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A study on the e-navigation modus operandi

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A STUDY ON THE E-NAVIGATION MODUS OPERANDI

By

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DECLARATION

I certify that all the material in this dissertation that is not my own work has been identified, and that no material is included for which a degree has previously been conferred on me.

The contents of this dissertation reflect my personal views and are not necessarily endorsed by the University.

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ABSTRACT

Title of Dissertation : **A Study on the e-Navigation Modus Operandi**

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Accidents in a marine setting have been overwhelmingly caused by human error (Weintrit, 2016). Around 50% of accidents occurring in the sea are attributed to navigational challenges. Maritime traffic is core in mitigating incidences such as collisions, grounding problems, oil spills, and piracy. Greater congestion and increased manning levels have provided impetus for developing reliable system to reduce laborious work. E-Navigation utilizes new and existing technologies that are acceptable within the operating standards. The central role of the process is to enhance marine safety as well as efficiency.

This dissertation takes an in-depth look at the *modus operandi* of the proposed e-Navigation concept, and discusses requirements and implementation plans of the complete concept as well as the potential limitations and benefits of e-Navigation. The findings of this study also revealed that the implementation of e-Navigation will create a mixed environment where the administrator and the mariner most likely have the same problem in the terms of cost and the necessity, which will identify the limitations of the concept. Some benefits were also recognized when the concept is applied properly. The study also found the importance of acknowledging non-SOLAS vessel within e-Navigation.

Through qualitative research, this dissertation involves the responses emanating from the experiences of the participants. As the concept is set to be completely implemented by 2020, interviews with key stakeholders give insight into attitudes on the role and predicted efficacy of the implementation of e-Navigation.

The concluding chapters discuss the results and offer recommendations on the effects of introducing the concept. The work concludes by summarizing all thoughts and ideas from all chapters.

Key words: e-Navigation, Strategy Implementation Plan, Safety of Navigation, IMO, Risk Control Option, Maritime Service Portfolio.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABBREVIATIONS

AIS	Automatic Identification System
BES	Bridge Equipment System
BIMCO	Baltic and International Maritime Council
CG	Correspondence Group
CLC	Closed-Loop Communication
CIRM	Committee International Radio Maritime
CVE	Common Vulnerabilities and Exposures
ECDIS	Electronic Chart Display and Information System
eNOA/D	Electronic Notice of Arrival/Departure
EEC	Electronic Communication Committee
ENC	Electronic Navigational Chart
FSA	Formal Safety Assessment
GDMSS	Global Maritime Distress and Safety System
GNSS	Global Navigation Satellite System
GRT	Gross Tonnage
HMI	Human Machine Interface
IALA	International Association of Marine Aids to Navigation and Lighthouse Authorities
IBS	Integrated Bridge System
IEC	International Electro-technical Commission

IGO	Intergovernmental Organization
IHO	International Hydrographic Organization
IMO	International Maritime Organization
INS	Integrated Navigation System
ITU	International Telecommunication Union
LPS	Local Port Service
LORAN	Long Range Navigation
MAS	Maritime Assistance Service
MSC	Maritime Safety Committee
MSI	Maritime Safety Information
MSP	Maritime Service Portfolio
NAS	Navigational Assistance Service
NCSR	IMO Sub-Committee on Navigation, Communications, Search & Rescue
NGO	Non Governmental Organization
OOW	Officer of the Watch
PNT	Resilient Position, Navigation and Timing.
RCO	Risk Control Option
SAR	Search and Rescue
SIP	Strategy Implementation Plan
SOLAS	The International Convention for the Safety of Life at Sea
SSN	Safe Sea Net

TMAS	Telemedical Assistance Service
TOS	Traffic Organization Service
US	United States
USCG	United States Coast Guard
VDES	VHF Data Exchange System
VMAS	Vessel Monitoring and Alert System
VTS	Vessel Traffic Services
WG	Working Group
WMO	World Meteorological Organization

1. INTRODUCTION

1.1 Background

Without a doubt, accidents and incidents at the sea mostly caused by human error. Weintrit (2016) pointed out “the combination of navigational errors and human failure indicate a potential failure of the main ship systems used for navigation and control”. Additionally, when the system is an extremely complex with low familiarity of the user, the performance of human machine interaction can be problematic (Lee et al, 2015). The research found that over 50 percent groundings and collisions are caused by the human error, whilst navigation decision making was the main issue (The Nautical Institute, 2009). There are so many factors that make the decision making difficult such as lack of awareness of a dangerous situation, insufficient resource awareness in a timely manner, or fear of failure of unintended consequence. However, the procedures about making decision is probably different in every situation, but combination of analytical thinking and logical sense might be the best way to address these problems. Thus, the information is the key where the decision maker needs to disprove bad propositions.

The revolution of technology has been growing fast, and continually changing. The evolution has resulted much more technology interconnection. Thus, the technology has been considered as a helpful tool to assist people to achieve their specific purpose, for instance making ships more efficient or to prevent unintended situations, working alongside traditional methods. Lützhöft (2004) discussed cognitive science and human factors in maritime field making a conclusion that integration is about co-ordination, cooperation and compromise. She points out “when human and technology met and work together, most of the time the human has to co-ordinate the resources, co-operate with devices, and compromise between means and ends” (p.57).

However, the revolution of technology in maritime industry sometimes replaces traditional methods. Today, we are facing the era of digitalization of information management, and taking the advantages of it in order to keep up with the business’s wave while protecting the people and the environment. In recognition to the digital age, and the need to improve the integrity and accuracy of information used by the main stakeholders, the IMO embarked on a new initiative, e-Navigation.

In Annex 20 of MSC 85/26 Add. 1 (para. 1.1) e-Navigation is defined as “the harmonized collection, integration, exchange, presentation and analysis of marine information on board and ashore by electronic means to enhance berth to berth navigation and related services for safety and security at sea, protection of the marine environment” (IMO, 2008). This initiative has a purpose to strengthen the navigation system to create eligibility outcomes on the future of marine navigation. In addition, its hoping to reduce the number of incident in marine environment caused by human error.

But does this make things easier or difficult to connecting ship and shore, and for them to use the information? Thus, when humans are introduced to some new systems that are controlled remotely, they often lose their sense of practical engagement. Further, the risk of system failure has been raised as well as human factors issues. To maximize the Human Machine Interface (HMI) the bridge system must be use good ergonomics and preferably a low cost budget.

IMO through its Strategy Implementation Plan (SIP) as set out in the NCSR document 1/28 Annex 7, is addresses those risks by set up five prioritized e-Navigation solutions. The NAV and COMSAR subcommittee and MSC created Correspondence Group (CG) and Working Groups (WG) addressing a Formal Safety Assessment (FSA) as the standard risk assessment tool to be used for the development of new rules and regulations of IMO, as described in the Annex of MSC 83/INF.2, to finally established the framework of SIP plan. In addition, it is hoped that e-Navigation concept will create a system where the mariner and crew's support can make a decision when they are facing unsafe situations on the ship's bridge, as well as simplifying navigation tools (Hong, 2015).

1.2 Objective

This dissertation researches e-Navigation's *modus operandi*. It mainly focuses on studies and discussions on how and to what extent the *modus operandi* of e-Navigation can be utilised to improve safety in marine navigation. As e-Navigation is currently still being developed, this dissertation will provide a benchmark for the benefits of e-Navigation to harmonize all vessels, but also the steps that need to be considered for the implementation of e-Navigation throughout the community.

In addition, this dissertation may serve as a reference in policy-making regarding maritime safety of the member states of the IMO and the other actors of e-Navigation related systems. Therefore, this dissertation:

- Examines the potential of e-Navigation and addresses how to accommodate aspects such as multilingualism and diverse vessel types in features needed on the ship, ashore, or on both sides.

- Identify weaknesses and the benefits of the implementation of e-Navigation, taking into consideration all vessels that are addressed by SOLAS as well as those that share the same waters, and what operational modes required and procedures that should be established.

- Identify potential changes to ensure the S-Mode, as consequence of e-Navigation might be failed.

1.3 Scope of the study

This dissertation includes six Chapters. Chapter 1 shows the background, objectives, scope and methodologies of the research.

Chapter 2 includes an overview of the development of e-Navigation, through examining and reviewing SIP developed by the IMO, including a general overview of tool kits used in IMO e-Navigation, namely Risk Control Option (RCO) and Maritime Service Portfolio (MSP).

Chapter 3 determines the methodology to be used in this dissertation. To define the methodologies, this chapter introduce the interview and cross check between results of interview and the SIP developed by the IMO and other e-Navigation related documents. The researcher also discusses about the limitation of the methodology.

Chapter 4 gives an in-depth analysis of e-Navigation *modus operandi*, including insights gained from interview results and SIP by IMO. The analysis will concern a shore side and an onboard side, as well as the role of communication between ship to ship, ship to shore, shore to ship, and shore to shore.

Chapter 5 discusses the potential impact of the implementation of the e-Navigation concept. Here, the shortcomings and the benefits, as well as the discussion of the impact of e-Navigation will be discussed. Recommendations for the future of e-Navigation will also be introduced and outlined.

Finally, Chapter 6 gives a summary and includes a final conclusion of this dissertation.

1.4 Methodology and sources of information

The research questions, which reflect the research objectives of this paper, are as follows:

1) Will there be a significant change of how the operator ashore and on board conduct navigation of vessels or advisory services to them with respect to e-Navigation and non e-Navigation vessels.
2) Will there are differences of “quality” and accuracy of e-Navigation services offered by different Coastal States to all vessels and how will a vessel deal with this.
3) What are the steps (if any) need to be taken to avoid grounding or collision with an assumption is taken that vessels and shore stakeholders that are interacting with each other will have different levels of sophistication of navigation and control equipment? Additionally, different levels of e-Navigation services will be experienced by the mariner for Vessel Traffic System (VTS), weather forecast, Just in Time Arrival at narrows or port requiring different steps.

To answer these questions, this dissertation will use qualitative research. An examination and review of the e-Navigation related documents developed by the IMO and other related research papers will be carried out in order to define the appropriate analysis tools. The aforementioned documents were collected from the IMO website, other sources on the internet, and the WMU library. In addition, an online interview with stakeholders will be carried out as one of the qualitative analysis items in order to verify real life and up-to-date information of the e-Navigation.

2. THE E-NAVIGATION CONCEPT

2.1 Introduction

As already stated, e-Navigation is a major initiative of the International Maritime Organization (IMO), and is intended to be implemented according to Strategy Implementation Plan (SIP), which was approved by MSC 94 in November 2014. The plan contains a list of tasks required to be conducted in order to address five prioritized e-Navigation solutions, namely:

- S1: Improved, harmonized and user-friendly bridge design;
- S2: Means for standardized and automated reporting;
- S3: Improved reliability, resilience and integrity of bridge equipment and navigation information;
- S4: Integration and presentation of available information in graphical displays received via communication equipment; and
- S5: Improved Communication of VTS Service Portfolio (not limited to VTS stations).

It is expected that these tasks, when completed within the period of 2015–2019, should provide the maritime industry with harmonized information that is essential to start designing products and services to meet the e-Navigation solutions (IMO, 2014).

The IALA and IMO who have already put forth great efforts to act as a driver of the evolution of portrayal and communication within the maritime community. It is understood that, in order to facilitate e-Navigation, processes used for technical transfer of data and information should be machine to machine and not require any human intervention to either receive or portray the information (IMO, 2014).

According to Baldauf and Hong (2016), the situation of maritime safety is different from country to country especially in coastal areas and SOLAS ships are always interfaced with non-SOLAS ships in real maritime practices. Furthermore, it has been realized within the community that e-Navigation should be able to include all vessels and not just a few complex ones; as such, a range of inter-communicability is required to transfer data, ensuring that all vessels are included within the concept. Though satellite communications are recognized to be an important element for e-Navigation, it is also recognized that other more basic communication would be required alongside it.

This inter-communicability needs to have led to work for evolving language independent protocols for the transfer of information between vessels, and vessels and infrastructure to include a methodology for the portrayal of data within the language of an operator. This work builds on "the international code of signals", first introduced at the International Radiotelegraph Conference in Madrid in 1932, and still used today.

Furthermore, e-Navigation not only impacts the way information will be communicated to a vessel, but also how information will be used on board. Because it requires data to be provided machine to machine, and because the purpose of e-Navigation is to improved resilience of the communication link but also to be used VTS and ship reporting. The interaction between ship and shore is likely to rely more and more on automated, or semi-automated procedures, where the mariner becomes an observer, and in certain circumstances, may even in the future be provided with some resolved solutions which can be rejected or accepted. This brings in to question what should happen to solutions that have not been acted upon by the mariner. What is the default scenario? Should the machine accept the solution?

