It was suggested by participants that all alarms are defined by priority. As discussed in the groups, the alarms on the bridge can be divided into groups with some alerting dangers, others reporting fault instruments or equipment, and the rest being reminders. "*There are so many alarms on the bridge, some report fault and others just routine reminder. Whether an indicative alarm or failure alarm, it may have same noise. In the future the failure alarm should be with higher priority to display. The effect of the alert should be stronger, and the reminder alarm should be friendly*." "*Even with failure alarm, there are many kinds of faults in your machine, such as the main engine fault, the ordinary machine fault, right? You can distinguish them by colour or noise depending on what criteria based on, safety standards, pollution-proof standards, or machine types*."

One participant suggested, "*you have to categorise them into collision hazards and others, or classify from emergency such as fire alarm, which should be in high frequency noise. If it is not urgent, the alarm may be lower, and the sound is softer. If two different alarms go off at the same time, the officer on watch can confirm which is emergent and respond as soon as possible*." "*For example, when a ship is entering or departing a port, the priority for the officer is to avoid collision. The alarm of the GMDSS obviously do not need to be dealt with urgently. We can press a button to turn off the audio of the alarm, then I'll deal with it after clearance of all ships or hazards. However, you should never turn off some urgent alarms such as fire alarm or failure alarm of main engine. An appropriate priority must be considered in many different situations during the navigation*."

Traditional alarms use audial and visual signals, both of which have certain limitations. "*It is possible that in some cases you may not be able to receive effective warning. In setting these standards, all manufacturers should follow the alarm protocol on alarms. Some alarms are directly related to safety of ship, for example, risk of grounding or too close to the dangerous target. These alarms should come with orange colour or high frequency noise. If general reminder alarms go off too frequently, the officer on watch will get tired eventually and don't pay attention to them.*" "*I think the sound of alarm must be graded, for example, sharp voice for the most dangerous, and lower voice for the second dangerous; red light for the most* *dangerous situation, orange for the second most dangerous, and so on*." "*There are a variety of alarms in Radar or ECDIS, we can set the alarm on or off. The main selected alarms go off either sound or light. In other words, the officer chooses which alarm should be switched on. Of course, some alarms should not allow for switch on or off because they are the most important, ones such as collision danger*."

One of the problems with alarms is the immediate and readily available information about what the alarm is and where it is from. "*For someone new to a ship, he would not be able to tell what it is and where it is from when an alarm goes off. This gets worse when there are several alarms beeping or flashing*." This brought the idea of turning alarms into voice message. "*If the alarm can supply more accurate information directly, for instance, I hope fire alarm can set as a voice of 'fire alarm'.*" This was echoed by another group: "*On an aircraft, like, the alarms will come out and tell you what the alarm is. You know, the voice will tell you what the alarm is. Where on a ship it's just a different type of alarm, right?... And we have been, like, an hour trying to figure out an alarm, where is it coming from? Where's the flashing light? There's no flashing light. There's nothing there. And everybody's ready to kill each other*." And "*There was nothing else. If we had heard that alarm on the ECDIS, we would have looked straightaway and seen it, but we didn't know what it was. There was no indication. Where, if you had been on an airplane it would have said, warning, gyro one failure, gyro one failure. You would have known where to look, right?*" However, one participant commented*, "voice message on alarms may be good in the open ocean. In the situation of entering a port, the voice alarm is more sensitive and may be less recognisable and less alerting among all the noise and conversations*." Another participant added, "*I think it would be helpful to use voice alarm. But if all alarms are made into voice, it would not be good due to so frequent alarm, such as so many alarms of radar. If the most urgent alarms are in voice message, four levels can be set from higher to lower priority*."

Integrated alarm systems

All groups suggested that somehow all alarms on bridge should be managed centrally and in an integrated way. "*Having a central location to have all the alarms, even to the point of it being on separate panel, I could just imagine some electronic manufacturer saying, we'll just put that on the sub-menu two layers down. This has to be like the fire alarm which is in its own box, separate. That's my feeling on it."* And: *"Can you centralise the alarms? If you look at the core concepts of navigation, either you will lead to collision or a grounding or stranding. So then can't they integrate these alarms with pull down to say what is contributing towards okay, now it is a collision warning. So, there is an alarm saying that there is a collision warning. And on submenus, that drop menu, it will say right, it's your speed, it's your depth so you know you'll get a pre-warning too*."

The centralised display is helpful for the crew to determine the source of alarm quickly and clearly. "*It will be very clear what and where the alarm is when you look at the centralised display panel. This thing is better. The control panel displays what and where the alarm is, and the details will come out when we press it*." "*It can get a comprehensive panel to prompt the alarm at that time, and it is more convenient to confirm where the alarm will be found. Anyway, this should not be a technical problem. Can it be displayed on a more prominent position on the bridge? such as a screen on the front window where almost all the alarms can be displayed*." The display location and content of the alarm panel should also be carefully considered, and the Head up display (HUD) was one of the recommendations. "…*actually, these alarms or other information from equipment and machines can also be displayed on the front window, which is the same as what we use in the car now. It is the most effective and graphical way and may need a unified standard*." One participant added, "*Because ships are* *getting larger, and when I look for the alarm over here, another is ringing over there. I even don't know what it is, so I have to check many alarms. It takes lots of time to check every alarm and keep walking from the left to the right. The contents of the information should be displayed according to the priority level, so that the duty officer can judge and deal with those alarms accordingly*." For the idea of using HUD, one commented, "*If all alarms are displayed in HUD, it is too much. I think alarms with high risk should be displayed there, and the others not. Because you don't have time to keep a close watch on HUD, you might miss some alarms soon. In addition, the duty officer must keep night vision at night, even they cover the equipment to reduce the brightness, the light from HUD will not suitable to keep good watch through the front window*."

4.2.6. Other functions (diagnostics)

In addition to standardisation, suggestions were also made on features or functions that are currently unavailable or are not user friendly in the current systems. Some important and interesting suggestions include fault diagnosis, automatic pop-up menu help, and operation cancellation. "*I think they'll have to harmonise a system where they pick the errors where they can sort of probably adjust them or give a user warning, saying, this integrity. Like the GPS rain connection, receiver autonomous connection. It tells you, gives you a warning saying don't rely on this position because your satellites are not positioned well or the inclination angles are not working well.*" Another participant agreed, "*And then you're totally overwhelmed because you don't know where or why it's happening. So, of course, there's a solution to that. You get a diagnostic computer. You attach it to it, and then you can zero in on what it is.*"

It is considered a user-friendly design if a help menu pops up automatically when the operation is wrong or inappropriate. "*The help menu is only available on ECDIS, so the first thing is to simplify the interface. Secondly, a help menu should display when you made a mistake. The menu should be as simple as possible so that people can understand clearly*." In addition, "*In order to prevent operation by mistake, a function should be set up by operating two hands or two keys together. Such as distress alarm must be launched by press two keys at the same time*" This suggestion was supported by another interviewee, "*operation by mistake should be reversible. Especially, it can't be pressed again when it failed during communicating on the GMDSS. Otherwise, you will be in trouble if you launch. If you found mistakes in operation, you can cancel the process by pressing a button or a key, similar to the revocation feature with time limit of Email or messages on WeChat.*"

