Enhancing safety of navigation by incorporation of additional data by automatic identification system

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ENHANCING SAFETY OF NAVIGATION BY INCORPORATION OF ADDITIONAL DATA BY AUTOMATIC IDENTIFICATION SYSTEM

By

RISHI MONDAL

India

A dissertation submitted to the World Maritime University in partial fulfilment of the requirements for the award of the degree of

MASTER OF SCIENCE

In

MARITIME AFFAIRS

(MARITIME SAFETY AND ENVIRONMENTAL ADMINISTRATION)

2018

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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 own personal views, and are not necessarily endorsed by the University.

(Signature): Rishi Mondal

(Date): 18-September-2018

Supervised by: Dr. Michael Baldauf (Associate Professor)

Supervisor’s affiliation: MSEA
Acknowledgements

I would like to express my sincere gratitude to the World Maritime University for providing me the platform to understand the global maritime industry, and challenges confronted by it from a broader perspective. The World Maritime University helped me to explore the vast expanse of the maritime world beyond seafaring.

I express my special heartfelt gratitude to my supervisor Dr. Michael Baldauf, without whose guidance and relentless support my dissertation would not have been possible. He instilled confidence in me and encouraged me throughout my entire research work.

I would also like to extend my gratitude to the head of our specialization, Dr. Jens-Uwe Schröder-Hinrichs, and other respected faculty members and staff. Their guidance and teachings have been extremely inspiring, and helped me to understand the maritime world with a profound insight.

I am indebted to the participants of my survey, whose contribution to my research work stands significant. I am thankful for the time they dedicated, out of their busy schedules for my survey.

I am grateful to my parents, brother and teachers for their continual support, encouragement and prayers. They have always been the source of inspiration for me.

Finally, I thank the almighty Lord for his kindness and for giving me this wonderful opportunity to obtain invaluable knowledge.
I dedicate this research to all the seafarers across the world.
“I must go down to the sea again, to the lonely sea and the sky; and all I ask is a tall ship and a star to steer her by.”

John Masefield
Abstract

Title of Dissertation: Enhancing Safety of Navigation by incorporation of additional data by Automatic Identification System.

Degree : MSc

This research endeavours to introduce “Electronic exchange and exhibition of ‘Day signals (shapes), Light signals, and Fog signals/Sound signals (Manoeuvring and warning signals)’ as required by COLREGs to provide quick, reliable and easy information to navigators to improve their situational awareness, which shall subsequently enhance safety of navigation.”

With considerable increase in the number and size of ships, a limited number of crew members and increased commercial pressure, safe navigation confronts uncertainty. The research explores the potential of ECDIS and AIS, by integrating them to form an enhanced ‘Model’, and focuses on assisting the navigators to identify ships correctly by the signals exhibited by them.

Conclusions were drawn with the help of surveys conducted through a questionnaire (online- by using e-mail), personal interviews, case studies and simulator experiments. The results suggest that navigators lack sufficient knowledge about the limitations of bridge equipment, and they also lack proper situational awareness while navigating. The outcome of the research also favours the introduction of the proposed enhanced ‘Model’ for improving situational awareness of the navigators and reducing human error, hence subsequently enhancing the safety of navigation.

KEYWORDS: Navigation, Collision avoidance, COLREGs, AIS, ECDIS, Signals, Model.
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List of Abbreviations:

AIS…………….. Automatic Identification System.
ARPA………….. Automatic radar plotting aid.
C.B.D………… Constrained by her draught.
CD-ROM……… Compact Disc Read-Only Memory.
COLREGs……….. Convention on the International Regulations for Preventing Collision at Sea.
COMSAR……….. Sub-Committee on Radio communications and Search and Rescue.
CPA…………….. Closest point of approach.
CSTDMA……….. Carrier sense time division multiple access.
DGPS…………… Differential Global Positioning System.
DOLOG………… Doppler log.
DSC……………… Digital selective calling.
ECDIS………… Electronic Chart Display and Information System.
ECS……………… Electronic Chart System.
EMSA…………… European Maritime Safety Agency.
ENC……………… Electronic navigation chart.
EPIRB…………… Emergency position indicating radio beacon.
ETA……………… Estimated time of arrival.
FATDMA………. Fixed access time division multiple access.
FM……………… Frequency modulation.
GBAS…………… Ground-Based Augmentation System (GBAS).
GLONASS……… Globalnaya navigatsionnaya sputnikovaya sistema Globalnaya Navigatsionnaya.
GMDSS………… Global maritime distress and safety system.
GMSK…………… Gaussian minimum-shift keying.
GNSS………… Global Satellite Navigation Systems.
GPS………… Global Positioning System.
HDLC………… High-level data link control.
HF……………….High frequency.
HO……………… Hydrographic offices.
hPa……………. Hectopascal.
IALA………….. International Association of Marine Aids to Navigation and Lighthouse Authorities.
IHO……………. International Hydrographic Organization.
IMO……………. International Maritime Organization.
INMARSAT…… International Mobile Satellite Organization.
INS……………. Integrated navigation system.
IRNSS………… Indian Regional Navigational Satellite System.
JPO…………… Joint Project Office.
MaRiSa………… Maritime Risk and System Safety.
MF…………….. Medium frequency.
MMSI………… Maritime Mobile Service Identity.
N.U.C………… Not Under Command.
NAVTEX……….. Navigational telex.
OOW…………….. Officer on watch.
QZSS………… Quasi-Zenith Satellite System.
R.A.M…………… Restricted in her ability to manoeuvre.
RATDMA………. Random access time division multiple access.
RCDS…………… Raster chart display system.
RNC……………… Raster navigational chars.
SART……………. Search and rescue radar transponder.
SBAS…………… Satellite-based augmentation systems.
SOG……………. Speed over ground.
SOLAS………….. International Convention for the Safety of Life at Sea.
SOTDMA.......... Self-organized time division multiple access.
TCPA.............. Time to closest point of approach.
TDMA............... Time division multiple access.
USB................. Universal serial bus.
UTC................ Coordinated Universal Time.
VDL............... VHF data link.
VHF................ Very high frequency.
VTS............... Vessel traffic system.
WMU............... World Maritime University.
1. Chapter 1- Introduction
1.1 Subject and Purpose:

The subject of this dissertation is maritime safety and specifically safety of navigation. The purpose of this dissertation is to research how safety of navigation could be further enhanced by specifically examining and investigating the potentials of incorporating new technological aspects, such as the exchange and display of additional navigational data (navigational status in pictorial form and fog signals/ sound signals) of vessels by using the Automatic Identification System (AIS). The research focusses only on the on-board perspective, even though AIS also has a shore-based perspective. Although AIS has obvious potentials to support the management of maritime operational risks, the research of this dissertation exclusively focusses on the handling of risk of collision.

1.2 Background:

Shipping has observed an exponential expansion and development in the application of advanced technology in its every operational sector (Låg, 2015) (Pestana). However, technological developments in the navigation associated sphere have not completely succeeded to alleviate the occurrence of accidents relating to collisions and groundings. Hence, further improvements and analysis to reduce collision and grounding incidents stands as a demanding requirement.