It is observed during this research that e-Navigation bridge of the future as will the operation centers ashore, result in changed roles of the watch keeper. The equipment itself will be designed to provide direct data access to and from systems used for the navigation and control, and possibly even effect the control of a vessel. Automatic information updates, instead of the current system of manual inputs in the form of corrections, will also be implemented.

2.2 The development of e-Navigation

During the MSC 81 session in 2006, USA, Japan, the Marshall Islands, the United Kingdom, the Netherlands, Norway, and Singapore made a joint proposal for e-Navigation, a concept that would contribute to reducing navigational accidents, error, and failures. As such, the NAV and COMSAR Sub-Committees developed a strategy for the development and implementation of e-Navigation (NAV 54/25 Annex 12) and a time frame for implementation (NAV 54/25 Annex 13), with suitable suggestions by several organizations such as the IALA and IHO. Ultimately, the MSC approved the strategy called the e-Navigation SIP (NCSR 1/28 Annex 7), and expect it to be implemented in 2020.

There are many stakeholders involved with the evolution of e-Navigation, who are working closely with the IMO NCSR sub-committee. A good understanding of the contribution of these other organizations is needed, as e-Navigation is dependent on the IALA, IHO, as well as the IEC and ITU. These organizations are very important in their own way for the development of the key components required for the communication and portrayal of information, as well as the design of the equipment used. For instance, the IALA is ready to change its status from Non Governmental Organization (NGO) to Intergovernmental Organization (IGO) in order to assist the advancement and accordance of aids to navigation globally (Weintrit, 2016). The interface between ashore and onboard developments will be heavily influenced by the work of these organizations. Additionally, there are procedures within the e-Navigation that will have most effect on the bridge in the future:

- portrayal of information required for safe navigation.
- communication of information from ship to ship, ship to shore, and shore to ship.

Both of these are interdependent of each other and will heavily involve the Electronic Chart Display and Information Systems (ECDIS) referred to IALA, IHO and IEC. And also satellite communication and VHF Data Exchange System (VDES) referred to IALA and ITU.

The e-Navigation concept "covers ship-side technologies like Integrated Navigation Systems (INS) integrating electronic charts, navigation and conning data or integrated surveillance systems on shore with technologies like VDES, Automatic Identification Systems (AIS), Global Maritime Distress and Safety System (GMDSS), Resilient Positioning, Navigation and Timing (PNT)" (Hahn et al., 2016). Furthermore, by forming a competent national SIP, member states are expected to enjoy the prosperity of applying e-Navigation to their waters in the terms of their distinctive priorities (Baldauf and Hong, 2016). Therefore, e-Navigation will establish more efficient and safer transit of vessels. This initiative provided that the communication link is used correctly, cooperation for maritime safety and security, protection of marine environment, and the appropriate interaction between stakeholders ashore and onboard is dealt with correctly.

Many research and vast resources have tackled e-Navigation as well as its related conventions, such as SOLAS, which regulates the safety of navigation. E-Navigation also affects not only all vessels, but also the country's conformation with those conventions related to their own fleets, their VTS, their ports, and how they interact with vessels as a coastal state. SOLAS presents itself as a major beacon for the evolution of e-Navigation, as it addresses many critical elements and operations that are included within e-Navigation, while a SIP (IMO NCSR 1/28) sets out the work required for stakeholders to enable e-Navigation. This provides guidance covering all aspects of human interaction in the way of user friendly bridge designs, technical requirements for automated reporting; and as such, the inter-communicability between stakeholders and required regulating bodies.

2.3 Strategy Implementation Plan (SIP)

In 2014, MSC 94 established a SIP through NCSR 1/28 Annex 20. As the core of the implementation of e-Navigation, the SIP provides solutions for the gaps analysis and user needs through the Formal Safety Assessment (FSA), which are addressed in the seven parts of the RCO and sixteen services of the MSP in the SIP as a kits to achieve the five prioritized e-Navigation solutions and sub solutions.

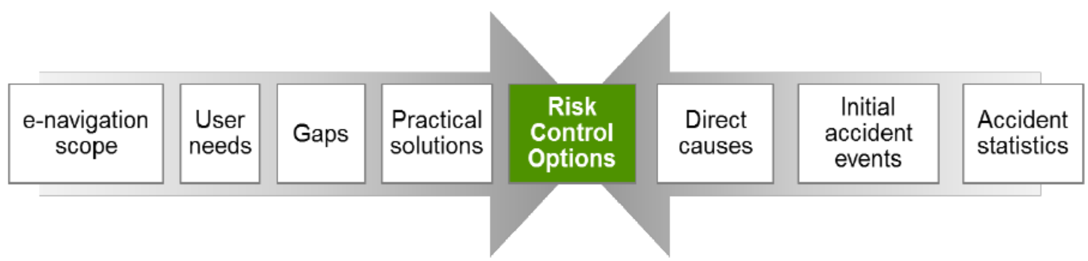

Figure 1. RCO Identification Process (NAV 59/6)

Solution	Sub Solution
S1 Improved, Harmonized and User-Friendly Bridge Design	(S1.1) Ergonomically improved and harmonized bridge and workstation layout
	(S1.2) Extended use of standardized and unified symbology for relevant bridge equipment
	(S1.3) Standardized manuals for operations and familiarization to be provided in electronic format for relevant equipment
	(S1.4) Standard default settings, save/recall settings, and S-mode

	functionalities on relevant equipment
	(S1.5) All bridge equipment to follow IMO Bridge Alert Management
	(S1.6) Information accuracy/reliability indication functionality for relevant equipment
	(S1 6.1) Graphical or numerical presentation of levels of reliability together with the provided information
	(S1.7) Integrated bridge display system (INS) for improved access to shipboard information.
	(S1.8) GMDSS equipment integration – one common interface.
S2 Means for Standardized and Automated Reporting	(S2.1) Single-entry of reportable information in single-window solution.
	(S2.2) Automated collection of internal ship data for reporting.
	(S2.3) Automated or semi-automated digital distribution/communication of required reportable information, including both "static" documentation and "dynamic" information.
	(S2.4) All national reporting requirements to apply standardized digital reporting formats based on recognized internationally harmonized standards, such as IMO FAL Forms or SN.1/Circ.289.
S3 Improved Reliability, Resilience and Integrity of Bridge Equipment and	(S3.1) Standardized self-check/built-in integrity test (BIIT) with interface for relevant equipment (e.g. bridge equipment).
	(S3.2) Standard endurance, quality and integrity verification testing for relevant bridge equipment, including software.
	(S3.3) Perform information integrity tests based on integration of navigational equipment – application of INS integrity

Navigation Information	monitoring concept
	(S3.4) Improved reliability and resilience of onboard PNT information
S 4 Integration and Presentation of Available Information in Graphical Displays Received via Communication Equipment	(S4.1) Integration and presentation of available information in graphical displays (including MSI, AIS, charts, radar, etc) received via communication equipment
	(S4.1.1) Implement a Common Maritime Data Structure and include parameters for priority, source, and ownership of information.
	(S4.1.2) Standardized interfaces for data exchange should be developed to support transfer of information from communication equipment to navigational systems (INS).
	(S4.1.3) Provide mapping of specific services (information available) to specific regions (e.g. maritime service portfolios) with status and access requirements.
	(S4.1.4) Provision of system for automatic source and channel management on board for the selection of most appropriate communication means (equipment) according to criteria as, band width, content, integrity, costs.
	(S4.1.5) Routing and filtering of information on board (weather, intended route, etc.).
	(S4.1.6) Provide quality assurance process to ensure that all data is reliable and is based on a consistent common reference system (CCRS) or converted to such before integration and display.

	(S4.1.7) Implement harmonized presentation concept of information exchanged via communication equipment including standard symbology and text support taking into account human element and ergonomics design principles to ensure useful presentation and prevent overload.
	(S4.1.8) Develop a holistic presentation library as required to support accurate presentation across displays.
	(S4.1.9) Provide Alert functionality of INS concepts to information received by communication equipment and integrated into INS.
	(S.4.1.10) Harmonization of conventions and regulations for navigation and communication equipment
S9 Improved Communication of VTS Service Portfolio	(S9) Improved communication of VTS service portfolio (not limited to VTS stations)

Table 1. Solution and Sub-Solutions Prioritized e-Navigation (Source. Annex 7 NCSR 1/28)

Therefore, it is crucial to have a deep understanding of the SIP to see how e-Navigation concept works. Further, the RCOs will be discussed analyzed in the next section by the researcher are extracted by the IMO related documents such as NAV. 59/6 and NCSR 1/28.

2.4 Risk Control Options (RCOs)

2.4.1 RCO 1 Integration of navigation information and equipment including improved Software Quality Assurance

As it is stated in Annex 1 NAV. 59/6 presented by Norway, RCO 1 is related to sub-solutions: S1.6, S1.7, S3.1, S3.2, S3.3, S4.1.2, and S4.1.6. The integration of navigation information and equipment will help the navigator when it comes to navigational decision making. In addition, there are 7 elements contained in RCO 1 that are incorporated with INS standards, as listed below:

1. Task route planning and monitoring
2. Task collision avoidance
3. Task navigation control data
4. Task status and data display
5. Display
6. Redundancy of important equipment
7. Software testing

As stated in the main RCO 1 text, it is essential that navigational information be centralized, allow it to be visible from all work stations. This will enable quicker decision-making and give crew members an overview of relevant information. Additionally, the document states that:

> Sophisticated bridge navigational systems are increasingly integrated with each other and with other kinds of systems on the ship. This, as well as the implicit ability of these systems to influence each other, increases complexity. As such, it is of increasing importance that these systems are usable, available, reliable and resilient. (p. 23)

2.4.2 RCO 2 Bridge alert management

RCO 2 is related to S1.5. The purpose of having a unified bridge alert system is to enable harmonized priority, classification, handling, distribution, and presentation of alerts (NAV 59/6). Through this system, situational awareness in the bridge team will be increased, so that when it comes to unwanted events, the bridge team will be able to respond quickly and save time on decision making. Furthermore, the vessel which have an audible alarm on the bridge will prioritize dangerous scenarios, such as collision or grounding displayed on the central alert management HMI.

According to the document NAV 59/6, one of the key problems faced in vessels without a centralized alert system is that alerts are not always easily identified. Additionally, if all alerts are not coming from a central system, it is often difficult to prioritise the alerts. Additionally, "Potentially unnecessary distractions of the bridge team by redundant and superfluous audible and visual alarm announcements may occur, increasing the cognitive load on the operator." (NAV 59/6 p. 23). With a centralized system, information from different alert sources will be available in the same place, facilitating decision-making with regard to prioritization.

2.4.3 RCO 3 Standardized mode(s) for navigation equipment

RCO 3 is related to S1.4. It refers to the standardisation of technology, an essential facet of a safe operation at sea. As stated in Annex 7 NCSR 1/28:

> Standard modes or default display configurations are envisaged for relevant navigational equipment. Such standard modes should be selectable at the task station and would reset presentation and settings of information to provide a standardized and common display familiar to all users. (p. 23).

This is particularly important in the context of commercialism: it is important to keep in mind that companies developing e-Navigation technologies must compete in the free market and maintain a competitive advantage. Therefore, guidelines and standards on display layouts and essential functions should be mandated for all e-Navigation products.

Enforcing such guidelines would ensure that a standardized training program can be implemented so that all crew members are on the same page in terms of using the e-Navigation technology. As stated in Annex 7:

> Safe navigation relies on the ability of key personnel of the bridge team to easily operate navigational equipment as well as to comprehend the information that is presented to them. Without proper familiarization, which can sometimes take a significant period of time due to the current differences between operating systems, this is not always the case when someone is new to a particular setup. Lack of familiarity with bridge equipment which can result in slow responses due to not finding correct information, system, control function or alarm is therefore likely to adversely affect safe navigation. (p. 23).

Annex 7 further describes specifics on the types of standardization that should be in place, mentioning information display, such as symbols and colours (in relation with MSC.191(79)); a standard layout for information presentation; as well as a standard mode of operation that can be accessible with a single user action.

2.4.4 RCO 4: Automated and standardized ship-shore reporting

RCO 4 is related to S2.1, S2.2, S2.3, S2.4. It stipulates the automation of ship-shore reporting through making information more easily accessible, in a user-friendly format. It is referred on NAV. 59/6 and NCSR 1/28 that the automation of ship-shore reporting is predicted to reduce workload, as forms are usually filled out manually by crew members, and such paperwork often takes 2 hours to complete.

The proposed automation system would integrate and collect the data and information needed for reporting. Additionally, since 2005 US established Electronic Notice of Arrival/Departure (eNOA/D) that requires all vessels up to 300 GRT have to use for in/out clearance in the US waterways. In Europe, the Facilitation Committee and the European Commission have already begun developing a system for ship-shore reporting. Europe SafeSeaNet (SSN) has established an Internet-based system to exchange the information between different authorities, which has implemented by Norway and Iceland (EMSA, 2012).