4. 3. Concerns of approaching S-mode from the perspective of METs

An interesting point about the implementation of S-Mode is the concern for innovation in navigational technologies. One group suggested that an aggressive approach to S-Mode may obstruct the adoptions of innovative solutions and new technologies. "*The more we tried to standardise these interfaces then the less room that the manufacturer has in order to develop new functions and new features that might be valuable*." "*I agree, we've got to think about the new inventions. They have to come in so there should be a room for them to come in as well.*" There were also concerns about the effectiveness of S-Mode implementation, especially when related to safety. "*I'm not always sure that more interface makes a safer environment.*" And "*And when we spring the S-mode in here, we need to make sure that this is not how it goes, well, we've got S-mode now and it's just another darn thing. We can't do that.*" Another one added, "*They all think they have the prettiest, and really it comes down to putting lipstick on, what's the phrase, putting lipstick on a duck or something?*"

While there was a bconcern about the timeframe of S-Mode implementation which may not allow enough time for MET to prepare the appropriate resources, the other side of the concern is the inefficiency inevitably exist in the process of regulations and the time taken for subsequent enforcement. If this occurs, a new system may be very much outdated when it is put in place. "*Like when I teach I always, not to get offbeat, but if you look at our industry you can see and here's a textbook example of that. When GMDSS gets implemented by the time, once was a bureaucratic IMO system and it actually went on ships, it was already outdated. That's how fast technology moves."* Another agreed, *"Well, I think we've kind of touched on this a little bit without coming right out and saying it, but S-mode's been talked about for a while, but it never quite gets that enough inertia to come to fruition."*

The possible over-reliance, either intended or unintended, on S-Mode may cause some safety concerns among MET. This could also create tension between teaching the conventional and essential principles of navigation and the simplified operation of navigational systems. In addition, as the nature of human-being goes, there is always a tendency of finding alternatives. "*We have to educate our seafarers. We have to keep on stressing the basics of safety. We have to keep on teaching them that. Because they will definitely find a backdoor… Like there was a sensor on the bridge, deadmans' alarm. You are supposed to walk past the sensor. I read an article where seafarers, what they did was because they had to walk all the time, they did not do that. They just blew up balloons. The balloons kept flying in the bridge and those balloons were acting as motion sensor so there's always a backdoor, isn't it? We always find a backdoor. A hack.*"

One group stated that overreliance on the features of S-mode may compromise the ability of operators to solve problems during complicated situations. "*But now education part of it is where we tell them the standard mode is not the safest mode to operate it on. So, there you are going in for the operation of communion. So, ground stabilisation, today there is as auto ground stabilisation. But does the student know if that auto fails how we should go back into the manual settings of it? So, it's up and down.*" "*People will adapt themselves to that very fast and they will not look beyond the window. So that's the danger.*" One participant added, "*When I read it first, that was my fear that well, then, why are we learning all this other stuff when S-mode is sufficient? Are we taking our standards way down?*"

However, some experts believed that the impact on current educational institutions is not too obvious. "*In fact, we always change no matter what you change, how to change, or not to change. Because the entire training in our country has a guide from China Maritime Administration, which will constantly revise the outline of knowledge according to the development and environment of the industry. Basically, every five years, or three years, crews must update knowledge in the training institution. Therefore, we must keep up with the new era of standardization, new technology, new regulations and new developments. So from our training point of view, we have been changing frequently in recent years, to be honest, new device are put into MET. The second, teacher's teaching idea and method are also update. Therefore, it will not have a significant impact on MET because of the promotion of S-mode.*"

Some believed that S-Mode may reduce the complexity and difficulty of training onboard. "*We can teach students to operate the equipment according to S-mode, that is to say, there may be such standardised menu and text in any device in future, and the rest is non-standardised, and it is more convenient for us to teach. After the students have finished training, no matter what kind of ship they go with whatever equipment, we know they will be able to operate the equipment.*" However, standardisation may also bring some negative impacts on maritime education and training according to some participants. "*If S-mode were used, substantial impact must not happen on the safety of navigation. I am afraid that the* *teaching and training or evaluation will become too much focus on one thing*." This may also create some inconsistent outcomes from MET. "If S-mode is implemented, the lower level training institutions may teach this S-Model only. That is very bad for students."

4. 4. Suggestions on the optimal approach of METs on S-mode

All groups suggested that the MET institutions should have been given more information about the S-Mode and its development and implementation. "*If we can somehow be a party or to update and what's going on and what's being decided on and what they're thinking about putting in S-mode, then it won't be just sprung on us at the last minute*." Another participant added, "*We need the updates coming out from somebody, Nautical Institute or somebody saying, hey, this is where it's going. It looks like we're going to vote on. This is what the manufacturers have agreed to so far even though it's not set in stone*." It is also important that educators or instructors have the opportunity to have hands-on experience before they go and teach students. "*And then we're going to need either some kind of CBT training that the instructors can get their hands on just to run through it before they start the semester. I've done one CBT with Safebridge, and it was actually fairly adequate honestly*." "*There's got to be some kind of documentation about what the S-mode is going to be both for the manufacturers to be able to create the interface and ultimately for us as educators to try to train mariners about it. So, finalising that document in the near term, that would be the number priority so that the educators know what they're going to be dealing with. Then we're going to have to lean on the simulator, the simulator manufacturers to produce something for us to start figuring out and creating exercises with*."

While standardisation through S-Mode may reduce the time to train people to operate onboard equipment under S-Mode, specific training is still required to ensure safety. "*This is universal everywhere, it doesn't matter if you're in the Philippines or UK or the US, we can't take people through a five-day class to teach you a piece of machinery that will do about 20,000 functions specific. You can call up all these little different functions, and then we send them to a one to three-day type-specific once they get ready to go to their company.*" Another one agreed, "*so we're talking about eight days of training for a super high-level piece of navigational equipment that you're going to use to get your 90,000-tonne super Panamax shipped from point A to point B. And it's a huge expectation for a small amount of training. So, I don't think cutting back on the type-specific would be helpful because they need to know what additional features are available on that specific type.*"

As educators and instructors, it is unclear how the training will be performed for S-Mode, through simulation or hands-on experience. "*You know, so then from an education training point of view, like do we need to have the real stuff to train people on S-mode, or is it just to educate people on this is what S-mode is going to look like when you get into the industry kind of thing, right? You know, so there's that and then you get your, sort of, hands on training when you get with the equipment.*" It is suggested by one group that the training on S-Mode should come after students have passed the education requirement. "*So I think from the education perspective, we have to have students with certain skills or a prerequisite before starting actually learning all these things. And we have to build on that capacity. This is important*." In addition, with increasing information and communication technologies being adopted in ship design, students coming to the nautical sciences courses should have adequate knowledge on computer. "*I think that our students, we have to be selective. Then request a certain capability to come for our new courses. Because it's not only this one. Later on, actually all these technologies are coming, they should have a better understanding to make sure for example they have good skills of using the computer.*" However, another group suggested that the training on S-Mode may provide the foundation for students to learn more advanced knowledge. "*That would be a lot easier to deal with if we had a standard display that we could teach them and then later in the semester switch to the more advanced modes of operation. So, I think S-mode if it ever comes to fruition would be a good step in the right direction.*"