Presently, a large volume of vessels plying internationally are equipped with modern navigational aids and improved present-day communication technology. In addition, stringent surveillance mechanisms exist for verification of compliance of various conventions established to enhance navigational safety. However, the question that still remains unanswered, is why do collisions and groundings still occur?

Is only the human behavioural aspect, which is responsible for accidents? Are the prevailing enforcement and implementation methods relating to concerned conventions adequate? Or, did technology advanced more rapidly than it could be accommodated for efficient applications?
As navigation comprises competence, skill and decision-making, the role of human behavioural aspect indispensably remains significant (Squire). Nevertheless, the human aspect/dimension is supported by technology, which assists in inferring to apposite decisions. Therefore, determining the root causes of an incident/accident is not simple, it is utterly complex in nature and is influenced by diverse factors. Major incidents/accidents can be fatal, it can result in fatalities, and cause acute damage to the environment and property (Ceyhun, 2014). Considering the economic impacts and implications of such consequential incidents/accidents in the backdrop of international maritime trade, liabilities of the concerned stakeholders stand out to be immoderately high.

This dissertation aims to research and explore the practicable possibilities of further reducing/alleviating the occurrence of accidents and incidents associated with collisions through an improved, extended, systematic and technologically feasible data exchange system, which shall ameliorate and enhance navigational safety and improve situational awareness.

1.3 A brief introduction to the research topic:

The research focuses on enhancing the safety of navigation by the incorporation and exchange of additional navigational data by using the Automatic Identification System (AIS) and displaying such information on the ECDIS screen at the receiver’s end. The aforementioned additional navigational data includes pictorial depiction of day signals (shapes) and light signals, and electronically audible sound/manoeuvring signals as specified in the Convention on the International Regulations for Preventing Collision at sea, 1972 as amended.
1.4 Methodological Approach of the research:

Figure 1- Methodological approach.

The methodological approach to validate research relating to this dissertation is represented in the above diagram, and described as follows:

i. The Analysis of accident reports: This includes the analysis of accidents, and endeavours to investigate whether incorporation and exchange of the additional navigational data mentioned earlier would have helped to avert such situations.

ii. The opinions of experts: This includes the views of experts such as master mariners, maritime administrators, navigating officers and pilots. This section has been addressed by questionnaire (online- by using e-mail) and personal interviews.

iii. Economic Considerations: For addressing and examining the economic viability of the proposed system for the exchange of additional navigational data by using
Automatic Identification System. This section has not been addressed by the research relating to this dissertation, and remains open for further research.

iv. The administrative and legal implications: This includes the analysis of administrative and legal feasibility for the application of the mentioned system of exchanging additional navigational data. The views and opinions of maritime administrators has been considered for analysis, which has been made possible through the questionnaire (online- by using e-mail) and personal interviews.

v. The technical feasibility: For addressing and examining the technical aspects and determining practical viability of employing the mentioned system of exchanging additional navigational data. This section has not been addressed elaborately by the research relating to this dissertation and remains open for further research.

1.5 Method of data collection, techniques for data analysis, and scope of study:

i. **Data collection:** The collected data comprises of both qualitative and quantitative data. The quality of the data has been ensured by considering inputs from highly qualified maritime experts.

   - Data has been collected by conducting personal interviews and sending questionnaires by e-mail. Maritime experts such as master mariners, navigators, pilots, maritime administrators, and personnel related to maritime education and training were accounted for interviews and answering the questionnaire.
   - Five case studies were referred and analysed to validate the proposed application.
   - Data has been collected by conducting simulation experiments as a pilot study, which aimed at discovering the advantages and limitations of the proposed new application.

ii. **Data analysis techniques:** The qualitative and quantitative data analysis method has been used for analysis of the collected data. Data collected through the questionnaire, personal interviews, case studies and simulation experiments have been thoroughly analysed both quantitatively and qualitatively.
iii. **Scope of the study:**

- This includes the proposal of a new ‘Model’ which aims at exchanging additional navigational data to enhance safety of navigation.

- The study and analysis of advantages and implications regarding application of the proposed model with the help of data collected through the questionnaire, interviews, case studies and simulation experiments. Various research papers were also referred to for the study.

**1.6 Research questions:**

a) What leads to collision incidents/accidents?

b) Can addition of technological advancements assist to improve situational awareness?

c) Is it only the human element that is responsible for incidents/accidents, or there exist a gap between human element and technology, which can be bridged by technological advancements?

d) Can ‘Automatic Identification System (AIS)’, and ‘Electronic Chart Display and Information System (ECDIS)’ be used more effectively to enhance the safety of navigation?

e) Will change in the existing provisions hinder safety of navigation?

The remaining thesis is structured as follows:

Chapter 2, provides a brief insight about the historical transition of navigational instruments and technology used in maritime industry;

Chapter 3, explains the chronological process of collision avoidance and reliability of navigational aids;

Chapter 4, gives a detailed overview of the proposed new application- “Development of an enhanced model”;

Chapter 5, deals with the analysis of the responses relating to questionnaires and personal interviews;
Chapter 6, refers to the design and conduction of simulation-based pilot study;

Chapter 7, is dedicated to case studies to validate the need for the proposed new application;

Chapter 8, includes conclusion of the research conducted.
2. Chapter 2- The new era of navigation

2.1 Transition from conventional methods to e-navigation- A brief history of the evolution of nautical instruments and technology in maritime industry:

2.1.1 The age of Celestial Navigation-

Navigation is an art, which essentially comprises of two basic principle, firstly determining position and secondly direction. Mankind, since the very beginning of sea transportation has explored various methods for finding position and direction. Along with growth in the world fleet and technological advancements, various additional aspects of navigation have evolved over period of time, which has added new dimensions to navigation.

During the medieval age, the Arabic empire contributed significantly in the field of navigation. They used an instrument known as the Kamal. The Kamal was an instrument, simple in construction, used for celestial navigation. It allowed the navigator to find the ship’s position with the help of the Polaris (Pole star) and adjust the position accordingly. The principle used was the altitude of the Polaris is approximately equal to the latitude of the observer. The Arabs used the unit of issabah, which is equal to one degree and thirty-six minutes (Ifland). The Arabs also used a primitive form of magnetic compass that consisted of lodestone (Bruyns & Dunn, 2009).

Another significant instrument used for celestial navigation was the Quadrant, which was first used in the fifteenth century and gained popularity in the mid-eighteenth century. It was used to measure the angles of celestial bodies over the horizon, and enabled the navigators to fix their position. The quadrant was the predecessor of an enhanced nautical equipment, called the Sextant (Suttmeier, 2017).

Shen Kou (1031-1095), a scientist in China, wrote about the magnetic needle and concept of the true north; this is the first known written document which mentions the
magnetic compass. The compass appeared in the Islamic world and Europe in around 1300 (Sparavigna).

Rabbi Levi ben Gerson (1288-1344) apparently invented the cross staff which was used to measure angular distances of celestial bodies, which assisted navigators to locate their position (Stern, 2003).

Hipparchus was born in Asia Minor about 180 BC, and his work on theory of astrolabe projection was credible. It is not known when stereographic projection took the form of the instrument we know as the astrolabe, but it is evident that the astrolabe existed in the seventh century. The astrolabe was introduced to the Islamic world in the mid-eighth century and was widely used in Europe in the Middle-Ages and Renaissance. It helped the mariners to find their position by taking observations of the celestial bodies (The Astrolabe, 2016).