2.4.5 RCO 5: Improved reliability and resilience of onboard PNT systems

RCO 5 is related to sub-solution 3.4. It outlines standards for enabling reliable Position Navigation and Timing (PNT) data, which is derived from a ship's position through the Global Navigational Satellite Systems (GNSS), and looking at multiple position and timing points to velocity, course, or speed over the ground. It goes without saying that this information is crucial in navigation at sea.

RCO 5 emphasizes the importance of resilience and reliability of PNT data. Resilience is defined as the system's ability to compensate for disturbances in data collection, such as malfunctions or breakdowns in the system. Increasing resilience of a PNT system does not necessarily require setting up extra GNSS systems; but is instead achieved "through a combination of existing space-based and terrestrial systems, modernized and future radio navigation systems, ship-based sensors and other services." (NAV. 59/6 p. 24). Some of these systems include:

1. Inertial navigation systems;
2. Signals of opportunity, such as radio, radar, sonar, echo sounder, etc.;

3. Electronically-enabled human-observed bearings and distances (i.e. Modern electronic coastal navigation using an e-pelorus, radar and ECDIS);
4. Autonomous celestial navigation; and
5. Other possibilities that could arise from research, for example in the areas of defence and robotic vehicle navigation. (p. 24)

According to NAV. 59/6, reliability on the other hand, refers to the chance and consistency at which the PNT system performs a function successfully under given conditions, for a specified time. As discussed in the section on RCO 3, standardized user interfaces and sets of functions would increase reliability, and ensure that all crew members, internationally, could be trained using the same system.

2.4.6 RCO 6 Improved shore-based services

RCO 6 is related to S4.1.3 and solution S9 as it is stated in NAV. 59/6. The Maritime Service Portfolio refers to a collection of information gathered by VTSs, ports, and other stakeholders at shore. This information includes: "navigational warnings, incidents, operations, tide, AIS, traffic regulations, chart updates, meteorological conditions, ice conditions, etc." (NCSR 1/28 p. 25).

In line with RCO 1, this information should be centralized, standardized, automated, and easily accessible at all work stations. This information may be helpful in navigation, and contrary to the paper-based delivery system used today, documents such as Maritime Safety Information (MSI), should be made digitally available. Digitizing this information would also allow for only voyage-relevant information to be shared with the respective crew. In the current system, "the Officer of Watch (OOW) may potentially receive several MSI messages daily, of which a large portion of the messages may not be of concern to the voyage" (NCSR 1/28 p. 25). With all of this noise, it is easier to miss critical voyage-relevant information, posing a safety risk. According to the RCO, “the most appropriate platform to present MSI may be either the INS tasks route monitoring and status and data display (resolution MSC.252(83)) or the ECDIS unit and optionally on another navigational display.” (p. 25). In addition, as stated in Annex 7 NCSR 1/28:

> Secondly, notices to mariners, updates to Electronic Navigation Chart (ENC) and corrections to all nautical publications should be received electronically without any delays in the delivery. Distribution via post is time consuming and may introduce risks to the ships sailing in waters, for which the nautical charts are not up to date. (p. 25).

Such information should be “fully integrated into the INS tasks route monitoring and status and data display (resolution MSC.252(83)) or the ECDIS unit and optionally on another navigational display” (p. 25). Updates and corrections should not have any file type dependencies, and should not require manual transfer by an operator.

This will not only increase efficiency, but also reduce costs of operation. However, important to note is that changes to operating procedures must be structured, involve sufficient training regimes to manage the data information, and conducted in a logical, standardized manner. Such changes should remain compatible with current systems, and build on their foundation.

2.4.7 RCO 7 Bridge and workstation layout standardization

RCO 7 outlines standards for bridge and workstation layouts. It is only logical that equipment layouts that do not consider workflow or utility adversely influence the performance of marine navigation operations. While developments in ergonomic workstation and bridge design exist, there are currently not standards for universal implementation of such designs. As stated in the RCO;

> Reference could be made to SOLAS regulation V/15 on Principles relating to bridge design, design and arrangement of navigational systems and equipment and bridge procedures, MSC/Circ.982 on Guidelines on Ergonomic Criteria for Bridge Equipment and Layout, SN.1/Circ.265 on Guidelines on the Application of SOLAS regulation V/15 to INS, IBS and bridge design, SN.1/Circ.288 on Guidelines for bridge equipment and systems, their arrangement and integration (BES) and ISO8468 on Ships Bridge layout and associated equipment. (p. 26).

In a similar way to standardization of information and system displays discussed in RCO 3, standardization of bridge designs would allow all crew members to undergo the same training regime and increase collective familiarity with bride and workstation layout and function.

2.5 Maritime Service Portfolio (MSP)

As stated in NAV 59/6, MSP is defined and described as “the set of operational and technical services and their level of service provided by stakeholders in a given sea area, waterway, or port, as appropriate. An MSP may also be interpreted as a set of "products" provided by a stakeholder.” (p. 7). More specifically, as part of the improved provision of services to vessels through e-Navigation, MSPs have been identified as the means of providing electronic information in a harmonized way, which is part of solution 9. The proposed list of MSPs is presented in table below. Further information about MSPs is set out in annex 2 of NCSR 1/28, and annex 3 of NAV 59/6.

According to IMO NCSR 1/28, Annex 7 addresses the following six areas that have been identified for the delivery of MSPs:

1. Port areas and approaches;
2. Coastal waters and confined or restricted areas;
3. Open sea and open areas;

4. Areas with offshore and/or infrastructure developments;
5. Polar areas; and
6. Other remote areas. (p. 10)

The following table gives an overview of the services and responsible service providers outlined in the document:

No	Identified Services	Identified Responsible Service Provider
MSP 1	VTS Information Service (IS)	VTS Authority
MSP 2	Navigational Assistance Service (NAS)	National Competent VTS Authority/ Coastal or Port Authority
MSP 3	Traffic Organization Service (TOS)	National Competent VTS Authority/ Coastal or Port Authority
MSP 4	Local Port Service (LPS)	Local Port/Harbour Operator
MSP 5	Maritime Safety Information Service (MSI)	National Competent Authority
MSP 6	Pilotage service	Pilot Authority/Pilot Organization
MSP 7	Tugs Service	Tug Authority
MSP 8	Vessel Shore Reporting	National Competent Authority, Ship-owner/Operator/Master
MSP 9	Telemedical Assistance Service (TMAS)	National Health Organization/dedicated Health Organization
MSP 10	Maritime Assistance Service (MAS)	Coastal/Port Authority/Organization
MSP 11	Nautical Chart Service	National Hydrographic Authority/ Organization
MSP 12	Nautical Publications	National Hydrographic Authority/

	Service	Organization
MSP 13	Ice Navigation Service	National Competent Authority Organization
MSP 14	Meteorological Information Service	National Meteorological Authority/WMO/ Public Institutions
MSP 15	Rea-time Hydrographic and Environmental Information Service	National Hydrographic and Meteorological Authorities
MSP 16	Search and Rescue Service	SAR Authorities

Table 2. Type of Services and Service Provider of MSP (Annex 7 NCSR 1/28)

3. METHODOLOGY TO EVALUATE E-NAVIGATION MODUS OPERANDI

3.1 Introduction

This chapter introduces the research methodology and how it has guided data collection, analysis, and development of the theory. Subsequently, data collection procedures are illustrated and discussed in-depth to get an overview of the entire process. This is followed by limitations which were encountered during the interview. Finally, it presents a brief discussion on qualitative techniques used to analyze the data collected.

3.2 Qualitative method

Comprehensive literature review comprising of peer reviewed journals covering e-Navigation were consulted. Besides, participation of the key stakeholders such as the IMO, IALA, and maritime administrations formed part of the study. They included publications on the internet, conventions, and regulations that are related to e-Navigation or impacted by it. The major benefit of qualitative type of study is attributed by versatility of information, and the diverse data that can be collected through interview instruments.

Lützhöft (2004) asserts that questionnaires are expensive to administer and yield little that can be used pragmatically. She also pointed out that "quantitative data may be useful in measuring attitude across a large sample, but paper interviews perform a powerful framework to learn about individual's perception based on their skills, knowledge, and experiences" (Lützhöft, 2004, p. 17-20). Marshall and Rossman (1999) discussed the characteristics of qualitative methods, such as valuing participant's perspectives, focusing on everyday life experiences, enquiry and primary descriptions. Through qualitative research, this dissertation involves the responses emanating from the experiences of the participants. The researcher transcribed interviews and analyzed them on a comparative and narrative basis to bring out the complexity of the work situation.

3.3 Interview and data source

The most important reason for using this method is traceability of facts regarding e-Navigation. One aspect of consideration is interviewing people with facts and versatile knowledge in the area of concern. In order to get an in-depth understanding of the topic, it is crucial to interview experts in this area. For example, the investigations in the frame of ACCSEAS project have shown that sometimes even lectures and instructors were not aware of what e-Navigation means (Baldauf, 2015).

For that reason, the interview candidates were selectively chosen with the goal of obtaining detailed and informative responses. Patton (2002) has described the concept of purposeful sampling comprehensively. He stated that:

> The logic and power of purposeful sampling lie in selecting *information-rich* cases for study in depth. Information-rich cases are those from which one can learn a great deal about issues of central importance to the purpose of the inquiry, thus the term *purposeful* sampling. Studying information-rich cases yields insights and in-depth understanding rather than empirical generalizations (p. 230, emphasis in original).

For this dissertation, the researcher did the interviews of key personnel who have been instrumental to the processes of e-Navigation. Members of international maritime organizations such as IALA, IMO, The Nautical Institute, CIRM, and officials of the maritime administrations were invited to participate. The participants selected come from countries such as Australia, Canada, Denmark, Germany, Norway, Republic of Korea, United Kingdom, United States, Singapore, and Sweden. The researcher found the interview candidates through WMU and IMO networking, as well as the candidate's publication on e-Navigation development, articles in academic journals, professional magazines on internet, and e-Navigation seminars. During the research, a total of 23 experts/stakeholders were chosen for interviews; 14 out of 23 participants confirmed their participation by sending back their answers via email.

The online interviews were conducted via email during May – August 2017. To achieve this, interview questions were emailed to individual participant for responses. Opdenakker (2006) affirms that email communication has enumerable advantages compared to other mode of collecting data. One, confidentiality of information is highly respected hence improving the reliability. Additionally, it facilitates wider coverage of respondents irrespective of geographic separation. Further, through this method, the researcher can accurately develop and standardize the questions, and less disturbance is witnessed hence efficiency to present the best responses possible from the participant.

Moreover, the researcher divided the interview questions into five sections bearing two parts: background review and technical and/or working conditions. For background review, the interviewee described their professional background in the maritime industry and its relation mainly to e-Navigation. The question also instructed them to list their publications (e.g. journal articles, seminar presentations or reports) on e-Navigation, and indicate the level of their own e-Navigation technical abilities. This part of the interview helped the researcher to find out on-sea experience or skill in ship navigation. On the technical and/or working condition's part, the interview questions were divided into four sections that related to e-Navigation: shore side, ship side, non-SOLAS vessels and e-Navigation in general. This helped the researcher understand the works of the e-Navigation from several different perspectives.

Apart from the e-mail interview questions, the researcher also had informal interviews with maritime users, experts and scholars in some particular fields relevant to the topic for example cyber security. Personal notes were recorded for comparison with the interview result and SIP to get more understanding on e-Navigation works. Results will be shown in chapter 4.

Consequently, analysis of data collected from the interviews and SIP was conducted to arrive at solutions to the problem statement. Along, it generated conclusions and recommendations. Notably the analysis was conducted based on interviewee's personal experiences with e-Navigation, the SIP established by the IMO, and personal notes. The limitations and benefits of e-Navigation for the maritime field and stakeholders will be shown in chapter 5.

3.4 Narrative analysis

Interview questions offered as little guidance as possible to allow the interviewees to talk about what was of importance to them within the given context. The researcher then extracted those phenomena or significant experiences of the interviewee as a construction to developing a theory using narrative analysis. Boréus and Bergström (2017) discussed narrative analysis as a viable way to organize and gain insights of participants in social science research, which is why narrative analysis is the primary tool used for the interview responses in this dissertation.

Additionally, Riessman (2008) supported this method with emphases on interviewing and the process of transcribing interviews as data for narrative inquiry. Labov (1969) described five key components of such narratives (as cited in Boréus & Bergström, 2017):

1. An abstract (summary of the event);
2. Orientation (time, place, situation, participants);
3. Complicating action (sequence of events);
4. Resolution (tells what finally happened);
5. Coda (returns the perspective to the present).