Some were very optimistic about the ability of new generation seafarers to work on new technology. Operating electronic equipment, advanced they may be, is almost intuitive to the young generation. "*And also, we are kind of underestimating our student's level. Future generation that's coming up, they're all, they take to technology like fish to the water. So, if you give them an instrument, even if they have no idea how to do, they'll just go into the instrument, dismantle everything. Well, not dismantle but they can really familiarise themselves with all the menus and all that much easier than what we were all or our or their fathers were used to.*"

In addition to training provided by MET, the shipping companies should also take responsibility to ensure that all crew are provided with necessary training especially skills related to the specific features of the ship. "*But what they have to do to make sure that the understanding and the safety has been taken care. The company, every ship should have a short training for their equipment so to make sure, like a checklist. So, if the person going on board then if they have particular system, should have a kind of training, either it is the CD that they provide for them or somebody comes and explains it. So that could be a short training for that specific equipment to tick the box.*"

It was acknowledged that every equipment would have its own limitations. This is also true to S-Mode. Underestimating or ignoring the limitations of onboard equipment may pose serious safety risks. One group made a specific comment on the possible limitations on S-Mode. "*I think the most important aspect in teaching is to tell the students its limitations. A lot of people operate radars. They don't know the limitation of the radar. They think over here a gift by god, radar, electronic chart. But they don't know they have limitations behind that.*"

For the MET institutions to be better prepared for the implementation of S-Mode, a collaborative approach among all MET institutions was suggested. "*The other approach might be those institutes that are providing these services to be better linked with each other. So, they can use their experiences, they can talk to each other. They can set up a forum for S-Mode. Those training the S-Mode they can be in contact with each other. And then they learn from each other. That's a learning experience.*"

4. 5. Issues not currently discussed

There were some very interesting points coming out of the focus group interviews. Some of these points either supported S-Mode initiative or provided innovative ideas to address the concerns being discussed under different topics. Others were about possible difficulties with the existing seafaring workforce when facing S-Mode. "*They are standardised. There are standardised icons, there are more of them now than there were 10 years ago. I think there's only, I look at my dashboard and I look the dashboard on a different car. They're all using the same symbols, that's been standardised. Electronic equipment, if you said to us 20 years ago, the power switch is going to be a circle with a little bit of a line through it.*" And "*I mean, like in an aircraft. All aircrafts of that type, like a 777 or something, everything is the same inside one. The first one off the production line is like the one thousandth that came off the production line. So, any pilot can just jump into that airplane and fly.*" One group suggested that artificial intelligence may help decide what information is needed to display or trigger an alarm. "*I see them going that way. It's more futuristic robot like I said it'll be the Alexa of the* *bridge. I definitely see that coming down the pipe but not today at my age here. But like I said the stuff that's coming out, it's unbelievable what comes out.*"

In the seafarer workforce, there is a very wide spectrum of age groups ranging from under 20 years old to those who have been in the shipping for over 40 years. New technologies are regarded very different among different age groups. "*It's harder on older experienced mariners whether it's the Navy or the Merchant Marine. It's harder on older experienced mariners to suddenly be faced with something that makes them feel inferior or uninformed in front of junior officers who come parading in there with their cell phone, their iPad and a good knowledge of ECDIS or a reasonable knowledge of ECDIS. And nobody wants to feel uninformed in front of their own junior officers. But somehow we have to move past that a little bit because until another ten years rolls by…*" Another participant added, "*I try to get that across to them because I've got older guys that are totally comfortable driving around Boston using Google Maps. But if you put them on an ECDIS and, I'm talking about the older generation, they'll freak out.*"

4. 6. Summary of results from interviews and instrument for the Delphi study

The nine focus group interviews generated very large amount of qualitative information. All the transcripts were analysed through NVivo (version 11). The key words were identified and their frequencies were then analysed. Figure 3 is a visualised representation of the key words, where the size of a word represents its corresponding frequency of being mentioned in the interviews. It is clear that 'equipment' was the most mentioned word in all interview sessions, followed by warning and problem. The result coincides with the purposes of the research project and the focal concerns related to the un-coordinated nature of bridge equipment design and manufacturing. To further analyse the identified key words, a tree map was created (Figure 4). This tree map visualised the hierarchical structure of the words or phrases mentioned in the focus group interviews. The three most frequently mentioned key words, 'equipment', 'warning' and 'problem', represent three areas of concerns. The results from the focus group interviews also helped develop a total of 55 statements, of which 14 related to the challenges faced by MET in providing training under the implementation of S-Mode (Table 2), 24 for proposed features of S-Mode from the MET perspective (Table 3), and 17 for the proposed optimal approaches for MET under S-Mode implementation (Table 4). These statements were included in the Delphi study for the expert panel to rank their level of agreement or disagreement. The outcomes of the Delphi study are presented in Section 5.

Table 2 Challenges faced by MET in providing Training under S-Mode

No	Challenges faced by MET for the implementation of S-Mode
1	In addition to operations, trainees should be better prepared to work and make decisions under stressful environment throughout the training process
2	The financial resources required to provide the right equipment and software for S-Mode training is a challenge to MET institutions
3	The lack of training of instructors on S-Mode is a challenge among MET institutions
4	A lack of information about the development of S-Mode negatively affects the implementation of training on S-Mode among MET institutions
5	Inappropriate design or operation makes the training simulation system inadequate in providing S-Mode training
6	A lack of guidelines on S-Mode training makes it difficult to develop appropriate content and materials for S-Mode training

7	Uncertainty of the timeframe for the S-Mode implementation negatively affects the preparedness of MET institutions for S-Mode
8	Infrequent software updates make the training simulation systems inadequate in dealing with S-Mode implementation
9	The current training regime (e.g. time and workload allocated) is lag far behind the rapidly increasing complexity of the bridge system
10	Time constraint affects the ability of MET institutions to provide S-Mode training on time
11	The inability of trainees in comprehending system operation obstructs the knowledge transfer process
12	The differences between the implemented training system and the actual systems onboard vessels make training ineffective
13	The inability of trainees in working with electronic devices obstructs the knowledge transfer process
14	The resistance of some seafarers in adopting new navigational technologies affects the effectiveness of training on operating the complex on-bridge system