The invention of the Octant in 1731 and the Sextant in 1757 added sophistication to celestial observations. The Sextant underwent refinements until about 1960 when use of celestial navigation started to decline (Bud & Warner, 1998).

Predicting longitude at sea was a challenge, and in 1714 the British parliament offered bounties of up to £20,000 for anyone who could find a practical solution to this challenge. A Yorkshire clock-maker named John Harrison found the answer. This led to the invention of the marine chronometer (Forbes, 1966).

2.1.2 The age of Radio-Communications-

The discovery of the electromagnetic waves in 1864 by James Clerk Maxwell was a major breakthrough, which added a new dimension to maritime field, the wireless communication. It was in 1895 when Guglielmo Marconi was able to send Morse radio signals for over a mile in distance. R.F Matthews was the first ship to request assistance in an emergency in 1899 by the help of the wireless apparatus (Wireless Communication, n.d.) (Massey, Jenkins, Katzdorn, & White, 2003-2004). This was followed by the invention of the radio direction finder and hyperbolic navigation, which assisted in finding position. Electromagnetic waves not only helped in
communication and position fixing, but also in the detection of targets by radar. Robert Watson-Watt is credited as the inventor of radar in 1935. 1941-1945 witnessed intensive developments in Radar. The first radar with a plan position indicator was installed in U.S.S. Semmes in 1941 (Blumtritt, Petzold, & Aspray, 1994) (Luse, 1981). Modern day radars are highly sophisticated and uses improved technology. Automatic radar plotting aid is also used in conjunction with modern radar for collision avoidance.

2.1.3 The age of Satellite Navigation-
Global Satellite Navigation Systems (GNSS) is the term used for satellite navigation systems that provide for obtaining a position automatically. 04-October-1957 marked the beginning of a new age, the ‘space age’, when Sputnik-I was launched. TRANSIT, the first GNSS was developed by the United States; it was declared operational in 1964 and opened for the use of civilians in 1967. Based on a similar concept the Soviet Union developed ‘PARUS’ and ‘TSIKDA’. The operation of TRANSIT was terminated on 31st December 1996. In 1972, another project of the United States called ‘TIMATION’ was in operation, but it provided two-dimensional fixes like the TRANSIT. The United States Air Force was studying a project called ‘621B’, which aimed at providing 3-dimensional fixes. On April 1973, these two projects were merged and the ‘Navstar Global Positioning System (GPS) Joint Project Office (JPO) was established. The existing systems, GPS (DGPS when GPS is used with correction from GBAS or SBAS) and GLONASS, are named as GNSS-1, while the GNSS-2 will include additional second-generation systems such as Galileo, Compass (CNSS), Indian Regional Navigational Satellite System (IRNSS), and Quasi-Zenith Satellite System (QZSS) (Bonnor, 2012).

2.1.4 The age of improved communications and Search and Rescue operations- the advent of INMARSAT and GMDSS-
The importance of satellites in search and rescue operations was recognized by the IMO in the 1960s. The International Maritime Satellite Organization, which later changed its name to International Mobile Satellite Organization (Inmarsat) was established in 1976.
The integrated communication system, the GMDSS, was full implemented on 01\textsuperscript{st} February 1999. GMDSS required ships to carry equipment like the NAVTEX receivers, EPIRB, Inmarsat ship stations, VHF/MF/HF with DSC etc. to improve safety of life at sea. GMDSS notably reinforced safety of navigation in more than one way. The exchange of meteorological information, navigational warnings, piracy warnings, routine communications etc. was made possible by the inception of GMDSS. The combination of terrestrial and satellite communication makes GMDSS a robust and efficient system (IMO, IMO- Radio Comunications- Introduction/History, n.d.).

2.1.5 Modern aids to navigation-
Recent developments include AIS, ECDIS, Virtual aids to navigation, INS, e-Navigation etc. A more detailed explanation about AIS, ECDIS and e-navigation is provided later in this chapter. The present state of the art will be analysed in order to support a better understanding of the research and the suggested technological developments.

2.2 An Analysis on the evolution of nautical instruments and its technology and effect on navigation:
Shipping has always been the life blood of global economy. From the age of oars and sails to the age of dual fuel engines, shipping has expanded and brought benefits to people across the world (Shipping and World Trade, n.d.). The number and size of ships grew exponentially over time. New types of ships emerged as a result of the demand to transport special cargoes (Corbett & Winebrake, 2008). Consequently, efficient navigation became a requisite for the productive shipping of cargo.

The degree of accuracy of a ship’s position improved from celestial observations to three-dimensional satellite fixes. This allowed the navigators not only to reduce the uncertainty of running into dangerous navigational hazards, but also improve the efficiency of the voyage. A ship’s position is also vital for search and rescue operations, and most importantly the added accuracy gives the navigator confidence to execute plans related to navigation in a more productive way. Direction finding also improved considerably from celestial calculations and magnetic compasses to
contemporary gyro-compasses. Modern gyro-compasses allow for the integration with other instruments to add reliability and sophistication to navigation.

The improvement in communication technology has helped to save lives, and to exchange information pertaining to safety of navigation and commercial aspects. The human element, an important component of shipping, benefits significantly from modern communication technology, as it allows seafarers to communicate with their families easily and economically.

Integration of modern instruments provide multidimensional information to assist decision-making, and enhance situational awareness.

Further, the emergence of collision prevention regulations has made navigation standardized, organized and systematic.

2.3 AIS- A new dimension to modern day navigation:

AIS is a system used for communication using the VHF maritime mobile band, for exchanging navigational data to enhance safety of navigation. AIS devices, known as stations are identified by their unique Maritime Mobile Service Identity (MMSI), a series of nine digits. The key feature of the system is that the stations operate autonomously. AIS facilitates the exchange of shipboard information automatically from vessels sensors, as well as manually by the operator. The International Convention for the Safety of Life at Sea, 1974 (SOLAS 74), Chapter V, requires all ships of 300 gross tonnage and upwards engaged in international voyages, and cargo ships of 500 gross tonnage and upwards engaged in international voyages, and passenger ships irrespective of size engaged in international voyages to carry AIS. Some administrations require non-SOLAS vessels to carry AIS as well. The purpose of AIS can be broadly classified as follows, firstly, in ship-to-ship mode for collision avoidance, secondly, for littoral States to obtain information, thirdly, as a VTS tool (IALA, 2011).