According to Kisser (1996), the value of the narrative analysis is "privileged human agency and it deals with particular and the specific, rather than the collective and statistical" (as cited in Boréus and Bergström, 2017, p. 124). Moreover, Robertson (2000) and Feldman and Almquist (2012) pointed out some of benefits of using narrative approach, stating that a "narrative attunes the analyst to nuance, helping us see things that would be overlooked in more technical readings, and making us aware of absences as well as presences" (as cited in Boréus and Bergström, 2017, p. 124). For the current study, the researcher also used the categorical-content approach as a mode of reading narratives. Lieblich et al. (1998) defined this mode focus on "the content of narratives as manifested in separated parts of the story, regardless of the context of the complete story" (as cited in Boréus and Bergström, 2017, p. 131).

3.5 Ethical considerations and limitation of the methodology

Although the interview method has many benefits, there are some limitations as well. For example, on occasion participants may have difficulty understanding the context of the question. In these instances, the researcher must respectfully bring them back to the content. But, in an online interview conducted by email, there are added challenges for the interviewer and the participant to connect directly in order to pursue follow up clarifications, especially when the participants are not in the same country/time-zone. There were also some unforeseen obstacles for this methodology, particularly in terms of varying response quality. For instance, for some questions, several participants answered in great detail, but others gave quick answers or comments that did not really address some part of question properly. Lastly, some participants were not willing to answer.

Marshall (2016) mentioned that face to face interviews are more impactful since clarification are done there and then. In hindsight, perhaps, face to face interview would have afforded the researcher a better opportunity to mitigate some of the aforementioned issues. Nevertheless, the online interview has some advantages, and the decreased cost and lowered potential for participant distraction made this methodology a sound choice for the current study.

However, given the exploratory purpose of the study, these limitations do not pose any foreseen issues for the credibility and relevance of the findings. The limitations did not hamper the data collection process, as the methodology of this dissertation was carefully considered and designated prudently prior to implementation. There were no concerns with attrition and subject variability that could impede external validation of the results.

4. ANALYSIS OF E-NAVIGATION MODUS OPERANDI

4.1 Introduction

The IMO has set up a project named e-Navigation that shall coordinate harmonized collection, integration and exchange of information on board and ashore. This is enacted electronically to control berth to berth navigation. The overall implication is beefing up the safety of navigation hence minimizing perils. In addition, SIP also pointed out that the relevant requirements for commercial communication links for e-Navigation should have certain availability and latency criteria for the defined service area. Withal, it should provide a two-way data communication channel and enabling acknowledgement of information delivery. Therefore, it could enable automatic quality assurance of service efficiency, availability in coverage of the communication service, and the ship borne communication installation and capability. It is expected that new equipment and processes will be adopted to realize e-Navigation globally, eventually integrating all ships and shore infrastructures into the e-Navigation concept. To understand how it works, the figure no 2 and 3, will help to picturing the e-Navigation architecture provided by IMO and also can be visualized by the 7 pillars concept.

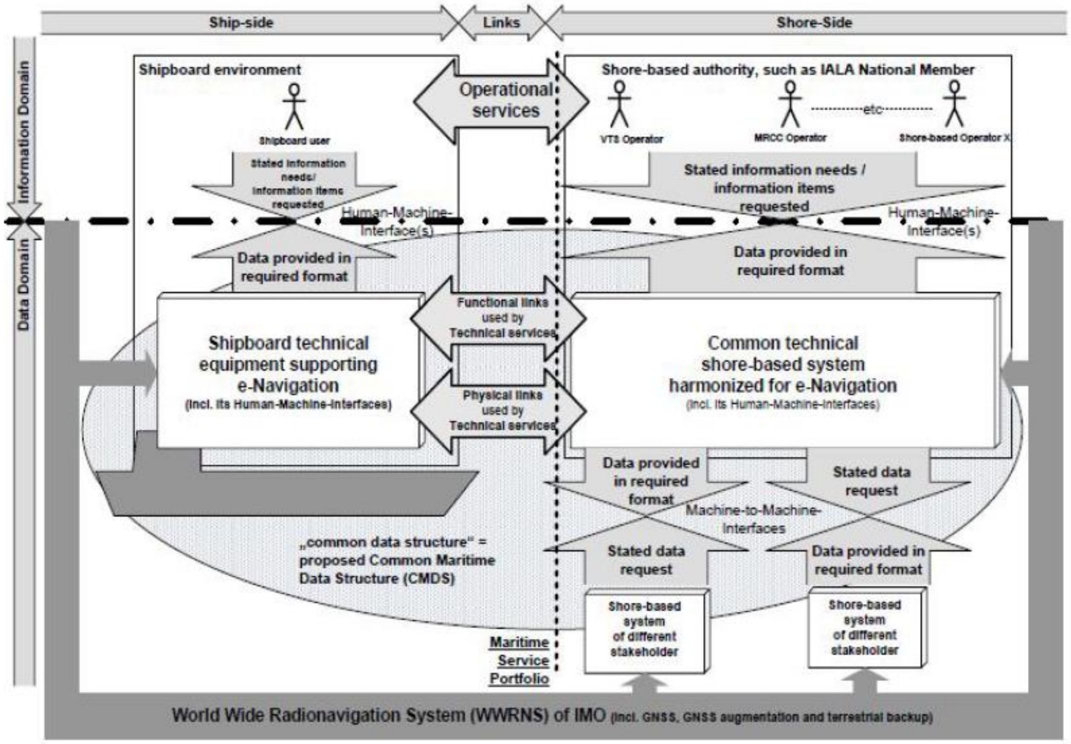

Figure 2. E-Navigation architecture (Annex 7 of NCSR 1/28 page 18)

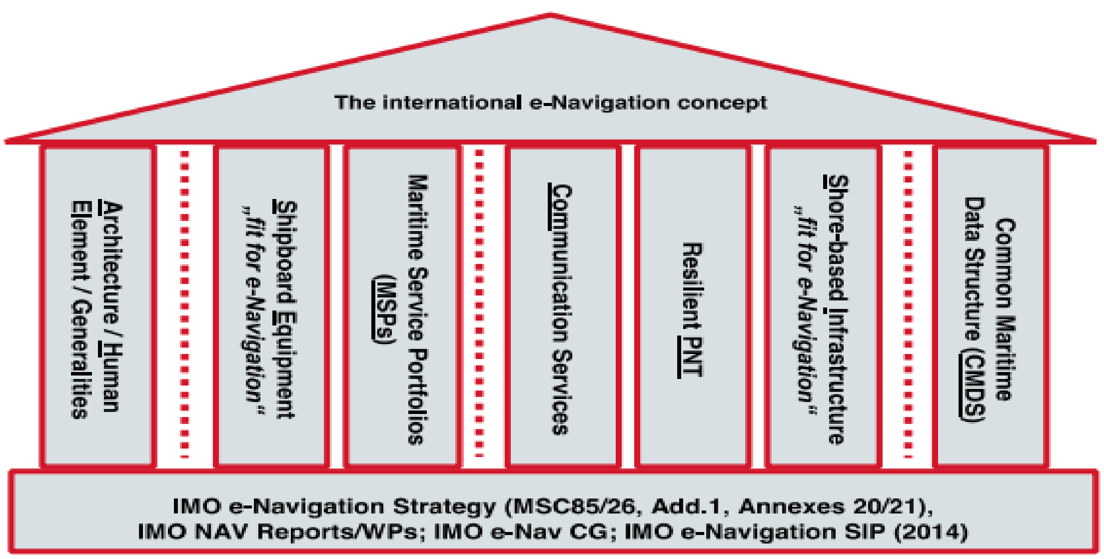

Figure 3. The 7 pillars of e-Navigation (ACCSEAS Feasibility Study of R-Mode using MF DGPS Transmissions Report 1.0 / 7.03.2014)

Furthermore, in a real life of e-Navigation implementation, there will be ships that are fully integrated, others partly integrated, and for a while many that are not at all. There will be ships with SOLAS, and others with non-SOLAS. Hence, the researcher categorized the questions in the interview into three perspectives to get clear understanding of e-Navigation; shore, SOLAS ship, and non-SOLAS vessel.

4.2 E-Navigation. How does it work?

4.2.1 Ashore

MSC 85/26/Add.1, annex 20, point number 4, described the shore-based related part of e-Navigation as:

> The management of vessel traffic information and related services from ashore enhanced through better provision, coordination, and exchange of comprehensive data in formats that will be more easily understood and utilized by shore-based operators in support of vessel safety and efficiency (p. 2).

E-Navigation requires standards and protocols that enable routing and sharing of data between actors and infrastructures. The concept must prevent duplication of information and ensure that the information is received in completely and reliable. Sea operations are very sensitive in any country. Any pertinent information should be shared according to standard operating procedures without violating any law. Accurate information is therefore a requirement which cannot be ignored. In order for the vessel to navigate safely, information has to be relayed from different sources. In the infrastructure ashore, it will likely use radar, AIS, VDES LRIT, ship database, and SAR. This information may include services for position or route advice, schedules and instructions for arrival, pilotage and tugs service, search and rescue, maritime safety information or traffic information, etc. It is worth noting that even the operators of the vessels such as ship need to communicate information to control department. Regular updates are required to ascertain security of the ship.

Moreover, e-Navigation is designed to provide 16 services that are addressed as MSP's. To facilitate e-Navigation ashore, collaborative maritime community systems that are able to route information from its source and deliver to the intended users is required. The general objective is to improve and to enhance the efficiency of the services. In addition, the development of shore based systems towards e-Navigation has been established prior to the SIP was conceived. For instance, few projects by the European Community such as Vessel Traffic Monitoring and Information System (VTMIS-Net, SafeSeaNet (SSN), Sea Traffic Management (STM) which is a project developed and conducted by Sweden, and ACCSEAS, a 3-year project which is completed in 2015, to name a few. These projects are aiming at enhancing the safety of maritime traffic by minimizing navigational risk. Meanwhile, among others, in Asia Region, Republic of Korea established the SMART-Navigation in order to implement e-Navigation on smaller vessels. Moreover, Hong (2016) conducted a research study on the effect of e-Navigation on reducing vessel accidents using SMART navigation concept.

These projects are in order to study and further develop the of e-Navigation services possibilities, despite the fact that the technology keep moving on. However, the information required will need to be integrated digitalized and be of high quality for all stakeholders. For instance, five interviewees (35%, n=14) stated that ENC streaming service will be considered as a reliable and resilient connectivity for the communication link. Currently, IHO has been working to increase ENC availability and it is hoped that the framework will be in line with the upcoming IALA standard for e-Navigation technical services.

According to IALA (2015) report of e-Navigation architecture ENAV17-10.4.2, the architectural analysis prompts succinct education to have an overview of complete operation of e-Navigation. The operators and other peripheral assistants should undergo training that would enable them coordinate the entire process with ease. (IALA, 2015). Nevertheless, even though two interviewees indicated that the operators ashore will likely have a different type of operator than a traditional VTS operator, most of the interviewees are agree that HCD should provide an easy way to engage with the operators. Since e-Navigation will be to a great extend machine to machine, therefore the operators here will be expected to have a sufficient technical knowledge in order to keep the competences and have capacity to deal with the new technologies and to be able to recognize problems and act correctly, even in a case when a problem might occurs. In the overall e-Navigation concept this is also true for the operator both ashore and on board.

However, it seems every country will have a different arrangement regarding e-Navigation concept (see also chapter 5!). Interviewees asserted during the interview that some coastal states won't be capable of afford sophisticated level of e-Navigation information service, besides it will takes time to upgrade their systems and not every coastal state will need to provide all MSP. Therefore, it is essential that traditional and e-Navigation methods must be complimentary as they will have to work side by side.

4.2.2 On board

According to MSC 85/26, annex 20, paragraph 4, described on board-based related part of e-Navigation as:

> Navigation systems benefit from the integration of own ship sensors, supporting information, a standard user interface, and a comprehensive system for managing guard zones and alerts. Core elements of such a system will require, actively engaging the mariner in the process of navigation to carry out his/her duties in a most efficient manner, while preventing distraction and overburdening (p. 02).

The vessels are always in need of the latest information on board to alert the mariner when necessary in order to ensure safe navigation. On board the vessel will likely use official nautical charts and publications, and SOLAS standard equipment like e.g. radar, AIS, and LRIT communications. Provision of information such as chart correction, weather forecasts, passage planning / route advice, MSI, must enable the bridge team to easily operate navigational equipment as well as comprehend the information that is presented to them. More and more vessels are being equipped with IBS that provide the possibility to route information to the consoles or equipment requiring it at specific time. These vessels could be considered e-Navigation compliant provided there is a portal to exchange data through a suitable data communication carrier. Beside the onboard processes, the e-Navigation concept also contains a component that requires vessels to provide information to other vessels and to actors ashore.