Table 3 Proposed features for S-Mode from the perspective of MET

No	Proposed features for S-Mode
1	Uniform terminologies and abbreviations should be used on all bridge equipment and devices
2	As an essential element of the current bridge system, ECDIS should be standardized in S-Mode
3	S-Mode should include a protocol on the alarm system with universal meaning (e.g. risk level and urgency) attributed to sound and colour
4	Symbols used for the display of navigation-related information on all navigational equipment, devices and systems should be presented in a consistent and uniform manner under S-Mode
5	A “Help” function should be provided on all equipment and devices to allow users to find the required information easily
6	Terms and abbreviations used for the display of navigation-related information on all navigation equipment, device and systems should be consistent and uniform under S-Mode
7	Updates can be made to S-Mode in the process of design and development so that it will not be outdated after approval by the IMO
8	Audial and visual alarms should be strong enough to attract the attention of duty officers but not interfere with their on-bridge operations (e.g. too bright or too loud)
9	An integrated display can be placed on bridge, where all alarm notifications can be seen, accessed for details, and actioned as needed
10	As an essential element of the current bridge system, radar operations should be standardized in S-Mode
11	S-Mode should standardize not only the menu interfaces but also the location of them
12	A situation awareness system should be provided for ECDIS in S-Mode so that the information needed to set up the voyage route is automatically selected and displayed
13	S-Mode should have a mechanism to diagnose failure scenarios based on comprehensive data when an alarm is triggered
14	There should be a dynamic system in S-Mode where the possibility of dangers is automatically displayed based on the situation (dynamic situation awareness)
15	S-Mode should have the ability to allow multi-users carry out tasks simultaneously on different displays
16	A menu in S-Mode should have multi-layers with the first layer being standard and not editable and the second layer allowing users to set up their own preferences

17	Voice message warning should be introduced in S-Mode with concise information about the risk and danger
18	The default user interface of S-Mode should be able to be personalized by one user without affecting others
19	S-mode should have the ability to undo executed tasks to cancel the operations carried out within a certain amount of time (similar to recall a message)
20	S-Mode should allow personalised settings (as in statement 14) to be saved in storage (USB, hard drive, or even cloud) and loaded to another navigational system as the person moves to another ship
21	The number of alarms should be reduced with the consideration of their importance in S-Mode
22	A situation awareness system is needed for radar systems in S-Mode so that the information needed to set up the voyage route is automatically selected and displayed
23	S-Mode should be integrated as a head-up display (HUD) on the bridge where information is displayed as a layer above the real-world view
24	S-Mode should allow innovations from manufacturers

Table 4 Optimal approaches for MET under S-Mode implementation

No	Optimal approaches for MET under S-Mode implementation
1	Instructors should be given adequate training on S-Mode before they train others
2	MET institutions should use simulations or on-machine practices to allow students to have hands-on experience with S-Mode
3	A more coordinated approach is required among all stakeholders (including MET, manufacturers, IMO, research & development) to ensure the successful implementation of S-Mode
4	Students should be given clear explanation about the possible limitations of equipment and system including the S-Mode itself
5	A community of practice should be established for sharing materials and experience related to S-Mode
6	MET institutions should be provided with information about the development of S-Mode in preparing for the implementation of S-Mode
7	Students should have adequate general knowledge on operating electronic device and equipment
8	MET institutions should pay more attention to training student the importance of on-board safety measures
9	MET institutions should explain to students the relationship between S-Mode training and other existing training programs
10	Students should be taught about standardised functions, display, and interfaces in S-Mode before undertaking more complicated and customised features
11	Innovative teaching and technologies should be used to make student learning interesting and effective
12	S-Mode used for teaching and training in MET institutions must be kept the same as the one being used on ships
13	MET institutions should actively engage in the discussion and development of S-Mode
14	Students should have a good understanding of the principles and functions of all different type of bridge equipment and devices before undertaking S-Mode training
15	S-Mode training is only an addition to the existing training that is currently being provided by the MET institutions
16	MET institutions should not overemphasize S-Mode in their teaching and training
17	S-Mode should only be briefly mentioned and introduced in the training process of MET institutions

Figure 3 the importance and frequency of key words

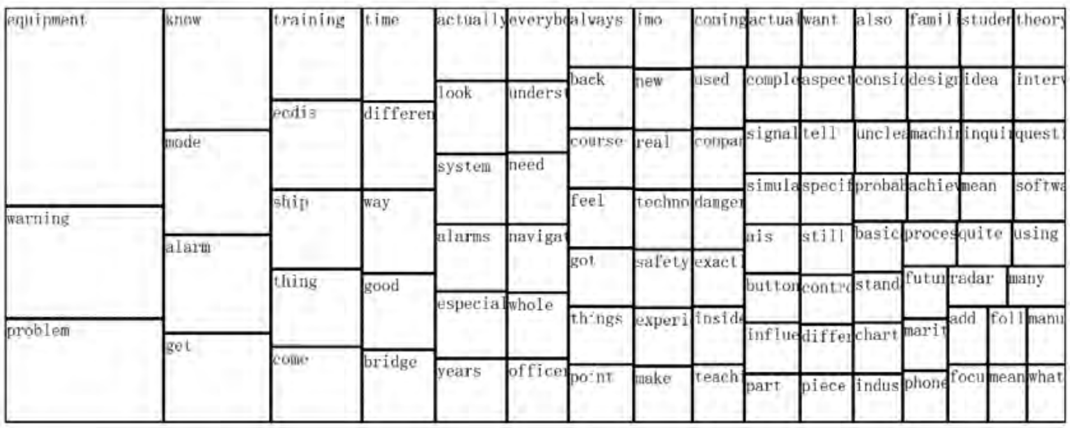

Figure 4 Tree map

5. Findings and discussion from the Delphi study

The results after the second iteration show an overall consensus of agreement among experts with all statements derived from the qualitative analysis phase reached over four in a 7-point Likert scale. An exception is "S-Mode should only be briefly mentioned and introduced in the training process of MET institutions" with a value of 3.81. Three general assessments about S-Mode were agreed upon by the expert panel. Firstly, there is a general lack of information on S-Mode. Secondly, the current communications between S-Mode advocates and MET institutions are considered, by experts, as inadequate. Thirdly, the three key stakeholders, MET institutions, ship equipment manufacturers, and S-Mode advocates do not show a strong sense of collaboration. These weaknesses may negatively affect the MET's ability to adequately prepare for S-Mode.

5.1. Project objective 1

The first project objective was to investigate the challenges that maritime education and training institutions may face in providing appropriate education and training based on S-Mode. Fourteen statements were agreed by the expert panel (Table 5). The training of the students to be resilient in stressful, decision-making environments was ranked the highest in agreement. Four types of resources were emphasised including, (1) financial, which is needed for adequate equipment and software; (2) instructors who understand and are able to transfer knowledge about S-Mode; (3) official and systematic information about S-Mode, which is needed to develop appropriate content and materials for S-Mode training; and (4) appropriate time and schedule allocated for S-Mode training. The implementation of S-Mode may be negatively affected by the inappropriate design or operation of the training simulation system, especially when the current training regime (e.g. time and workload allocated) is lagging behind the increasing complexity of the bridge navigational system. Adopting a new standard requires attention of simulation providers in updating their systems such as reducing the differences between the training system and the actual systems onboard vessels. The inability of trainees in comprehending systems operation is also a potential obstacle, especially with the tasks on electronic devices. The younger generations seem to cope well with this problem while a proportion of seafarers still resist the adoption of new navigational technologies.