The AIS system consists of one VHF transmitter, one VHF DSC receiver, two VHF TDMA receivers, and standard marine electronic communications links
(IEC 61162/NMEA 0183) to shipboard display and sensor systems. Timing and position information is obtained from an external or integral global navigation system receiver, including a differential global navigation satellite system in coastal and inland waters for a more accurate position. Other information broadcasted by the AIS is fed manually or obtained from various sensors using standard marine data connection. Transmissions use 9.6 kb GMSK FM modulation over 25 or 12.5 kHz channels using HDLC packet protocols. Each Station determines its own transmission schedule (slot), based on the knowledge of other stations’ future actions. Position report from one station fits into one of the 2250 time slots that are repeated every 60 seconds, there are two frequencies used, AIS 1(Channel 87B) and AIS 2(Channel 88B), which is divided into 2250 time slots as mentioned. The AIS stations synchronize themselves to avoid the overlap of a slot. A station pre-announces the new location and timeout for an existing location when the station changes its slot assignment. This allows new stations and other stations that appear suddenly within radio range closer to the vessel, to be received by the vessel. The ship reporting capacity as per IMO performance standard is a minimum of 2000 time slots per minute, but the system provides 4500 time slots per minute. SOTDMA broadcast mode allow overload of the system by 400 to 500% through the sharing of the slots. Thus, a great number of ships can be accommodated simultaneously. The range is a function of the height of the antenna.

The elementary methods by which AIS devices access the link are as follows:

1) Self- Organised (SOTDMA) - this method is used as a basic access for mobile stations,
2) Random Access (RATDMA) - to access the link for unscheduled transmissions,
3) Fixed Access (FATDMA)- where reservation of slots is used by AIS stations to transmit at predetermined intervals,
4) Carrier Sense (CSTDMA) – used by some mobile stations to access the link only when they find an unused slot (USCG, n.d.) (IALA, 2011).
Figure 2-AIS System Overview (Sketch taken from (IMO, NCSR 1/28-Annex 9, 2014)).

Figure 3-AIS Components (IMO, NCSR 1/28-Annex 9, 2014).
2.4 AIS Data exchange and types of Information:

There are four types of information provided by the AIS; the input of this information is either automatically from various sensors of navigational equipment, or manually by the operator.

Table 1-Type of AIS Information according to (RESOLUTION MSC.74(69), 1998).

<table>
<thead>
<tr>
<th>Static</th>
<th>Dynamic</th>
</tr>
</thead>
<tbody>
<tr>
<td>IMO number (where available)</td>
<td>Ship's position with accuracy indication and integrity status</td>
</tr>
<tr>
<td>Call sign &amp; name</td>
<td>Time in UTC</td>
</tr>
<tr>
<td>Length and beam</td>
<td>Course over ground</td>
</tr>
<tr>
<td>Type of ship</td>
<td>Speed over ground</td>
</tr>
<tr>
<td>Location of position-fixing antenna on the ship</td>
<td>Heading</td>
</tr>
<tr>
<td></td>
<td>Navigational status (e.g. N.U.C, at anchor, etc. - manual input)</td>
</tr>
<tr>
<td></td>
<td>Rate of turn (where available)</td>
</tr>
<tr>
<td></td>
<td>Optional - Angle of heel (where available)</td>
</tr>
<tr>
<td>Voyage related</td>
<td>Optional - Pitch and roll (where available)</td>
</tr>
<tr>
<td>--------------------------------------------</td>
<td>--------------------------------------------</td>
</tr>
<tr>
<td></td>
<td>Ship's draught</td>
</tr>
<tr>
<td></td>
<td>Hazardous cargo (type)</td>
</tr>
<tr>
<td></td>
<td>Destination and ETA (at master’s discretion)</td>
</tr>
<tr>
<td></td>
<td>Optional - Route plan (waypoints)</td>
</tr>
<tr>
<td>Short safety-related messages</td>
<td>-</td>
</tr>
</tbody>
</table>

### 2.5 Types of AIS equipment and installations:

There are various types of AIS and are mentioned as follows:

*Table 2-AIS stations (IALA, 2011) (USCG, n.d.)*

<table>
<thead>
<tr>
<th>AIS Station</th>
<th>MMSI format</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AIS class A</td>
<td>MIDXXXXXXX</td>
<td>Shipboard mobile equipment that complies with the carriage requirements and performance standards adopted by the IMO.</td>
</tr>
<tr>
<td>AIS class B</td>
<td>MIDXXXXXXX</td>
<td>Shipboard mobile equipment that are compatible with other AIS stations but do not comply with the performance standards adopted by IMO.</td>
</tr>
<tr>
<td>AIS base station</td>
<td>00MIDXXXX</td>
<td>These are shore-based stations used by competent authorities to facilitate ship-to-shore and shore-to-ship information transmission by managing the VDL.</td>
</tr>
<tr>
<td>AIS Aids to Navigation</td>
<td>99MIDXXXX</td>
<td>These stations are used to provide the status and position of an aid to navigation. They may be fixed (i.e. attached to lighthouse) or floating (i.e. attached to a buoy).</td>
</tr>
<tr>
<td>AIS of Search and Rescue (SAR) aircraft</td>
<td>111MIDXXX</td>
<td>Aircraft mobile equipment, used for</td>
</tr>
</tbody>
</table>
search and rescue operations, and safety of navigation.

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>AIS-SART</td>
<td>970YYXXXX</td>
<td>It is used for homing itself during a search and rescue operation. It provides greater range than a radar SART.</td>
</tr>
<tr>
<td>MOB-AIS</td>
<td>972YYXXXX</td>
<td>Man-Overboard AIS transmitters are used to indicate the position of an individual in water.</td>
</tr>
<tr>
<td>EPIRB-AIS</td>
<td>974YYXXXX</td>
<td>It is used to assist in locating.</td>
</tr>
<tr>
<td>AIS Repeater</td>
<td>00MID4XX</td>
<td>It is used to increase the range of other AIS.</td>
</tr>
</tbody>
</table>

### 2.6 Reporting Interval for AIS data exchange:

*Table 3-Class A shipborne mobile equipment reporting intervals (Recommendation ITU-R M.1371-5, 2014).*

<table>
<thead>
<tr>
<th>Ship’s dynamic conditions</th>
<th>Nominal reporting interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ship at anchor or moored and not moving faster than 3 knots</td>
<td>3 min</td>
</tr>
<tr>
<td>Ship at anchor or moored and moving faster than 3 knots</td>
<td>10 s</td>
</tr>
<tr>
<td>Ship 0-14 knots</td>
<td>10 s</td>
</tr>
<tr>
<td>Ship 0-14 knots and changing course</td>
<td>3 1/3 s</td>
</tr>
<tr>
<td>Ship 14-23 knots</td>
<td>6 s</td>
</tr>
<tr>
<td>Ship 14-23 knots and changing course</td>
<td>2 s</td>
</tr>
<tr>
<td>Ship &gt;23 knots</td>
<td>2 s</td>
</tr>
<tr>
<td>Ship &gt;23 knots and changing course</td>
<td>2 s</td>
</tr>
</tbody>
</table>
Table 4—Reporting intervals for equipment other than Class A shipborne mobile equipment (Recommendation ITU-R M.1371-5, 2014).