Furthermore, e-Navigation facilitates machine to machine communication which eliminates, the certain extent, the need of human intervention. The Officer of the Watch (OOW) is assumed in the e-Navigation environment in the future will only has to know that the equipment is functioning and how to retrieve the data he needs from the equipment. Because every ship has different equipment on their navigational bridge, thorough familiarization is needed for the operator. This fact is supported by the investigation in the project of ACCSEAS Training Needs Analysis Report (Baldauf, 2015). Further, one interviewee stated that in the future e-Navigation reality, there will be a quality indicator to inform the mariner. So the information received can be trusted and is correct. But when there is a conflicting information from different source, the competence of the mariners (Master/OOW) will still be needed and especially challenged in such cases. During the interview, it was found that the professional judgment will be used to handle this situation which is sourced mostly from the mariner’s experiences. If the mariners can use the data information correctly and properly, it is assumed that the e-Navigation concept will have a positive impact on the ship's performance as well. For instance, the ship will navigate more safely and OOW will have more time to maximize his duty. But, on the other hand, it is also questionable whether the mariners will use the information received or not. The final decision will be with them. A generally good Bridge Team Management (BTM) and the competences of the mariners are expected from the interview's result, this is an intrinsic key component for implementation of e-Navigation functions.

4.2.3 The role of communication between ship to ship, ship to shore, shore to ship, and shore to shore

According to the definition given in "Vision of e-Navigation" point 4 MSC 85/26 annex 20, communication is described as: "an infrastructure providing authorized seamless information transfer on board ship, between ships, between ship and shore and between shore authorities and other parties with many related benefits" (p.2).

E-Navigation will support the seamless communication. Nevertheless, a proper communication infrastructure is required both aboard and ashore to exchange data. As such, e-Navigation lends itself to data exchange systems by satellite, or terrestrial VDES services. Presently VDES is evolving and is expected to enable data to be exchanged terrestrially when a vessel is in range of ashore station, whilst long range e-Navigation communication between ship and shore or ship to ship will use satellite communication services. Therefore, VDES is about to be integrated in the communication link. To understand the concept of operation by VDES, figure no.4 will give a brief description.

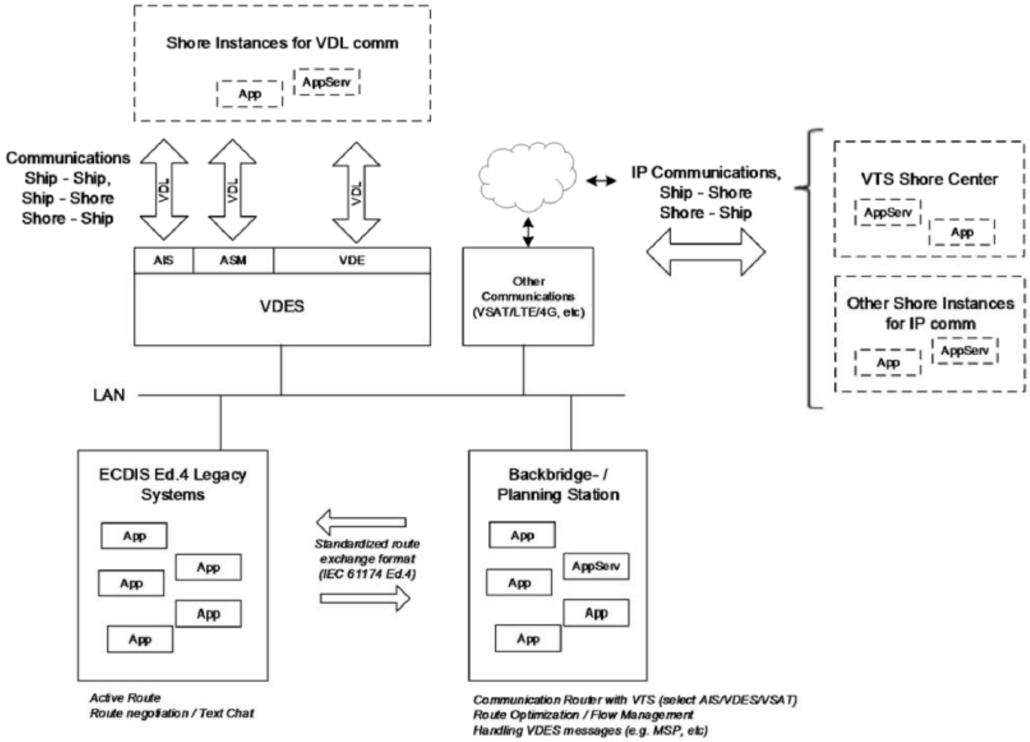

Figure 4. Concept Operation by VDES (Source. IALA)

However, there are very different volume capabilities of data exchange via satellite services depending on the communication equipment on the vessel. As such e-Navigation services and data requirements have to be designed either;

1. Around the less sophisticated vessels to ensure that all vessels have the same information.

Or,

2. To provide information that is based on the sophistication of each vessel, but using a protocol that ensures that important information is received by all vessels when the opportunity arises.

5. POTENTIAL IMPACT OF THE IMPLEMENTATION OF E-NAVIGATION

5.1 Introduction

Following Chapter 4 that gave us an understanding of how e-Navigation works, this chapter discusses the impact of e-Navigation for the maritime world, from the perspective of the researcher and the different kinds of stakeholders that are represented by the 14 interviewees. Moreover, the interviewees' e-Navigation technical knowledge is divided into these categories: basic, intermediate, and advanced. The percentage of participants with each e-Navigation skill level is shown in the pie chart below.

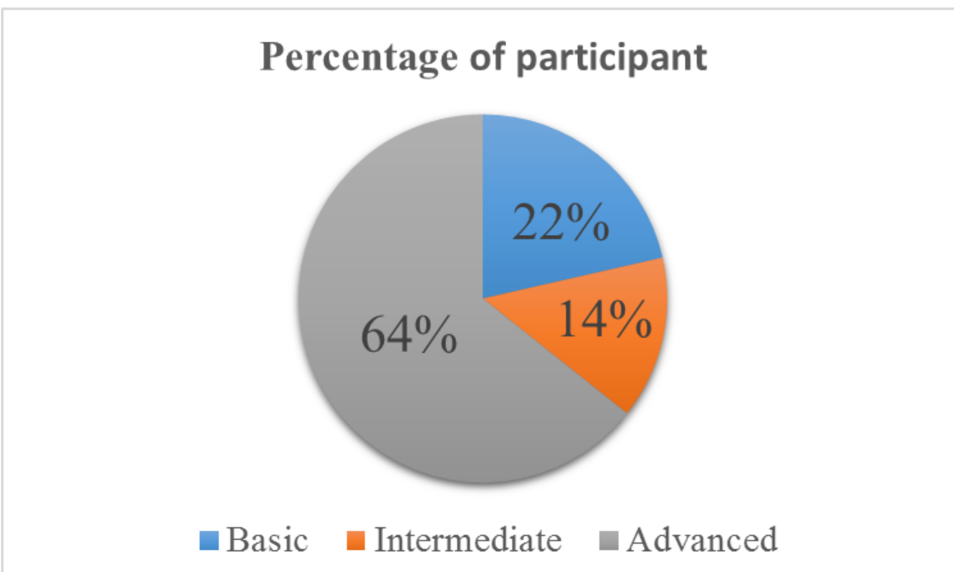

Figure 5. Statistic of participants' e-Navigation technical knowledge

In addition, 9 out of 14 interviewees considered their technical knowledge advanced and have a sea going experience. All interviewees (100%, *n*=14) were working directly in the development of e-Navigation also had released some publications in academic journals or magazine articles as well as presentations at e-Navigation seminars organized by IALA or IMO. The number of participants involved in these endeavors is shown in Figure 6 below.

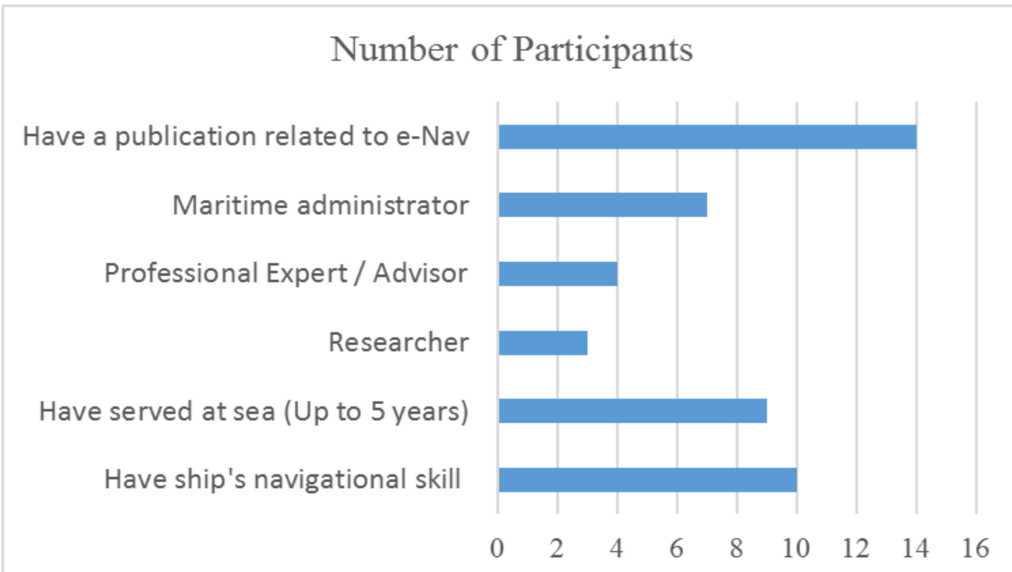

Figure 6. Distribution of category of interviewee professional background

Furthermore, these statistics indicate that the interviewees who participated in this research study were very knowledgeable and well-experienced. More than half of the total sample are participating in working groups of IALA or IMO (71%, *n*=14). Therefore, their comments on the interview are considered a crucial input for this dissertation. Interestingly, the interviewees also shared some facts in the real field that were not yet obvious in the other related documents or research so far.

5.2 Identified shortcomings

There are a number of shortcomings that range from the human element and technology restrictions to the loss or equivalence of quality information among all actors that share the seas. Lately, Integrated Bridge Systems are commonly used at sea. Coastal States are implementing uniform methods of processing information and evolving better systems for intercommunication to improve awareness and dissemination of the state of the art of e-Navigation. However, at the implementation level, various challenges arise, as discussed below.

5.2.1 The problem of data / information integrity.

One opportunity for error occurs when using e-Navigation technology to inform the vessel when a waypoint is reached. However, if the waypoints had been set into the system incorrectly, this could result in a serious casualty.

Not all vessels need the same level of information depending on their voyage status, operational character, and differing regulatory regime. Six interviewees (42%, *n*=14) mentioned that if vessels in the same area have "different" information (e.g. one vessel has the current information and the others do not, or all but one vessel is up-to-date) due to their onboard equipment capabilities onboard, a risk of casualty is created. The responses gathered from the interviews showed that the development of e-Navigation should offer all vessels the same quality and accuracy of the services to minimize the risk of casualty. Some standards to certify the quality are ongoing, for instance Software Quality Assurance developed by IMO and Standard Software Maintenance of Shipboard Equipment developed by BIMCO and CIRM. However, all interviewees strongly agreed it is foreseen that not all vessels will receive the same latest information offered by the concept as it is being designed today.

At this point, many participants identified that delays or inaccuracies in the latest information could place vessels in problematic situations, or even danger. For example, one interviewee stated,

> First, data communication delays can create situations in dynamic areas that could result in conflicts due to updates not being received in time. This would be the case with just-in-time arrival technology as a significant delay in a changed arrival time might mean two ships arrive at the same time, causing congestion. Secondly, unverified decision support services could provide wrong suggestions that could result in an accident.

Interestingly, another three interviewees expressed a similar answer like the statement above. The first interviewee stated, "if ENC updating is not proper or providing wrong information, the ship can be led into dangerous situations. If updating is delayed because of a malfunctions of shore system. It causes wrong decision-making on a vessel". Correspondingly, a second interviewee remarked, "more over non-compliant vessels may be unprepared for a severe danger such as Tropical Revolving Storm, due to information delay". Furthermore, a third interviewee stated that an accident might happen due to "erroneous information which would draw attention from safety administrations and would halt development due to fear of poor implementation. All efforts must be done to ensure the info being promulgated by Government authorities is correct".