5.2. Project objective 2

The second objective of the project was to propose the features that S-Mode should have for future-proofed solutions from the perspective of MET. Twenty-four (24) statements were agreed by the expert panel (Table 6). The standardisation of *location*, *terminologies, abbreviations,* and *symbols* on all bridge equipment and devices was the most agreed feature. ECDIS and radar systems were the elements of the bridge system that need the most for standardisation in S-Mode. A protocol attributed to sound and colour with universal meaning (e.g. risk level and urgency) was stressed as a needed improvement of the current alarm systems. A "Help" function to quickly find the needed information was also recommended by experts. Experts suggested that S-Mode should be continuously updated in its developmental phases to avoid being outdated when it is ready for wide implementation. Ergonomics is a field that S-Mode should engage. Audial and visual alarms should be strong enough to attract the attention of duty officers but not interfere with their on-bridge operations. Centralization of the alarm system is proposed as another feature where all alarm notifications can be seen, accessed for details, and actioned as needed. Higher level of automation is also a promising development. The ability to undo executed tasks was agreed by the panel. A dynamic and situational awareness system that can automatically display useful information will be helpful (e.g., automatic information for ECDIS in route setup, radar in navigation, and automatic diagnosis of failure scenarios). The collaboration on bridge can be facilitated by the multiplicity and simultaneous multi-tasks on different displays. Audial alarms based merely on noises can be changed to voices message with literal meaning is recommended referencing the practices in aviation. Evolution of personalised setting in S-Mode can be achieved through either multi-user mode support or external media such as a USB to save and upload personalised settings to S-Mode. Being relatively less agreed upon were the reduction of alarms, head-up display (HUD), and the ability for innovations from manufacturers.

Table 5 Ranking of statements for Objective 1

Rank	Challenges faced by MET for the implementation of S-Mode	Arithmetic Mean
1	In addition to operations, trainees should be better prepared to work and make decisions under stressful environment throughout the training process	6.03
2	The financial resources required to provide the right equipment and software for S-Mode training is a challenge to MET institutions	5.63
3	The lack of training of instructors on S-Mode is a challenge among MET institutions	5.57
4	A lack of information about the development of S-Mode negatively affects the implementation of training on S-Mode among MET institutions	5.50
5	Inappropriate design or operation makes the training simulation system inadequate in providing S-Mode training	5.40
6	A lack of guidelines on S-Mode training makes it difficult to develop appropriate content and materials for S-Mode training	5.40
7	Uncertainty of the timeframe for the S-Mode implementation negatively affects the preparedness of MET institutions for S-Mode	5.37
8	Infrequent software updates make the training simulation systems inadequate in dealing with S-Mode implementation	5.20
9	The current training regime (e.g. time and workload allocated) is lag far behind the rapidly increasing complexity of the bridge system	5.20
10	Time constraint affects the ability of MET institutions to provide S-Mode training on time	5.10
11	The inability of trainees in comprehending system operation obstructs the knowledge transfer process	5.07
12	The differences between the implemented training system and the actual systems onboard vessels make training ineffective	4.87
13	The inability of trainees in working with electronic devices obstructs the knowledge transfer process	4.73
14	The resistance of some seafarers in adopting new navigational technologies affects the effectiveness of training on operating the complex on-bridge system	4.47

Table 6 Ranking of the statements of Objective 2 based on arithmetic mean

Rank	Proposed features for S-Mode	Arithmetic Mean
1	Uniform terminologies and abbreviations should be used on all bridge equipment and devices	6.50
2	As an essential element of the current bridge system, ECDIS should be standardized in S-Mode	6.43
3	S-Mode should include a protocol on the alarm system with universal meaning (e.g. risk level and urgency) attributed to sound and colour	6.43
4	Symbols used for the display of navigation-related information on all navigational equipment, devices and systems should be presented in a consistent and uniform manner under S-Mode	6.39
5	A "Help" function should be provided on all equipment and devices to allow users to find the required information easily	6.36
6	Terms and abbreviations used for the display of navigation-related information on all navigation equipment, device and systems should be consistent and uniform under S-Mode	6.29
7	Updates can be made to S-Mode in the process of design and development so that it will not be outdated after approval by the IMO	6.14
8	Audial and visual alarms should be strong enough to attract the attention of duty officers but not interfere with their on-bridge operations (e.g. too bright or too loud)	6.11
9	An integrated display can be placed on bridge, where all alarm notifications can be seen, accessed for details, and actioned as needed	6.07
10	As an essential element of the current bridge system, radar operations should be standardized in S-Mode	6.04
11	S-Mode should standardize not only the menu interfaces but also the location of them	6.00
12	A situation awareness system should be provided for ECDIS in S-Mode so that the information needed to set up the voyage route is automatically selected and displayed	5.93
13	S-Mode should have a mechanism to diagnose failure scenarios based on comprehensive data when an alarm is triggered	5.93
14	There should be a dynamic system in S-Mode where the possibility of dangers is automatically displayed based on the situation (dynamic situation awareness)	5.86
15	S-Mode should have the ability to allow multi-users carry out tasks simultaneously on different displays	5.86
16	A menu in S-Mode should have multi-layers with the first layer being standard and not editable and the second layer allowing users to set up their own preferences	5.82
17	Voice message warning should be introduced in S-Mode with concise information about the risk and danger	5.79
18	The default user interface of S-Mode should be able to be personalized by one user without affecting others	5.79
19	S-mode should have the ability to undo executed tasks to cancel the operations carried out within a certain amount of time (similar to recall a message)	5.75
20	S-Mode should allow personalised settings (as in statement 14) to be saved in storage (USB, hard drive, or even cloud) and loaded to another navigational system as the person moves to another ship	5.64
21	The number of alarms should be reduced with the consideration of their importance in S-Mode	5.54
22	A situation awareness system is needed for radar systems in S-Mode so that the information needed to set up the voyage route is automatically selected and displayed	5.46
23	S-Mode should be integrated as a head-up display (HUD) on the bridge where information is displayed as a layer above the real-world view	5.29
24	S-Mode should allow innovations from manufacturers	5.25

5.3. Project objective 3

The third objective of the project was to propose the best approaches for MET to prepare for the implementation of S-Mode. Sixteen (16) statements were agreed by the expert panel (Table 7) and one was disagreed with consensus. The first one is the assurance that the instructors should have adequate S-Mode training. Hands-on experience was still considered the best way to get the trainees ready for actual operation of S-Mode. The coordination between related parties was again emphasised as vital for the successful S-Mode training, especially the possibility of a community where S-Mode training materials and experience can be shared. Total reliance on a single platform was not recommended by the expert panel. Students have to be presented with the possible limitations of equipment and systems on bridge including the S-Mode itself. To ensure the quality and time allocation for courses, trainees should have adequate operating ability of electronic devices and equipment, as well as a good understanding of the principles and functions of different bridge equipment and devices before undertaking S-Mode training. To avoid situations in which onboard crew may intentionally disable safety measures, MET institutions should strongly stress the possible serious consequences of such behaviour. If S-Mode is introduced as a module in MET, it should be presented as a standardised basis explaining its relationships with other existing training programs. S-Mode is expected to be designed using ergonomic principles. The significance and promising contribution of S-Mode is reflected by the uniformed disagreement on the statement, which says S-Mode should only be briefly mentioned and introduced in the training process.