<table>
<thead>
<tr>
<th>Platform’s condition</th>
<th>Normal reporting interval</th>
<th>Increased reporting interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class B “SO” shipborne mobile equipment not moving faster than 2 knots</td>
<td>3 min</td>
<td>3 min</td>
</tr>
<tr>
<td>Class B “SO” shipborne mobile equipment moving 2–14 knots</td>
<td>30 s</td>
<td>30 s</td>
</tr>
<tr>
<td>Class B “SO” shipborne mobile equipment moving 14–23 knots</td>
<td>15 s</td>
<td>30 s</td>
</tr>
<tr>
<td>Class B “SO” shipborne mobile equipment moving &gt;23 knots</td>
<td>5 s</td>
<td>15 s</td>
</tr>
<tr>
<td>Class B “CS” shipborne mobile equipment not moving faster than 2 knots</td>
<td>3 min</td>
<td>-</td>
</tr>
<tr>
<td>Class B “CS” shipborne mobile equipment moving faster than 2 knots</td>
<td>30 s</td>
<td>-</td>
</tr>
<tr>
<td>Search and rescue aircraft (airborne mobile equipment)</td>
<td>10 s</td>
<td>-</td>
</tr>
<tr>
<td>Aids to navigation</td>
<td>3 min</td>
<td>-</td>
</tr>
<tr>
<td>AIS base station</td>
<td>10 s</td>
<td>-</td>
</tr>
</tbody>
</table>

2.7 ECDIS—A revolutionary transition in navigation:

ECDIS is an intricate, software-based, safety-related system with various options for display and integration. The benefits of ECDIS were recognized through the voluntary use of it for many years and by the Formal Safety Assessment submitted to the IMO. The ECDIS carriage was mandatory for High-Speed craft from 01-July-2008. For other ships, carriage requirements were mandated in a phase in manner from 01-July-2012 onwards, and by 01-July-2018 all ships required an ECDIS onboard (IMO, MSC.1/Circ.1503/Rev.1, 2017).

2.8 Components of ECDIS:

1) **Computer hardware, software and network:** These components enable the processing of information gathered from sensors of various navigational equipment. It also allows the flow of information between various components of the system. A typical ECDIS comprises of a display screen/monitor, processing
unit, keyboard, power supply, device to update ECDIS (e.g. CD-ROM, USB port etc.) and applies corrections to the electronic charts. ECDIS is interfaced with various navigational equipment such as DGPS, echo-sounder, doppler log, gyrocompass, AIS, Radar, NAVTEX, etc.

2) **Chart database:** The ECDIS comprises of a database of electronic charts; it is either vector charts or raster charts. ECDIS can operate in two modes, namely, the ECS mode when it operates with vector charts (ENCs) and the RCDS mode when it operates with raster charts (RNCs). Electronic navigation charts (ENCs) and raster charts are both issued under national hydrographic offices (HOs). RNCs is used in areas for which ENC are not yet present. The raster chart consists of coloured ‘digitized picture’ of nautical charts, whereas the vector chart consists of layers of organized data. In the case of vector charts, information is stored as files that form the layers; this allows the user to decide on the amount of information to be displayed. S-57, S-63 and S-52 are some of the IHO standards developed for ECDIS and ENCs.

3) **System display:** This consists of the screen on which electronic charts are displayed along with processed data obtained from various navigational equipment. There are two modes of display, namely, true mode and relative mode respectively. The brightness and contrast of the screen can be adjusted by the operator. There are various display requirements as per ECDIS performance standards adopted by the IMO that are required to be complied.

4) **User interface:** This serves as a link between the system and the operator. It allows the operator to use various functions of the ECDIS and makes allowable changes to the system according to his/her convenience. For example, the navigator may choose to use radar overlay on the ECDIS screen, or he/she may change the dimension of the safety domain of the ship (such as safety depth and look-ahead settings) (NIMA).
2.9 Towards digital voyage planning and navigation with ECDIS:

Compared to conventional voyage planning on the basis of paper charts, pilot handbooks, various publications, etc. ECDIS facilitates complete voyage planning, i.e. incorporation of various functions along with the planned route. Voyage planning on ECDIS can be resolved into three perspectives as follows:

1) Navigational disciplines: This include meteorological data, tidal data, anti-collision regulations, ocean currents, ship manoeuvring and communications, hydrographic data, and positioning data.

2) Process perspective: This comprises of the planning phases which include planning, preparation, execution and evaluation.

3) System perspective: This includes the user, procedures, user-interface, algorithms and data.
The above figure represents the integration of various perspective that aids navigation. Passage planning primarily consists of four procedures; appraisal, planning, execution and monitoring. Appraisal relates to the collection of voyage related information, planning involves charting of the route based on information gathered, execution refers to tasks performed during the course of the voyage, and monitoring relates to the supervision of the progress of the vessel with reference to the planned route. A navigator can plan routes and electronically save them on the ECDIS. When the vessel is ready to sail the planned route can be activated. By doing so, ECDIS will allow monitoring functions and alert the navigator by various integrated alarm systems (SABELIS, 1999).

RESOLUTION A.817(19)- Performance standards for Electronic Chart Display and Information System (ECDIS) adopted by the IMO, specifies the technical requirements of ECDIS regarding route planning, monitoring and voyage recording.

2.10 ECDIS interfaces and potentials:
As mentioned earlier ECDIS is interfaced with various navigational equipment which enables the navigator to get access to the integrated information. Some of the recent developments have suggested a broadened potential of such interfaces, whereas a few of them are described as follows:

![Figure 6-General scheme of ECDIS inputting and VHF DSC connection (Miyusov, Koshevoy, & Shishkin, 2011).](image)
1) Integration of the Digital Selective Calling VHF Marine Radio Communication System and ECDIS-

A paper published in the International Journal on Marine Navigation and Safety of Sea Transportation proposed a project on simplification of VHF DSC radiocommunication by integrating the VHF DSC controller of the Automatic Identification System (AIS) and the Electronic Chart Display and Information System (ECDIS). It explores the presence of the MMSI number. The proposed method provides the capability to form a call by only clicking the mouse on the chosen vessel or the coast station. A calling vessel can be identified by the receiver end on the display by a blinking mark which will allow the OOW of the called vessel to access the navigational situation and make appropriate decision. This system will not require the entering of the MMSI number as it can be sent automatically from AIS-ECDIS system to the DSC controller, which will save time. It is cost-effective as well as not requiring additional changes to the existing setup (Miyusov, Koshevoy, & Shishkin, 2011).

2) Reliability of positional information on ECDIS-

Document NAV 51/6/3, proposed by Japan, suggested the requirement in regards to the redundancy of GPS systems, as it provides ECDIS with positional information. As Satellite navigation system like Galileo could provide independent source of space-based position fixing information, and redundancy in positional information could be achieved (IMO, Ammendments to the ECDIS performance standards (NAV 52/5), 2006).