Indeed, not all vessels will be equipped to participate in the e-Navigation concept; enforcement of e-Navigation for all vessels is not possible due to the limitations of SOLAS. Flag states have the responsibility to ensure that their vessels of all sizes have an e-Navigation awareness. Moreover, not all coastal states will provide all e-Navigation services, and the provision of such is dependent on the states' capabilities and needs. Three interviewees mentioned the e-Navigation implementation can be handled differently by each country (different port service, different vessel, etc.). This non-uniformity is recognized as one of biggest challenges of e-Navigation. The stakeholders will need to face this challenge and address it using a suitable “handshake” protocol to ensure smooth transitions and cooperation between maritime users and the competences of the mariner. Therefore, it seems clear that this issue creates the possibility of inequality in the quality of services offered by the coastal authorities. This contrasts the main benefits of e-Navigation to promote and enhance the safety through improved decision support (MSC 85/26 Annex 20).

5.2.2 No acknowledgement of information being received by the operator.

The interview results revealed that one important aspect to be considered is the receipt or acknowledgement function of the concept. All interviewees agreed that e-Navigation so far does not acknowledge messages sent. This concern was elicited by asking “How will the operator know whether all vessels have received the information?”. It is important to know the status of the information, particularly when information is critical. This potential deficit can be resolved by having a message acknowledgment that can be recorded within a journal database shared by all stakeholders.

As recognized by the interview results, a receipt function is greatly needed in e-Navigation, and one interviewee noted this also can be effective in closed-loop communication (CLC), which is a technique where a recipient repeats back a message from the sender. CLC may work to avoid misunderstandings between the sender and the receiver, but it would entail massive duplication of information, which could be cost prohibitive for satellite communication services and utilize precious bandwidth. According to Chan and Özgüner (1995), there are many systems needed to implement closed loop control through a communication network. Due to remote sensor, actuator and processor locations, the operators both ashore and onboard need to know whether the information is received and correct, and if the system has a problem. Such exposition gives the mariner the chance to seek for alternative. This function could be available in e-Navigation to enhance situational awareness for some modus operandi.

Another consideration is the possibility of components of the system breaking-down, even though e-Navigation systems are expected to be resilient and reliable. Examples of malfunction may range from deficiencies of onboard equipment and interference of sunspots with GNSS to the failure of a critical satellite payload. The question of whether the machine or the mariner can recognize when such an event occurs has not been sufficiently addressed by the interviews thus far. Are there robust systems planned that will alert a mariner when such an occasion arises, and provide measures to correct them? This is a serious challenge within the e-Navigation concept.

5.2.3 Loss of the traditional skills

Traditional skills of mariners have been tried and tested over generations. Because e-Navigation practices provide the processes to alert a mariner if they are not functioning correctly, there is a risk that the operator might be over-dependent on automated systems and lose their traditional skills. From the interviewees' outlooks, some degree of automation on the bridge will not require a skilled OOW to maintain 24 hours of watch.

Additionally, five interviewees confirmed the convenience of e-Navigation concept introduced over reliance and satisfaction on automated systems for mariners, hence leading to the loss of situational awareness, and over time, traditional navigation skills. Mariners who used the traditional way had opportunities to check the progress of route planning and could cross-reference the position of waypoints with the planned course as the voyage proceeded. Meanwhile, reliance on e-Navigation that provides high reliability and integrity of data and information might cause the mariner to not look out the window or check the radar anymore to correlate information presented with what is observed due to overreliance on the systems.

5.2.4 Two tier society

By implementing e-Navigation in maritime society, there will be ships that are fully integrated, others partly integrated, and, for a while, many that are not at all integrated with the concept. Moreover, there will be ships with SOLAS, and others with non-SOLAS. The result of this inevitably unequal environment will create a two tiered maritime society: the compliant vessels and the non-compliant vessels. If the compliant vessels are using services from a VTS (alternative course, or speed optimization) and have not recognized that a small vessel that is not AIS or e-Navigation equipped, and so would not be recognized by the VTS, is in their vicinity, it is possible that over reliance on e-Navigation tools could lead to an incident.

E-Navigation compliant vessels would be expected to possess satellite communications enabling them to have intermittent or continuous communication from the ship to the global e-Navigation service providers. The onboard systems would be able to interface and receive nautical updates to be installed seamlessly within onboard systems, and other specific information could be requested to update systems and knowledge as required by the bridge team. This would be a top-level e-Navigation scenario. However, other vessels would have only the occasional ability, if any, to receive data rich information by satellite, and may not be able to update any onboard systems due to the unavailability of suitable interfaces. These non-compliant vessels, therefore, will only be able to update their knowledge by using NAVTEX or other traditional radio communication services, and, as such, will not have the same quality or quantity of information as the e-Navigation compliant vessels.

This means that chart corrections may be updated on one vessel, and missing on another just a mile away. Safety of navigation information would be automatically displayed on the compliant vessel without any human intervention, but on the non-compliant vessel, the operator would have to manually search for information through printed or handwritten paperwork, or data displayed on a screen. The non-compliant vessel may likely not have the information at all. In the worst case, two vessels of similar sizes could be provided with information that could lead one into danger, and the other to safety. It could be said that there is no e-Navigation for the non-compliant vessel, and as such they would proceed with very little planning. However, there is no reason, except maybe royalties, as to why the compliant vessel could not automatically update some of the information to the non-compliant vessel using simple “handshake” protocols (IALA), standardized databases (IHO), and VDES (IMO / IALA).

5.2.5 Worst case scenario

During the research, interviewees were asked to give examples of the worst case scenario if e-Navigation failed. Apart from the shortcomings mentioned above, some interviewees identified concerns such scenarios in which information could be compromised by inconsistencies or threats to cyber security . For instance, one interviewee stated,

> A real danger is that regional (rather than internationally-agreed) e-navigation solutions will be implemented, particularly ashore, and in isolation from other providers in the region. The aim should be to implement harmonized solutions, as far as practicable. We should not get to a situation where, like prior to the 1970s, there were some thirty different maritime buoyage systems in existence. This is detrimental to safety.

Meanwhile, two other interviewees mentioned the topic of cyber security. One of them stated, “hacking and manipulation of information can mislead vessels. It is important to develop the right level of cybersecurity, learning from other relevant industry. But not overkill because that will reduce the benefit of e-navigation”. Another noted that developers may “fail to ensure sufficient quality in the software used for the fundamental e-Navigation infrastructure, which could make the whole thing break down due to a logical error or hacking.

5.2.6 Non-compliance possibility of non-SOLAS vessel within e-Navigation

When considering the above factors related to the kind of communication and onboard infrastructure needed to handle e-Navigation information, it is clear that state of the art communication and routing systems are required. SOLAS vessels have a required minimum for communication aids fit on them. With the changing trends of information needs in maritime sector, all SOLAS vessels might can be e-Navigation compliant. On the other hand, non-SOLAS vessels may or may not be fitted with appropriate equipment. It has been a common issue that non-SOLAS vessels may find it difficult to keep up with the latest technology of e-Navigation equipment, simply because of the cost or the perspective of necessity. Prior to e-Navigation, all vessels, regardless of size or complexity, had the same opportunity to source information in their way. With e-Navigation, this is no longer the case and non e-Navigation compliant vessels, especially non-SOLAS vessels, risk becoming outdated. Being able to take advantage of the e-Navigation world for non-SOLAS vessels is worth the cost incurred.

Furthermore, some interviewees agreed that all the ships, including non-SOLAS vessels, should receive the same data quality to mitigate the risk of casualty. VDES, which is currently evolving within IALA, will provide terrestrial and satellite data connections. One interviewee mentioned the possibility of extending the terrestrial range of communication using ad-hoc networking and updating each onboard system bulletin board as a possible solution to enable all vessels to have equal information. It is important to understand the risks of having different quality of information sharing, and the needs of the non-SOLAS community within the e-Navigation are being recognized. So far, South Korea has been working on a project called SMART navigation that is expected to service the non-SOLAS vessel. Moreover, Hong (2016) discussed briefly the SMART navigation service for non-SOLAS vessel and its implementation of e-Navigation on reducing vessel accident.

5.3 Identified benefits

When it comes to the positive impact, many researchers have made efforts and observations. An article that published in the February 2009 edition of *Seaways* by The Nautical Institute pose five main benefits, shown in the table below:

No	Impact	How
1	Improved safety through promotion of standards in safe navigation	Improved decision support, enabling the mariner and competent authorities ashore to select relevant unambiguous information pertinent to the prevailing circumstances
		Reduction in human error through the provision of automatic indicators, warnings, and fail-safe methods
		Improved coverage and availability of consistent quality electronic navigational charts (ENCs)

		Introduction of standardized equipment with an S-Mode* option, but without restricting the manufacturers' ability to innovate
		Enhanced navigation system resilience, leading to improved reliability and integrity
		Better integration of ship and shore-based systems, leading to better utilization of all human resources
2	Better environmental protections	Improved navigation safety as above, thereby reducing the risk of collisions and groundings, in addition to the associated spillages and pollution
		Reduced emissions by using optimum routes and speeds
		Enhanced ability and capacity in responding to and handling emergencies, such as oil spills.
3	Augmented security	Enabling silent operation mode for shore-based stakeholders' domain surveillance and monitoring.
4	Higher efficiency and reduced costs	Global standardization and type approval of equipment augmented by a 'fast track' change management process (in relation to technical standards for equipment)

		Automated and standardized reporting procedures, leading to reduced administrative overhead
		Improved bridge efficiency, allowing watchkeepers to maximize time for keeping a proper lookout and to embrace existing good practice, such as using more than one method to ascertain the ship's position.
		Integrating systems that are already in place, precipitating the efficient and coherent use of new equipment that meets all user requirements
5	Improved human resource management	Enhancing the experience and status of the bridge team.

Table 3. Benefits of e-Navigation (Adapted from the Nautical Institute, 2009)

Table 3 clearly presents the benefits of the concept. Moreover, the positive implications of embracing e-Navigation are further increased by the elimination of human errors. The process takes place electronically, which guarantees efficiency in the output. Human services are sometimes prone to mistakes, which might render the operations futile. Consideration of this fact could provide evidence of unfathomable costs of casualty that are saved by e-Navigation. This in turn mitigates:

- The potential for human error when updating information onboard a vessel.
- The provision of incorrect information to actors ashore or onboard other vessels.

To illustrate, the following scenarios provide more tangible effects of using incorrect information during navigation processes. Take for example a port that is preparing to receive a vessel. If actors ashore at the port receives inaccurate information, the port or other services may find themselves unready for the vessel's arrival, which could lead to unsafe conditions or inappropriate arrival instructions that could lead to a disaster. For instance, if the vessel sent information of its draft indicating the vessel was less deep than it was, the Pilot or VTS might inform the vessel to use a channel that was not appropriate for the vessel. If the area had hard seabed, then this could lead to damage to the hull, pollution, and loss of life. Similarly, if historic information was used because a mariner was not aware of later information, subsequent actions could lead to a vessel arriving in an inappropriate window, whereby the vessel could endanger itself and others. an inappropriate window, whereby the vessel could endanger itself and others.

Apart from the aforementioned benefits, interviewees also identified several key contributions to safety from e-Navigation systems. For example, one interviewee suggested that such technology reduces the complexity of integrated systems and improves the design of navigation and communication systems, while others noted that e-Navigation could increase situational awareness by all stakeholders and may provide information that is amiable and user-friendly. Similarly, one interviewee mentioned that e-Navigation is effective to address the issues of distraction and language barriers among VTS operators, while another stated that the e-Navigation concept can contribute to monitoring and warning mariners of deviations from the ship's intended path. Additionally, one interviewee expressed, "since the information registered is machine to machine, therefore, it will remove the possibility of errors and misinterpreted, and that information will be timely, efficiently, and reliable manner globally" .

5.4 Discussion on the shortcomings and benefits of e-Navigation

Over the past 20 years, vessels have become more and more dependent on technology to sail in the oceans. “Greater” technology within navigation and communication systems is evolving faster. As dependence grew on technology to reference the vessels position, and plan its routes, it was soon evident that, unless the human component of the system regularly updated the systems and applied corrections to them, the accuracy of the vessels could degrade substantially. The human can become a weak link. Casualties have occurred because of poor design or missing updates to these electronic systems and services.

Moreover, there is now an over dependence on GNSS and subsequently e-Navigation, as it is used for the timing of information, the location of vessels, the coloration of position, and timing for navigation. There has been a recent trend of following a screen rather than orientating the progress of a vessel by lights, shapes and topography of the coastline. E-Navigation is expected to provide not just the automatic update of systems aboard for navigation, but also the tools for route planning, corrections, navigation warnings, and other information critical for safety in navigation without any intervention of the navigator. However, these automated practices can lead to the possibility of the mariner losing orientation skills that would previously have allowed them to identify an error. Though e-Navigation is the future of planning and executing voyages around the planet, it inevitably leads to a loss of seamanship orientation by the bridge watch-keeping officer. It remains that human operators need to be trained well to maintain their skill levels and use the information correctly.