Table 7 Ranking of the statements of Objective 3 based on arithmetic mean

Rank	Recommendations for MET institutions	Arithmetic Mean
1	Instructors should be given adequate training on S-Mode before they train others	6.37
2	MET institutions should use simulations or on-machine practices to allow students to have hands-on experience with S-Mode	6.33
3	A more coordinated approach is required among all stakeholders (including MET, manufacturers, IMO, research & development) to ensure the successful implementation of S-Mode	6.33
4	Students should be given clear explanation about the possible limitations of equipment and system including the S-Mode itself	6.30
5	A community of practice should be established for sharing materials and experience related to S-Mode	6.15
6	MET institutions should be provided with information about the development of S-Mode in preparing for the implementation of S-Mode	6.11
7	Students should have adequate general knowledge on operating electronic device and equipment	6.11
8	MET institutions should pay more attention to training student the importance of on-board safety measures	6.07
9	MET institutions should explain to students the relationship between S-Mode training and other existing training programs	6.07
10	Students should be taught about standardised functions, display, and interfaces in S-Mode before undertaking more complicated and customised features	6.07
11	Innovative teaching and technologies should be used to make student learning interesting and effective	6.00
12	S-Mode used for teaching and training in MET institutions must be kept the same as the one being used on ships	5.96
13	MET institutions should actively engage in the discussion and development of S-Mode	5.89
14	Students should have a good understanding of the principles and functions of all different type of bridge equipment and devices before undertaking S-Mode training	5.63

15	S-Mode training is only an addition to the existing training that is currently being provided by the MET institutions	5.07
16	MET institutions should not overemphasize S-Mode in their teaching and training	4.85
17	S-Mode should only be briefly mentioned and introduced in the training process of MET institutions	3.81

6. Conclusions and Recommendations

The continuous and rapidly development in technologies have brought considerable improvement in productivity in all industries including the shipping. Over the last 30 years, advanced technologies, especially information and communication technology, have been adopted into the shipping industry to improve the efficiency and cost-effectiveness of ship operations. Many of such technology adoption had the intention to improve ship safety in addition to many other intended benefits. However, the increasing complexity of onboard navigational systems presented in an uncoordinated manner may significantly hamper the advancement of technology in shipping. The results of this project show that S-Mode, as a means to standardise essential functions, display, and interface of all bridge equipment regardless of their manufacturer or model, is considered a positive and necessary move.

The participants in the focus group interviews, as well as the experts in the Delphi study, expressed the concern of having limited information about S-Mode even after 10 years of discussion. This may partly be due to the reactive nature from the MET institutions. The little engagement of the MET in the consultation process of S-Mode reflects a disconnection among some key stakeholders of ship safety. These may result in some unwanted consequences when the S-Mode starts to be implemented. Throughout the project, it was unclear to all participants as what the guidelines look like and what the timeframe is for implementation. Such situation created uncertainty among the MET institutions which may negatively affect the ability of MET to be better prepared for providing required training on S-Mode.

The focus group interviews attracted a high level of interest among the participants. The discussions yielded many interesting, and sometimes, innovative ideas to address some of the challenges currently faced by the shipping industry.

Recommendations:

1. Information on S-Mode is urgently needed for key stakeholders including MET institutions. Such information may include the guidelines on S-Mode, the process for implementation, and the timeframe for each step.
2. As education and training providers, MET institutions should be more actively involved and engaged with initiatives where MET is affected or can play a role.
3. The IAMU may play more roles in S-Mode implementation. There is an urgent need for MET to develop relevant training package so that there is enough time for MET to train their own instructors. A collaborative approach led by IAMU may be more efficient and effective in creating quality resources for training programs.
4. It is also suggested that a platform (or community of practice) containing S-Mode related information could be developed. This platform can be used for sharing information, experience, and innovative ideas in teaching and training. It can also be used for collaborative research.

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Appendix

9. Appendixes

Appendix 1 GMDSS Communication Equipment

GMDSS Communication Equipment		
Type	**Manufacturer**	**Model**
1.MF/HF	1.1 JRC, Japan	□ JSS-196GM
		□ JSS-296/596/896
		□ JSS-2150/2250/2500
		□ NCH-700
		□ JSS-800
	1.2 FURUNO, Japan	□ FS-1570/2570
		□ FS-1575/2575/5075
		□ FS-1503
		□ FS-150
		□ FS-5000
	1.3 Thrane & Thrane, Denmark	□ HC4500
		□ SAILOR System 4000/5000
		□ SAILOR 6301
	1.4 SKANTI, Denmark	□ TRP 1000 (MF/HF DSC)
2.VHF	2.1 JRC, Japan	□ JHS-32B
		□ JHS-770S/780D
		□ JHS-7（Two-way VHF）
	2.2 FURUNO, Japan	□ FM-8500
		□ FM-8700
		□ FM-8800S
		□ FM-8900S
		□ FM-2721
	2.3 Thrane & Thrane, Denmark	□ RT2048
		□ RT4822
		□ SAILOR 5020/5022
		□ SAILOR 6210-6215
		□ SAILOR 6222
		□ SP3520（Two-way VHF）
	2.4 SKANTI, Denmark	□ VHF 1000 DSC
3.Inmarsat-C	3.1 JRC, Japan	□ JUE-85
		□ JUE-87
		□ JUE-95LT

		□ JUE-95SA
		□ JUE-75C
	3.2 FURUNO, Japan	□ FELCOM-12
		□ FELCOM-15
		□ FELCOM-16
		□ FELCOM-18
	3.3 Thrane & Thrane, Denmark	□ 2095C
		□ TT-3026M
		□ SAILOR 6110
		□ TT-10202
		□ TT-3020C
4.Inmarsat-F	4.1 JRC, Japan	□ JUE-410F
	4.2 FURUNO, Japan	□ FELCOM-70
	4.3 Thrane & Thrane, Denmark	□ TT-3084a
	4.4 Nera, Norway	□ Fleet 77
5.Fleet Broadband	5.1 JRC, Japan	□ JUE-250/251
		□ JUE-500/501
	5.2 FURUNO, Japan	□ FELCOM-250
		□ FELCOM-500
	5.3 Thrane & Thrane, Denmark	□ SAILOR Fleet Broadband 150
		□ SAILOR Fleet Broadband 250
		□ SAILOR Fleet Broadband 500
6.NAVTEX	6.1 JRC, Japan	□ NCR-300
		□ NCR-330
		□ NCR-333
	6.2 FURUNO, Japan	□ NX-500
		□ NX-300
		□ NX-700A/700B
	6.3 McMurdo, UK	□ Smartfind NAVTEX
		□ NAV6
		□ NAV7
	6.4 ICS, UK	□ NAV5
7. EPIRB	7.1 JRC, Japan	□ JQE-103
	7.2 McMurdo, UK	□ E3 EPIRB
		□ Smartfind/E5 EPIRB