3) AIS targets in ECDIS -

The idea of display of AIS targets on the ECDIS screen should be made mandatory was proposed by Russia. Russia was in the opinion that AIS information should only be used along with the radar overlay on the ECDIS screen, while, Germany suggested that AIS should only be used for situational awareness and not for collision avoidance (IMO, Ammendments to the ECDIS performance standards (NAV 52/5), 2006).
2.11 E-navigation- The dawn of a new era of navigation:

In the eighty-first session of the Maritime Safety Committee of the IMO, a proposal was placed by Japan, Marshall Islands, the Netherlands, Norway, Singapore, the United Kingdom and the United States regarding e-navigation (IMO, MSC 81/23/10, 2005). The idea was to incorporate new technologies in a structured manner and ensure its compatibility with the existing navigation and communication technologies. The NAV -Subcommittee in co-operation with COMSAR Sub-Committee developed “Draft strategy for the development and implementation of e-navigation ” (IMO, NAV 54/25-Annex 12, 2008) and “Draft framework for the implementation process for the e-navigation strategy” (IMO, NAV 54/25 -Annex 13, 2008), IALA and IHO also played a significant role to this cause. Maritime Safety Committee approved the strategy and framework for implementation of e-navigation consolidated in the following documents, “Strategy for the development and implementation of e-navigation” (IMO, MSC 85/26/Add.1-Annex 20, 2008) and “Framework for the implementation process for the e-navigation strategy” (IMO, MSC 85/26/Add.1-Annex 21, 2008) respectively. IMO defined e-navigation 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 and protection of the marine environment”. The vision, core objectives, benefits, and requirements of e-navigation were also agreed upon by the IMO. (IMO, MSC 85/26/Add.1-Annex 20, 2008).

There are three key elements of e-navigation as follows:

1) Onboard:

   The Navigational system should benefit from

   • Integration of sensors,
   • Supporting information,
   • Standard user interface,
   • Systems for managing alerts and guard zones,
- Engaging the mariner to carry out navigational duties efficiently,
- Prevent overburdening and distraction.

2) Ashore:
   Enhanced management of vessel traffic and related service from ashore by
   - Better provision, coordination and exchange of data,
   - Standardized formats.

3) Communications:
   Seamless transfer of information
   - Between ships,
   - Ship to shore,

Architecture of e-navigation:

Figure 7—Overarching e-navigation architecture (IMO, NCSR 1/28-Annex 7, 2014).
The figure above represents the comprehensive architecture of e-navigation. It shows the “Operational service links”, and the “Functional links and Physical links” used by the technical services. It explains the operational and technical services, functional and physical links in a hierarchical standpoint. It describes the “Data domain” and the “Information domain. It also specifies the “Maritime service Portfolio” and explains the relationship of the shore-to-shore data exchange (IMO, NCSR 1/28-Annex 7, 2014).

In this chapter a brief summary of the main technical issues related to the research of this dissertation has been given to support a clear understanding of the development of suggestions for new, innovative technical features for collision avoidance. The basics of collision avoidance are addressed in the following chapter.
3. Chapter 3- Collision Avoidance and the reliability of navigational aids

The collision of vessels at sea causes fatalities, loss of property and environmental pollution. As per EMSA report, from 2011 to 2016, collision incidents accounted for 16% of total ship casualties (Pedersen, 2010) (EMSA, Annual Overview of Marine Casualties and Incidents, 2017).

The “Convention on the International Regulations for Preventing Collision at Sea (COLREGs)” serves as guideline for navigators to avoid the unwanted situations, such as close quarters or collision situations. The “Convention on the International Regulations for Prevention Collision at Sea” was adopted on 20-October-1972 and entered into force on 15-July-1977, replacing the Collision regulations of 1960. It underwent a series of amendments in 1981 (Resolution A.464(XII), 1987 (Resolution A.626(15), 1989 (Resolution A.678(16), 1993 (Resolution A.736(18), 2001 (Resolution A.910(22), 2007 (Resolution A.1004(25), and 2013(Resolution A.1085(28)) (IMO, IMODOCS).

Various control measures have been adopted to reduce the risk of collisions, some of which follows:

- Traffic separation scheme,
- Vessel traffic and information service,
- Pilotage,
- Modern and advanced aids to navigation,
- Redundancy in ship’s machinery and navigational equipment,
- Integration of navigational equipment,
- Modern navigational equipment and communication equipment,
- Technologically improved means for passage planning,
- Improved design and manoeuvrability of ships,
- Improved modern training methods and tools (Pedersen, 2010).
Although there exists established and well-structured set of collision avoidance rules, modern equipment and easily accessible information, but the human element plays a pivotal role (Gregory & Shanahan, 2010). Situational awareness, a key component of the human element, is of vital importance to appraise the data/information collected manually and through equipment(s) to diligently exercise the collision avoidance rules. Chronologically, the steps involved in developing situational awareness are as follows: Firstly, having the correct perception of elements involved in a given situation; Secondly, integration, interpretation, and retention of data/information acquired; and finally, the ability of projection (Hetherington, Flin, & Mearns, 2006).

3.1 Chronological process of Collision Avoidance:

The figure below shows the steps involved in avoiding collision at sea.

1) **Data collection: Observation of the sea space for target/object identification:**
   The first step involves the identification of target(s) and other hazard(s) in the proximity.

   a) **Identification of targets:** As per the COLREGs, depending on their manoeuvrability vessels are classified into various categories, such as “Vessel not under command”, “Vessel constrained by her draught”, “Vessel restricted in her ability to manoeuvre”, “Vessel engaged in fishing”, etc. The collision avoidance rules are based on the principle that gives privilege to vessels with limitations in their manoeuvrability. Further, vessels are required to display shapes during daylight, and light signals during hours of darkness. In or near areas of restricted visibility, vessels are additionally required to sound fog signals. The navigational status of a vessel, which indicates any limitations in manoeuvrability could be assessed by the signals exhibited by the vessel (IMO, Convention on the International Regulations for Preventing Collisions at Sea, 1972). The identification of vessels can be done visually, by hearing, and by using navigational instruments. Equipment such as radar is used to identify the existence of a target, whereas AIS can be used to determine the navigational status of any target. Generally, visual means of identifying a target is considered as prudent
seamanship, but is not always free of human error. If the required signals are wrongly exhibited or not exhibited, incorrect information can be communicated to other vessels.

Every navigational instrument has its own limitations; if the OOW then fails to appreciate such limitations, he/she may end up having an incorrect perception about the navigational status of other vessels, especially in conditions of restricted visibility where reliance on navigational instruments is greater (MSA, 1998).

b) **Identification of other hazards in proximity:** Before taking any action the OOW should be also aware of any navigational hazard(s) other than the concerning vessel(s). Some of the navigational hazards are shallow waters, rocks, buoys, wrecks, oil platforms etc. Some of the surface targets may be identified visually or by radar, but the underwater hazards are difficult to identify physically. The echo-sounder, which provides the depth of water can indicate whether the vessel is approaching or within shallow waters, but in the case of a submerged wreck or rapid depth reduction it will not be able to warn the navigator well in advance. The safe principle is to ascertain and monitor one’s own ship’s position and refer navigational charts to locate the proximal dangers.

2) **Data Analysis** (Situation assessment regarding existing or developing risks of collision): This step involves analysing collision situations on the basis of information gathered, such as characteristics of the targets, meteorological conditions, available sea-room for manoeuvre, own ship’s characteristics etc. and interpret the collision regulations for applying it to avoid a close quarters situation or a collision. To determine if risk of collision exists with any target, a series of bearing of the concerned target shall be taken. This gives an indication of whether a target is ‘closing in’ or ‘opening out’ (IMO, Convention on the International Regulations for Preventing Collisions at Sea, 1972). This can also be done by taking visual bearings or radar bearings where the former shall be always given preference due to its higher degree of reliability. Understanding the target vessel’s ‘aspect’ is essential, as it provides information of the target vessel’s heading with
respect to one’s own vessel. Comprehending the aspect of the target vessel essentially has consequential effect on the action that should be taken to avoid collision. Various alarms, such as ARPA alarms, AIS alarms, ECDIS alarms etc. could be used to assist analysing a collision situation.