Nevertheless, there seems to be a clear benefit to the coastal state and vessels that trade in their surrounding area to reduce casualties, pollution, and loss of life, as well as improving efficiency of the port environment. However, the benefits of e-Navigation will be restricted mostly to large commercial vessels that are covered by SOLAS, and the implementation of e-Navigation might risk leading to an imbalance of the quality of information and processes used between vessels in proximity of each other. To avoid such discrimination, and to ensure that all vessels are able to be served with the same quality of information, all coastal and onboard services must allow non e-Navigation compliant vessels to continue to have the same opportunity to source information in their way for the purpose of vessels lacking the new invention. This inevitably means that, unless the cost benefit of e-Navigation included non e-Navigation compliant vessels, which most waterborne vessels will be, either the shore infrastructure and personnel required for non e-Navigation compliant vessels will have to continue in parallel to the provision of e-Navigation services, or e-Navigation compliance has to be extended to the non-SOLAS community without any financial burden to this community.

In conclusion, all risks that are observed within this dissertation should be considered within the comprehensive view of the future development of e-Navigation. Lützhöft (2004) stated that new technology could possibly create new types of accidents if it is not properly designed. Furthermore, this finding was supported by Weintrit (2016), who says:

> If current technological advances continue without proper coordination, there is a risk that the future development of marine navigation systems will be hampered through a lack of standardization onboard and ashore, incompatibility between vessels and an increased and unnecessary level of complexity (p. 568).

Patraiko, Wake, and Weintrit (2010) also stated that "e-Navigation systems should be designed to engage and motivate the user while managing workload" (p.14). This is a difficult task and will need remarkable research and testing to accomplish.

5.5 Consideration for potential future direction on e-Navigation

E-Navigation has to ensure that all sea users are brought up to a common standard of service without large cost to the small vessels, of which there are several million globally. Currently, e-Navigation addresses only a small number of users, given that they are responsible for the world's trade and use very large, sophisticated vessels. As such, the community has a responsibility to provide the networking ability to ensure that less sophisticated vessels are able to share in the state of the art information e-Navigation compliant vessels enjoy. Even though not all information will be needed for non-SOLAS vessels, one must consider the risk of grounding or collision that could occur if vessels are inequitably equipped for e-Navigation.

Lastly, there is recognition that training is needed even though the e-Navigation proposed provides usable HCD based on user needs. The training will be likely non-technical because the operator is expected to have the appropriate technical skills upon operation; the familiarization and knowledge to manage the information are more important training topics for the human operator. As one interviewee noted:

> It is vital that the human being is always central to decision-making onboard. Machines should be left to do what machines are good at – processing lots of data / information rapidly and error-free. But where judgement, experience and 'gut feel' are required, the human element is paramount. Learnings from a number of accidents suggest that the more the automation, the more humans must be trained to do. The human element needs to have a developed understanding of the level of automation and be capable of understanding automation processes.

5.6 S-Mode

The concept of Standard Mode or 'S-Mode' was first proposed to IMO by the Nautical Institute in 2010. According to Patraiko, Wake, and Weintrit (2010), S-Mode uses a standard presentation, menu, and interface as the default for onboard e-Navigation displays in the proposed system. It may also allow for the use of personal settings stored within the system or on a personal memory device so that a pilot or mariner could quickly configure their preferred or personalized settings, overlay custom features on the display, or provide access to specialist information (p.12-14). Therefore, IMO mentioned S-Mode in document NAV 59/6 Annex 1, particularly in RCO 3.

Additionally, one interviewee indicated that the S-Mode is designed on the complex onboard systems to ensure that a mariner does not get overloaded:

> e-Navigation (and digitalization efforts in general, maritime Internet of Thing (IoT), etc.) will mean having potential access to a lot of information. This can be both a benefit and a hazard. If this information lead to information overload, then e-Navigation could actually lead to accidents.

S-mode can be engaged when the mariner becomes overwhelmed by the information, allowing the navigator to remove unnecessary clutter information, give access to specialist information, or set the system to their preferred configuration.

E-Navigation is dependent on complex communication and routing infrastructures that may or may not include big data or clouds. However, communication services, clouds, and big data resources are all liable to fail at one time or another. E-Navigation has to be considered in a similar context. How can a mariner source the information to continue with his operational needs? To ensure a Safe Mode:

1. The equipment or services dependent on e-Navigation must provide an alert to the mariner immediately if the system is compromised, irrespective of where that failure may be.

2. A fall back provision of e-Navigation service must be available to all vessels and shore actors by the time an update of information of either is required.
3. All vessels (SOLAS and non-SOLAS) must immediately be informed when the failure is detected and if there is an alternative source of information available.
4. Measures to offset the imbalance of the e-Navigation and non e-Navigation compliant vessels must ensure enhanced safety of life to a much wider community.

5.7 Cybersecurity

Cybersecurity was not a focus of the current study, but the theme emerged in many of the interview results, which indicates a need for further research in this area.

To begin with, IMO awareness of recent cyber attacks was initiated by the report of Canada and United States MSC 94/4/1 in 2014. According to Hahn et al. (2016), international shipping companies such as BIMCO, ICS, INTERCARGO, and INTERTAKO are developing guiding principles which would enable management of data security and reduce the chances of cyber-attacks. On June 2017, BIMCO, CLIA, ICS, INTERCARGO, INTERTANKO, OCIMF and IUMI published the second edition of The Guidelines on Cyber Security Onboard Ships (BIMCO, 2017). Furthermore, this guideline also been aligned with the adopted recommendations given in the Implementation of Cyber Risk Management that established by the IMO Maritime Safety Committee's meeting in June 2017, in Resolution MSC.428(98) (Montgomery, 2017). Before that, in April 2017, IMO established a working group including FAL/MSC (IMO FAL 41/WP.1) to develop guidelines on cybersecurity (IMO, 2017).

Indeed, system hacking has proliferated in the current era of technological development. Any move to incorporate workable computerized system is followed by an understanding of possible threats in the internet. The shipping organizations have corporately been in discussion evaluating topics such as integrity of information, awareness of cyber threats, management and confidentiality of data. These are pillars to identification of any impeding attack.

Meanwhile, a federally funded research and development center called The National Cybersecurity FFRDC (NCF), operated by an American not-for-profit organization which also supports the U.S. government agency, developed The Common Vulnerabilities and Exposures (CVE), which is a system that provides the database of information security vulnerabilities and exposures. Figures 7 and 8 show the statistics of total vulnerabilities by year and type from 1999 to 2017.

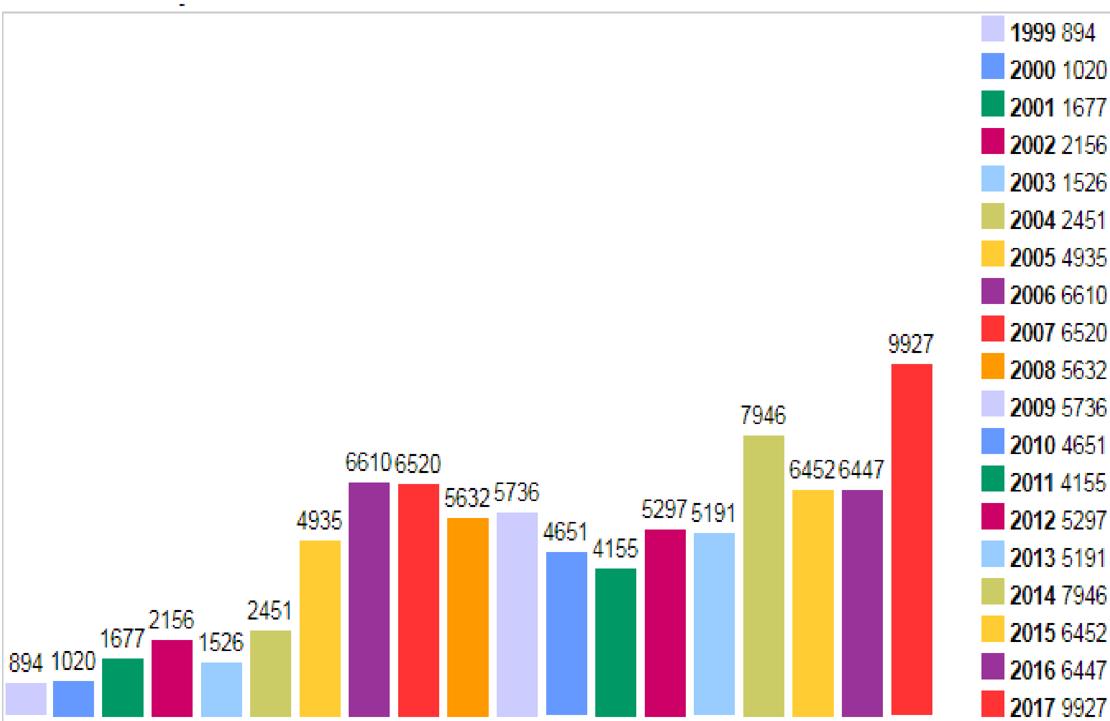

Figure 7. Total vulnerabilities by year (source: www.cvedetails.com)

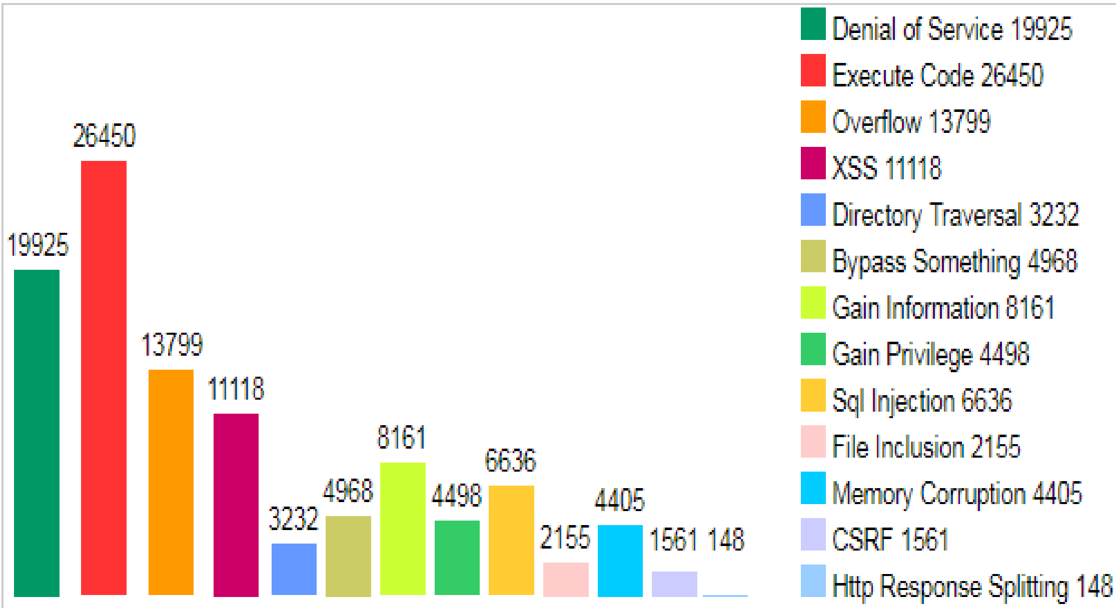

Figure 8. Total vulnerabilities by each type within 18 years (1999 to 2017) (source: www.cvedetails.com)

According to the CVE database, it is observed that the total of system vulnerability is increasing almost every year. Surprisingly, the highest increase came from last year. From 2016 to September 2017, the system vulnerabilities jumped from 6447 to 9927. In sum, the highest vulnerability came from the execute code and exploits type within 18 years, and the total number of vulnerabilities continues to increase, as shown in Figure 9 below.