		□ Smartfind Plus/G5 GPS EPIRB
	7.3 KANNAD, France	□ Kannad Marine EPIRB Non GPS
		□ SafeLink EPIRB (with GPS)
	7.4 Thrane & Thrane, Denmark	□ SAILOR 406 MHz SATELLITE EPIRB
	7.5 ACR, USA	□ RLB-38 Satellite3 406 MHZ EPIRB
		□ GlobalFix PRO 406 MHz GPS EPIRB
8.SART	8.1 JRC, Japan	□ JQX-30A
		□ JQX-20A
	8.2 McMurdo, UK	□ RT9 SART
		□ S5-AIS SART
		□ S4 SART
	8.3 KANNAD, France	□ Rescuer 2 SART
		□ Rescuer SART
		□ Safelink AIS SART
	8.4 Thrane & Thrane, Denmark	□ SAILOR SART II
		□ 5051 AIS-SART
	8.5 ACR, USA	□ ACR Pathfinder 3 SART
	8.6 Jotron, Norway	□ Tron AIS-SART
9. Weather Faximile Receiver	9.1 JRC, Japan	□ JAX-91
		□ JAX-9B
	9.2 FURUNO, Japan	□ FAX-30
		□ FAX-408
		□ FAX-208
		□ FAX-207
		□ FAX-410
	9.3 TAIYO, Japan	□ TF-708
		□ TF-712

List of Radar Brands and Types

No.	Country	Brand	Type
1	Japan	Furuno	FAR-2117BB
2			FAR-2127BB
3			FAR-2137S BB
4			FAR-21×7
5			FAR-21×8
6	Japan	JRC	JMA-900B
7			JMA-7100
8			JMR-5400
9			JMR-7200
10			JMR-9200
11	UK	Sperry	VisionMaster FT Radar
12			VisionMaster SeaGuard
13			VisionMaster FT Chart Radar
14			VisionMaster FT Naval Radar
15			VisionMaster FT Total Watch
16	Norway	Kongsberg	K-Bridge Radar
17	China	Highlander	HLD-RADAR 900/900C
18	UK	KELVIN HUGHES	Integrated Radar
19	Netherlands	ALPHATRON Marine	Sea Radar CAT-2

Appendix 2 Focus Group Interview questions

International Association of Maritime Universities (IAMU)

Research Project

Developing optimal approaches for the implementation of S-Mode in MET

Focus group interviews

Discussion guide

Welcome and thank you for participating in this focus group. The purpose of this session is to find out more about the understanding and implementation of S-Mode in Maritime and Education Training (MET). The International Association of Maritime Universities (IAMU) has an important role to play in developing the guidelines for, and shaping, the S-Mode so that MET institutions are better prepared to cater for the educational and training needs of our future seafarers. This research project is to develop optimal approaches in MET for the implementation of S-Mode.

Focus group discussions will be recorded for ease of reference during the data analysis stage. All responses will be kept strictly confidential by the researchers and the institution, and no individual comments will be identifiable in the final project report. Please respect the confidentiality of the focus group discussions and do not discuss any sensitive comments or responses outside of the focus group. Before the focus group discussion begins, we would like to ask if any participant would like to withdraw from this research.

We will now begin recording the focus group discussion.

Can everyone please introduce yourself?

- Name
- Teaching area/subject and years of teaching experience
- Years of seafaring experience and current certificate of competence

We now start discussing the questions.

1. How do you currently train students/seafarers on operating the navigation system (including all instruments, devices and equipment) on bridge (e.g. on-machine training vs. simulation-based)?
   Follow-up questions:
   - On-machine training: Which manufacturer(s) (brand and model) and for how long they have been used?
   - Simulation-based: which developer(s) and how often the software/program has been updated/upgraded to reflect the changes in the industry?

2. Have you encountered any challenges or identified any issues with the current way of training? If yes, what are they?

3. Do you think the different design, function, display, and interface currently exist in on-bridge instruments, devices and equipment a safety concern? Why?

4. If you were given an opportunity to choose a setting that allows you to use and operate on-bridge instruments, devices, and equipment (regardless their brand and model) in the same way across all ships, what would you like to include in your preferred setting?

5. Have you been in situations where you were distracted by visual or audial information/signals generated by instruments on bridge? If yes, please elaborate.

6. Would a protocol on alert/warning signals (visual and audial) generated by on-bridge instruments, devices, and equipment reduce the chances of on-duty officers to miss or misinterpret the alert/warning signals? Please explain and provide examples wherever applicable.

7. If you were to develop a protocol on alert/warning system for all on-bridge instruments, devices and equipment, what should it look like?

8. If S-Mode is implemented, what are the immediate and long-term challenges to maritime education and training?

9. With the challenges you have identified, what can and/or should be done in maritime education and training in order to be well prepared for the implementation of S-Mode?

Appendix 3 Delphi Study Instrument

Developing optimal approaches for the implementation of S-Mode in MET

Delphi Study

About this IAMU project

The prevailing differences in design, display, and interface among the same type of navigation devices and equipment on bridge pose significant challenges to seafarers and pilots alike since they have to familiarise themselves with all the devices and equipment within a very limited time when they board a different ship. In emergency situations, such differences may lead to wrong decisions or actions causing serious maritime incidents. Due to its significance to maritime safety, the IMO has chosen the development of S-Mode as one of its top six priorities for e-Navigation and called the wide maritime industry to contribute to the development of guidelines for S-Mode by 2019. IAMU has an important role to play in developing the guidelines for, and shaping, the S-Mode so that maritime education and training (MET) institutions are better prepared to cater for the educational and training needs of our future seafarers. This IAMU project aims to identify the challenges that MET institutions may face, the features that S-Mode should have from a MET perspective, and the optimal approaches for MET to prepare for the implementation of S-Mode.

As an expert on this topic, your participation will greatly contribute to the development and implementation of S-Mode.

About the Delphi Method applied in this study

In this Delphi study, after you have completed the survey questions for the first time, you will be invited to return to the survey in the subsequent rounds. This allows you to see an aggregated result of what others have responded (anonymously) so that you may re-evaluate your responses, change them if appropriate, and comment on them in order to help the panel reach a consensus wherever possible.

Each time you log in you can change your responses and add comments based on the shifting consensus of the Delphi panel as topics are explored. A consensus in this study is considered reached when there is no conflict left in each statement and the study is completed.

Below are some instructions for you to complete the survey as well as viewing the current results of the panel.

1) Answer the questions

A 7-point scale (Strongly Agree - Strongly Disagree) is used throughout this study for all statements, except the demographic questions in the next page. You can add comments under each statement or make comments on other responses.

2) Use the SAVE, NEXT or BACK buttons

Your answers will be saved when you click on the SAVE, NEXT or BACK buttons at the bottom of the page. You can navigate between pages either through the << "BACK" and "NEXT" >> buttons or directly by clicking the page menu located on top of each page. You can also move directly to a numbered page by the page indicator on top of any page.