As mentioned before, one of the key elements that should be taken into account is the limitations of the navigational aids. Failure to appreciate the limitations of navigational aids can lead to incorrect conclusions (MSA, 1998). Analysis forms an integral part of the collision avoidance process as it leads to the next vital step of taking action to avoid collision.

3) **Decision Making and Taking Action:** This step involves taking action in accordance to the COLREGs to avoid a close quarters situation or a collision. As per COLREGs, action to avoid collision shall be positive, taken in ample time and in observance of good seamanship. Such actions shall be readily apparent to another vessel observing visually or by radar. Generally, it involves the alteration of course and/or speed. While taking action, due regard shall be given to the available sea-room, navigational hazards, meteorological conditions, and the limitations of the vessels involved (IMO, Convention on the International Regulations for Preventing Collisions at Sea, 1972).

4) **Monitoring:** It is of significant importance to monitor the effectiveness of the action taken to avoid collision. This shall be done visually in conjunction with the navigational aids. Monitoring shall be carried out diligently until the vessel is past and clear by a safe distance; and risk of collision ceases to exist or the action taken does not lead to another close quarters situation (IMO, Convention on the International Regulations for Preventing Collisions at Sea, 1972).
Figure 8-Chronological process of Collision Avoidance.
3.2 Visibility and Reliability of navigational aids:

Meteorological visibility has a consequential impact on ship’s navigation. In good visibility conditions visual navigation can be supplemented by navigational aids. However, when the visibility is not good or restricted, the OOW has to completely rely on his/her navigational aids and fog signals which he/she is able to hear.

In case of restricted visibility, there lies a high chance of assembling insubstantial information and/or erroneous information due to limitations of navigational aids and/or inefficacious practices during navigation.

![Distance-time graph of targets with respect to visibility.](image)

*Figure 9- Distance-time graph of targets with respect to visibility.*
The above figure illustrates the relationship between “Distance of target vessel from own ship”, “Time” and meteorological “Visibility”, represented by three mutually perpendicular axes respectively.

Let us consider Case-1, where conditions of \textbf{restricted visibility (‘zero visibility’)} prevail. The relationship of the target vessel’s distance with respect to time is represented in the figure, which shows that the closest distance the target would pass own vessel is “d”. Let us consider this curve represents distance-time relationship of the target from detection to the time when it is finally clear. With respect to one’s own vessel, while taking an action to avoid collision, this curve can be broken down into three phases, namely ‘Identification’, ‘Analysis’ and ‘Action and Monitoring’. As shown in the figure, “d” represents desired safe distance of own vessel. It is important to note that the process of ‘identification’ is totally dependent on information gathered through navigational aids and hearing fog signals. If limitations of the navigational aids are not accounted for, or the navigational aids furnish erroneous information, the curve will take the wrong shape which can lead to a dangerous out-turn.

As per COLREGs- Annex III, a vessel of 200 metres or more in length is required to be fitted with a whistle which has minimum audible range of 2 nautical miles, and for vessels of length less than 200 metres the required audible range of the whistle is even less. The actual audible range is essentially influenced by factors, such as heavy seas, strong wind, own ship’s noise etc. which may result in a considerably lesser effective audible range of the fog signals (IMO, Convention on the International Regulations for Preventing Collisions at Sea, 1972).

Modern large vessels with fairly high average speeds make things even more complex, as the time allowed for identifying targets, making decision and acting to avoid collision is substantially reduced; if we were to consider it with respect to the time-distance curve, then the curve would get squeezed within a shorter time interval.

We need reliable and shorter ‘identification’ segment (referring the time-distance curve), which will allow more time for ‘analysis’ so that action to avoid collision/close quarters situation can be taken comfortably with conviction. One way to improve
reliability of information is to have means of crosschecking, that is to have independent additional means of information. As elaborated in the later chapters, the research relating to this dissertation is intended for the exchange of additional navigational data which would improve reliability of information, and subsequently assist in an easy and quick identification of the targets and their navigational status as per COLREGs.

**Case-2**, represents much simpler conditions where the **visibility is good**. In this case sources of information relating to any target could be obtained visually and by navigational aids. Hence, apparently the information gathered is much more trustworthy. Besides the limitations and errors of the navigational aids, human error such as failure to exhibit appropriate signals as per COLREGs can severely affect the ‘identification’ process, which can have a consequential effect on the collision avoidance mechanism. It can be noticed that reliability of information is probably higher in this case, which allows a quicker identification of the targets and hence longer duration for a precise analysis. However, there can still be a presence of error(s) which could result in dangerous outcomes, for example if navigational status in the AIS is updated, but the corresponding day signals are not displayed. The first impression of any navigator keeping a visual lookout will turn out to be incorrect. As mentioned earlier, means for crosschecking the correctness of information is quintessential for the safety of navigation.

**Case-3**, portrays a situation where **visibility is variable**, that is, in this case it reduces as the target approaches one’s own vessel. This is a very critical situation as changing visibility can be a navigational predicament in addition to other challenges mentioned in the above two cases. Also, during dawn and dusk, when the natural light condition changes, it takes time to get adjusted to the conditions. A navigator observing targets visually may face challenges during this period.

In brief, examining the reliability of information plays a vital role in the ‘identification’ and ‘analysis’ process in regards to collision avoidance, hence use of the additional means to ascertain correctness of information collected can be of a decisive significance.
4. Chapter 4- Development of an enhanced ‘model’

The following figure provides an illustration for the draft functional concept of integrating AIS information in an enhanced manner into the collision avoidance process.

*Figure 10- Enhanced 'Model'- for exchange and display of additional navigational information.*
The basic idea of the proposed new model includes enhancing the integration of AIS into the existing systems for better and more reliable situation awareness, and a more profound/comprehensive decision-making in the form of graphical visualization of the navigational status information (including audible fog signals). Until today, navigation status information is only provided in alphanumeric form. The innovation suggested here is to use symbols and colours as provided in COLREGs for shapes and light signals (including audible fog signals) to show the navigational status of target vessels.

With these basics the following aims and objectives shall be addressed.

4.1 Aim:
The draft model aims to electronically exchange and exhibit ‘Day signals (shapes), Light signals and Fog signals/Sound signals (Manoeuvring and warning signals)’ as required by COLREGs to provide quick, reliable and easy information to navigators to improve their situational awareness, which shall subsequently enhance navigational safety.

4.2 Equipment(s):
Transmitting Ship: Automatic Identification System (AIS), an interface between AIS and Navigational light panel, and an interface between AIS and Fog Signal panel/Ship’s whistle.

Receiving Ship: Electronic Chart Display and Information System (ECDIS), Automatic Identification System (AIS), a sound speaker attached to the ECIDS and interface between AIS and ECDIS (AIS-ECDIS interface).