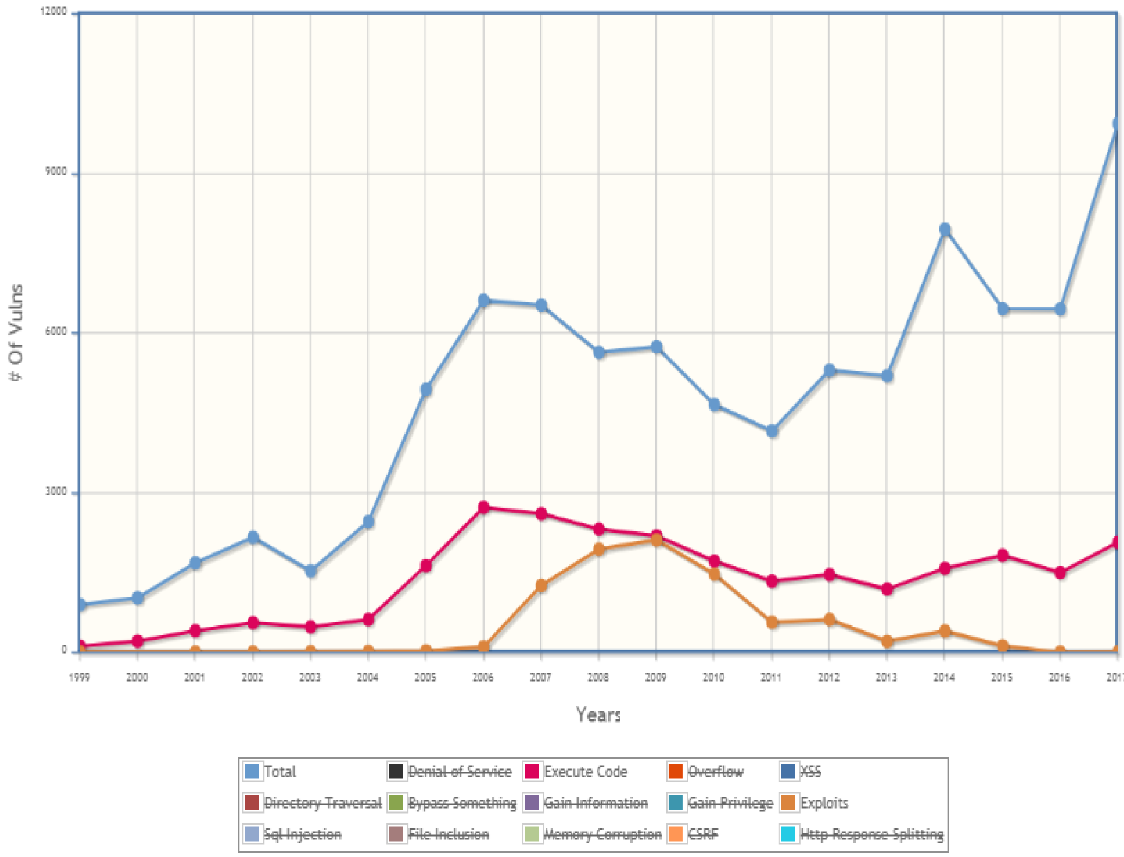

Figure 9. Vulnerabilities by type and year (source: www.cvedetails.com)

During 2017, *wannacry* was reported to have attacked more than 230,000 computer systems in over 150 countries (source needed here). *Petya*, which happened on 27 June 2017, infected several companies including the biggest shipping company, Maersk, causing delays in their logistic chain all around the world.

In addition, new exploits are created every day. There are different kinds of them; some can give a root privilege, while others just expose private information. It seems impossible to make a system that will not be vulnerable of new ways of attacking. This issue is kind of problematic for all of us. a short discussion during the WMU symposium week in June 2017 with an IT expert from a company that provide maritime IT service revealed that the shipping industry is not used to that kind of speed. He also noted that it is frequently too enthusiastic to adopt advanced technology. It sounds like they “skip ahead [in] the development process, and this is extremely worrying and so far the industry has no answer for it at all”, he said.

It looks like the need for new technology and digitalization cannot be avoided within the maritime industry. For instance, block chain and autonomous ships. may find a system convenient, but is it secure enough to be used? On the other side, the regulator takes time to establish or implement policies and regulations about cybersecurity. Long processes and bureaucracy dominate the procedure. For example, the cybersecurity issue within IMO started in 2014 until now. However, system security should not be limited by protection from exploits alone, but it should also take into account human factors that cannot be underestimated. Mitnick (2002) popularized the term of social engineering (the human element of security) in his book called The Art of Deception. He mentioned that social engineering bypasses all safeguards like intrusion detection systems, firewalls, encryption, or other security technologies. As a conclusion, there will be no standard regarding whether the system is secure enough because security of systems is a process, not a state. The only possibility is to mitigate risk to an acceptable degree, but it is impossible to remove all risk (Mitnick, 2002).

Furthermore, e-Navigation concept will provide a single window solution for a communication link between actors ashore and the ship. However, if the concept uses internet, there is a possibility that everything that goes online is not secure. Probable attacks could dismantle every bit of information. This can result in the loss in terms of funds and human resources employed in the system. Nowadays, there are other services that are using internet, not the core of e-Navigation services itself. For instance, some passenger ships upgraded their ship using VSAT to use unlimited internet, but not all vessels have this privilege.

On the other hand, it is observed that VDES and LRIT systems and data exchanges provide the capability to facilitate numerous applications for the core services of e-Navigation. These applications provide things like safety and security of navigation, protection of marine environment, weather, efficiency of shipping, and others (ECC,2013). Moreover, one interviewee mentioned hacking and manipulation of information as the worst scenario that could happen within e-Navigation. Therefore, using secure networks such as LRIT or VDES would be best choice to mitigate the risk of cyber-attacks, rather than a system that uses internet. This is an important consideration for the development of e-Navigation.

6. CONCLUSION

This dissertation's objectives were to examine the potential limitations and benefits of the implementation of e-Navigation, and especially how to address diverse types of vessels within this concept. To achieve the main objectives, the study comprehensively looks at the *modus operandi* of the proposed e-Navigation concept, and discusses requirements and implementation plans of the complete concept onboard and ashore. A thorough analysis included reviewing the SIP, journals, and articles related to e-Navigation are performed. Moreover, an interview study with some selected key stakeholders was performed in this dissertation.

E-Navigation is still under development, but it is targeted for implementation by 2020. In the state of art of e-Navigation nowadays, vessels and shore infrastructures are following the path for its implementation. However, the study found that the primary challenge is that neither every ship nor every country will have a similar arrangement for the implementation, because it is not mandatory. It is also foreseen that in the future not all vessels will be equipped according to the e-Navigation concept, as some vessels will not be sophisticated enough to reach the state due to the increased cost or suitability of achieving e-Navigation readiness. Consequently, the loss of the opportunity for all vessels to get the latest information that was available before e-Navigation, or receiving different quality of information from e-Navigation disparities, undoubtedly will put a vessel at a risk of casualty. At this point, it is crucial to have the receipt log, or bulletin board function, within the e-Navigation system to avoid a misunderstanding between users. Therefore, the issue of vessel capability also leads to the two-tier maritime society that might be caused by this condition.

When a coastal state decides to proceed with the e-Navigation concept, it will take time until full implementation can be reached. Therefore, it will be necessary for each type of vessel to communicate each other's information (maneuver, actions, ship's position, etc.) to mitigate the risk of casualty within the scenario of receiving different "quality" of information. To address this issue, the traditional method of information and data exchange will likely remain in use until the complete implementation of the e-Navigation concept is available for all vessels. Moreover, it is important for the authorities to understand the inherent challenges discussed, as they have the main responsibility for the quality and control of information.

Nevertheless, e-Navigation will make an enormous positive impact on the maritime world, if it is properly applied. The language barrier for VTS and inter-ship communications system will be diminished and replaced by an accurate and high quality integrated marine information system. This will amalgamate with the shore-based capacity development to control and guide vessel traffic, that is expected to reduce accidents related to human error significantly in the future.

Finally, this dissertation makes some recommendations for the future development of e-Navigation. The main emphases of this section are in the S-Mode, communications, and cyber security. Firstly, with an assumption that e-Navigation might fail, the concept itself provides a S-Mode. In order to provide "S-Mode" e-Navigation, the concept will probably have to continue using its existing infrastructure and personnel employed for traditional methods of information sharing. Furthermore, it is intended to servicing the needs of non e-Navigation compliant vessels to ensure the equity of quality information in the maritime community

Secondly, after researching cyber security, the hypothesis of not using internet within the e-Navigation concept was established. Meanwhile, VDES technology is on the horizon, and could successfully addressing the imbalance between the e-Navigation compliant and non-compliant vessels by providing the networking capability to share information from sophisticated vessels to large peer groups of vessels that they encounter during their voyage. While expanding AIS does not seem to be a good idea within busy channels such as the Strait of Malacca, it seems that two-way communication provided by VDES perfectly suits the e-Navigation. On this point, the recognition of VDES can secure the system using point to point services via satellite, which is expected to reduce any imbalance markedly, and thus will enable the sharing of enhanced safety of life to a much wider community.

Although this dissertation's data has limited representativeness, a further study could expand this data collection to address some of its shortcomings, as the problems explored cannot be answered quickly and further research is needed. In addition, a qualitative survey or questionnaire might provide some comprehensive outcomes, and bring more perspectives to answer the issues.

With the full implementation of e-Navigation on the horizon, successful use of this concept requires key ideas as the acknowledgement of information delivery and consideration of the importance of the role of non-SOLAS vessel. As a conclusion, the convenience of e-Navigation proposed "system" should be equally to minimize the risk of casualty. All shortcomings possibilities should be taken into consideration within the development of e-Navigation for the sake of safety of navigation and environmental protections.

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APPENDIX I
INTERVIEW FORM

BACKGROUND REVIEW

This is a list of questions designed to gather information relating to an individual's professional background and its relation to e-Navigation.

Interviewer: Where do you work at the moment and tell me what how many years you have been working in maritime industry?

Interviewer: Describe your experience and list all your work related to e-Navigation?

Interviewer: List any other publications (journals, seminars, report, etc.) related with the working of e-Navigation? (If any)

Interviewer: Which skills have you acquired in your present or previous positions that related to ship's navigation?

Interviewer: Are you a seafarer or maritime administrator? If yes, how many years you have the experience?

Interviewer: Regarding the topic of e-Navigation, do you consider your technical abilities basic, intermediate, or advanced?

TECHNICAL AND/OR WORKING CONDITIONS

This is a list of questions designed to gather information relating to an individual's past work experience, working conditions, and opinion which are related to e-Navigation.

SHORE'S SIDE

Interviewer: How will the operator know whether all vessels have received the information? Is this important for him to know?

Interviewer: Will your country upgrade its infrastructure to enable e-Navigation or will you continue to use traditional methods? Or both?

Interviewer: Not all the vessel will be sophisticated enough to keep up with e-Nav requirement. Regarding the information given to the vessel, do you think e-Navigation concept will create a problem on a shore side? Like what?

Interviewer: Do you often found / identified potential malfunctions of navigational equipment? How did you discover the potential malfunction? What did you do to correct the problem?

Interviewer: Will traditional methods of information promulgation still be available and at what stage should the operator onshore resort to them?

Interviewer: Will the services offered to vessels have a quality and accuracy standard to ensure that the information provided is accurate, current and applicable?

Interviewer: Having e-Navigation shore based system in your country, certainly requires a lot of technical knowledge for the operator. What do you think about this?

SHIP'S SIDE

Interviewer: Do you foresee that not all vessels will have e-Navigation equipment? Do you see this as a problem? (If Yes / No, describe your explanation)

Interviewer: Is there a risk that some vessels will have a different quality of information? Explain the risk.

Interviewer: What factors can create a problem when each vessel gets a different information?

Interviewer: Will vessel's based e-Navigation system, requires the watch keeper to have a lot of technical knowledge. What do you think about this?

Interviewer: How will the watch keeper or Master know what information is correct if there is conflicting information from different sources?

Interviewer: How the e-Navigation effect the performance of the vessel considering that the information is machine to machine?

Interviewer: How would a mariner know when to resort to traditional means of information reception and will the services and equipment still be available to enable them to do so?

NON-SOLAS VESSEL'S SIDE

Interviewer: How would you propose to ensure all vessels receive the same quality information and services, even though less sophisticated will share the same waters as e-Navigation compliant vessels?

Interviewer: Will the presence of vessel's equipped with E-Navigation effect the way non-SOLAS vessels that are not e-Navigation equipped will react in navigation and operational scenarios?

Interviewer: What factors can contribute to collision/grounding in the sea when non-SOLAS vessels facing the vessel with e-Navigation?

Interviewer: In your idea, what methods/tools will you use to keep the non-SOLAS vessel informed with what is going on in your area through E-Navigation system?

Interviewer: Will there be a need for non e-Navigation equipped vessels to communicate e-Navigation information with e-Navigation equipped ones. If so how do you ensure that they can communicate / update each other's information?

GENERAL

Interviewer: What do you consider the most important contribution of E-Navigation for the safety of navigation?

Interviewer: What is your opinion regarding the possibility of the reliability of Electronic Navigation Chart (ENC) and streaming service (maritime cloud)?

Interviewer: Do you think it's possible for the e-Navigation system to create services that can communicate both to SOLAS and non-SOLAS vessels at the same time? If yes, then how?

Interviewer: Give me an example of a worst case scenario that you think that E-Navigation system could cause? And tell me how to mitigate or eradicate the possibility of this happening?

--end--

APPENDIX II
INTERVIEW RESPONSES

The data collection of the interview responses is available on demands.