3) Review others' answers and revise your own

From Round 2 onward, you will find tabs for "Graphs", "Stats" and "Comments" underneath each statement. These tabs provide you an aggregated view of all responses to the statement. Please read other respondents' comments and consider whether you would like to change your answers in light of the aggregated results and comments made by other participants.

If you have any questions about the survey or wish to know more about the real-time Delphi methodology employed in this study, please direct your questions to Son Nguyen (son.nguyen@utas.edu.au) or click on the private "chat" function at the bottom of each page. For overall management, research coordination, and other supervising affairs, please contact Dr Jiangang Fei (jiangang.fei@utas.edu.au). Your chat will only be seen by the moderators.

Click on the >> (NEXT) button below to start the survey. You can always come back to the previous page by using the << (BACK) button.

1. Demographic information

1) What Certificate of Competency do you currently hold?
    a. Master Mariner (Captain)
    b. Chief Officer (Chief Mate)
    c. 2nd Officer (2nd Mate)
    d. 3rd Officer (3rd Mate)
2) How many years have you worked on ships?
    a. Less than 5 years
    b. 5-10 years
    c. More than 10 years
3) How many years have you worked in maritime education and training
    a. Less than 5 years
    b. 5-10 years
    c. More than 10 years

2. The challenges that MET may face in providing appropriate education and training based on S-Mode:

1) Infrequent software updates make the training simulation system inadequate in dealing with S-Mode implementation.
2) Inappropriate design or operation makes the training simulation system inadequate in providing S-Mode training.
3) The current training regime (e.g. time and workload allocated) is lag far behind the rapid increasing complexity of the bridge system.
4) The inability of trainees in comprehending system operation obstructs the knowledge transfer process.
5) The inability of trainees in working with electronic devices obstructs the knowledge transfer process.
6) The resistance of some seafarers in adopting new navigational technologies affects the effectiveness of training on operating complex on-bridge system.
7) The differences between the implemented training system and the actual systems onboard vessels make training ineffective.
8) A lack of information about the development of S-Mode negatively affects the implementation of training on S-Mode among MET institutions.

9) The financial resources required to provide the right equipment and software for S-Mode training is a challenge to MET institutions.
10) The lack of training of instructors on S-Mode is a challenge among MET institutions.
11) Time constraint affects the ability of MET institutions to provide S-Mode training on time.
12) In addition to operations, trainees should be better prepared to work and make right decisions under stressful environment throughout the training process.
13) Unsure of the timeframe for the implementation of S-Mode negatively affects the preparedness of MET institutions for S-Mode.
14) A lack of guidelines on S-Mode training makes it difficult to develop appropriate content and materials for S-Mode training.

Others (please specify) ________________________________

3. The features that S-Mode should have for future-proofed solutions:

1) As an essential element of the current bridge system, ECDIS should be standardized in S-Mode.
2) As an essential element of the current bridge system Radar operations should be standardized in S-Mode.
3) Symbols used for the display of navigation-related information on all navigational equipment, devices and systems should be presented in a consistent and uniform manner under S-Mode.
4) Terms and abbreviations used for the display of navigation-related information on all navigation equipment, device and systems should be consistent and uniform under S-Mode.
5) S-Mode should standardize not only the menu interfaces but also the location of them.
6) S-Mode should include a protocol on the alarm system with universal meaning (e.g. risk level and urgency) attributed to sound and colour.
7) Audial and visual alarms should be strong enough to attract the attention of duty officers but not interfere with their on-bridge operations (*e.g.* too bright or too loud).
8) The number of alarms should be reduced with the consideration of their importance in S-Mode.
9) An integrated display can be placed on bridge, where all alarm notifications can be seen, accessed for details, and actioned as needed.

10) A situation awareness system should be provided for ECDIS in S-Mode so that the information needed to set up the voyage route is automatically selected and displayed.
11) A situation awareness system is needed for Radar system in S-Mode so that the information needed to set up the voyage route is automatically selected and displayed.
12) Voice message warning should be introduced in S-Mode with concise information about the risk and danger.
13) There should be a dynamic system in S-Mode where the possibility of dangers is automatically displayed based on the situation (dynamic situation awareness).
14) The default user interface of S-Mode should be able to be personalized by one user without affecting others.
15) S-Mode should allow personalised settings (as in statement 14) to be saved in storage (USB, hard drive, or even cloud) and loaded to another navigational system as the person moves to another ship.
16) S-Mode should have a mechanism to diagnose failure scenarios based on comprehensive data when an alarm is triggered.
17) S-Mode should allow innovations from manufacturers.
18) Updates can be made to S-Mode in the process of design and development so that it will not be outdated after approval by the IMO.
19) Uniform terminologies and abbreviations should be used on all bridge equipment and devices.
20) S-mode should have the ability to undo executed tasks to cancel the operations carried out within a certain amount of time (similar to recall a message).
21) S-Mode should have the ability to allow multi-users carry out tasks simultaneously on different displays.
22) S-Mode should be integrated as a head up display (HUD) on the bridge where information is displayed as a layer above the real-world view.
23) A ‘Help’ function should be provided on all equipment and devices to allow users to find required information easily.
24) A menu in S-Mode may have multi-layers with first layer being standard and not editable and second layer allowing users to set up their own preferences.

Others (please specify) ________________________________

4. Recommendations for implementation of S-Mode in MET:

1) MET institutions should pay more attention to training student the importance of on-board safety measures.
2) MET institutions should explain to students the relationship between S-Mode training and other existing training programs.
3) MET institutions should not over emphasise S-Mode in their teaching and training.
4) S-Mode training is only an addition to the existing training that is currently being provided by the MET institutions.
5) MET institutions should actively engage in the discussion and development of S-Mode.
6) MET institutions should be provided with information about the development of S-Mode in preparing for the implementation of S-Mode.
7) Instructors should be given adequate training on S-Mode before they train others.
8) MET institutions should use simulations or on-machine practices to allow students to have hands-on experience with S-Mode.
9) S-Mode should only be briefly mentioned and introduced in the training process of MET institutions.
10) Students should be taught about standardised functions, display, and interfaces in S-Mode before undertaking more complicated and customised features.
11) Students should have a good understanding of the principles and functions of all different type of bridge equipment and devices before undertaking S-Mode training.
12) Students should have adequate general knowledge on operating electronic device and equipment.
13) Students should be given clear explanation about the possible limitations of equipment and system including the S-Mode itself.
14) Innovative teaching and technologies should be used to make student learning interesting and effective.
15) A community of practice should be established for sharing materials and experience related to S-Mode.
16) S-Mode used for teaching and training in MET institutions must be kept the same as the one being used on ships.
17) A more coordinated approach is required among all stakeholders (including MET, manufacturers, IMO, research & development) to ensure the successful implementation of S-Mode.

Others (please specify) ______________________________

5. General information about S-Mode

1) There is a lack of information on S-Mode.
2) There is a lack of communication between S-Mode advocates and maritime education and training institutions.
3) There is a lack of collaboration between MET, ship equipment manufacturers, and S-Mode advocates in developing S-Mode.

Thank you for your participation

Please press the SAVE button at the end of this page to save your answers.

Please remember than you can come back and change your answers any time until the end of this round.

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