Note:
- Navigational light panel, ship’s whistle and Fog signal panel is fitted in all COLREGs compliant vessels, as they are required to display/exhibit shapes and signals specified in the COLREGs.
- Automatic Identification System (AIS): As per SOLAS Chapter V-Regulation 19 (2.4) all Passenger Ships, all Ships of 300 gross tonnage and upwards engaged on international voyage and cargo ships of 500 gross tonnage and upwards not engaged on international voyage are required to be fitted with Automatic Identification System (AIS) (IMO, International Convention for the Safety of Life at Sea, 1974). About 37% of the world fleet comprises of vessels below 500 gross tonnage, but it is not obvious that all of them are not equipped with AIS, local regulations may require carriage of AIS, which leads us to the conclusion that substantial number of vessels carry AIS onboard (EMSA, Equasis, 2016).
- Electronic Chart Display and Information System: As per SOLAS Chapter V- Regulation 19 (2.10), by 01-July-2018 a major portion of the world fleet was required to be equipped with ECDIS (IMO, International Convention for the Safety of Life at Sea, 1974).
4.3 Configuration:

i. **Transmitting Ship:** As illustrated in figure 10, the ship’s whistle/ fog signal panel and navigational light panel are required to be interfaced with the AIS control panel. The concept is, whenever a set of lights describing the navigational status of the ship is switched on, the information should be conveyed to the AIS control panel. One of the practically possible arrangement is shown in figure 10, where a single switch is provided for each possible navigational status for a particular ship.

For sound signals, generally, there are two ways for sounding fog signals, firstly, automatically when initiated by the bridge watchkeeping officer, and secondly, when operated manually by the bridge watchkeeping officer. In both the cases the information should be conveyed to the AIS control panel.

For transmitting information, a transmitting antenna for the AIS is required, the transmitting antenna is necessarily fitted in ships equipped with AIS.

ii. **Receiving Ship:** As shown in figure 10, the ship shall have the AIS Antenna for receiving information, which is necessarily fitted on ships having AIS. The antenna shall be connected to the AIS control unit, which shall be interfaced with the ECDIS control panel. Therefore, it is a simple AIS-ECDIS interface, where data or information exchanged through AIS could be exhibited on the ECDIS display.

4.4 Working:

As mentioned, the aim of this enhanced model is to electronically exchange Day signals, Light signals and Fog signals/ Sound signals as required by COLREGs to provide quick, reliable and easy information to navigators to improve their situational awareness, which shall subsequently enhance navigational safety.

Let us understand the working of this model with the help of an example. Let us consider two ships, Ship “A” and Ship “B” in the vicinity of each other, in open waters, rough seas, and having zero visibility conditions. Consider Ship “A” to be a “Vessel Not Under Command”. When the OOW on Ship “A” turn on the N.U.C lights and fog signal as per COLREGs, the status on the AIS of Ship “A” gets automatically updated without having the OOW to change the navigational status on the AIS manually. Once
this is done, the AIS information/data from Ship “A” will be transmitted by using the Self-organized time division multiple access (SOTDMA) principle at pre-set time intervals. On the receiving ship, that is, ship “B”, when the information/data of Ship “A” is received, the OOW in Ship “B” can access the details of Ship “A” on his/her ECDIS display. Any ship with special navigational status such as C.B.D, N.U.C, R.A.M, mine clearance vessel, wing in ground craft, fishing vessel etc. will be brought to the notice of the receiving ship’s OOW by means of a visual and audible alarm on the ECDIS display of the receiving ship. In this specific case, the OOW of Ship “B” will be alerted by a visual and audible alarm indicating the special navigational status of the transmitting ship, that is, Ship “A”, which is a “Vessel Not Under Command”. The OOW of the receiving ship, that is, Ship “B” can click on Ship “A” on his/her ECDIS display for detailed information of Ship “A”. Once when clicked, a pop-up window will appear on the ECDIS screen providing information such as pictorial representations of the Day signals, Light signals and Fog signals/ Sound signals which Ship “A” is exhibiting (N.U.C signals). Besides the exhibition of signal, the fog signals sounded by Ship “A” will be sounded electronically through a sound speaker attached to the ECDIS of Ship “B”. The pop-up window can be closed by a simple click (on the trackball control unit), exactly like in the case of pick reports on the ECDIS. The OOW of the receiving vessel will have the choice to define the range for target vessels at which he/she would like such alarms regarding special navigational status of target vessels to be activated, for example, he/she may choose a range of 10 nautical miles, 20 nautical miles, 30 nautical miles, or ‘x’ nautical miles depending upon the weather, traffic and various other conditions. The OOW will have the choice of just acknowledging the alarm where he/she does not want to access the additional information/ details. The Sound Signals/ Fog Signals will electronically sound at the receiving ship’s sound speaker connected to the ECDIS only when the target ship (transmitting ship) giving alarm on the ECDIS display of the receiving ship is clicked for additional details. In the above case, if the transmitting ship (Ship “A”) did not exhibit the Fog signals, then in the receiving ship (Ship “B”) such signals will not be heard electronically. For example, if the transmitting ship, Ship “A” was a “Power
driven vessel” and exhibited the required fog signals, then the receiving ship, Ship “B” would be alerted with an alarm regarding Ship “A”. However, suppose Ship “A” did not exhibit the fog signals, then Ship “B” will not be alerted by any alarm.

Whenever transmitting vessel’s navigational status is other than “Power driven vessel” or “Moored”, and whenever fog signals/ sound signals (Manoeuvring and warning signals) are exhibited (for normal “Power driven vessel” also), this will trigger an alarm on the receiving vessel’s ECDIS display within the pre-set range chosen by respective receiving ships.

Let us consider another situation where Ship “A” and Ship “B” are both “power driven vessel” involved in a crossing situation and where risk of collision exists. Consider visibility is good. Consider Ship “A” to be the “give-way vessel” and Ship “B” which is approaching from the starboard side of Ship “A” to be the “stand-on vessel”. If Ship “A” does not take action to avoid collision as per rule 15 and 16 of COLREGs, then Ship “B” shall act in compliance with rule 17 of COLREGs. Ship “B” shall consider sounding five short blasts as per rule 34(d) of COLREGs to convey the message to Ship “A” that her intentions are not clearly understood by Ship “B”, and then as required, manoeuvres can be conducted by Ship “B” to avoid collision as per rule 17 of COLREGs.

If the enhanced ‘Model’ was employed on both the vessels, then Ship “A” could have received an audible and visual alarm of the sound signals (Manoeuvring and warning signals) exhibited by Ship “B”, provided that Ship “B” is within the pre-set range set by the OOW of Ship “A”. When an alarm is received on the ECDIS display, the OOW on Ship “A” is alerted of the fact that Ship “B” wants to convey some information. He/she can crosscheck visually and physically hear the sound signal exhibited by Ship “B”. Suppose a third Ship, Ship “C” is present close to Ship “B” during daylight, it can become enormously difficult for Ship “A” to identify which ship is sounding the signal. By using this ‘Model’, OOW of Ship “A” will know exactly which ship is exhibiting the signal(s). Sometimes due to various weather-related factors and other factors sound/ fog signals becomes very difficult to be heard
by the navigator. The enhanced ‘Model’ will allow unhindered exchange of such
details/ information.

4.5 Limitations:

- The navigational lights shall be kept on at all times, which is not generally a bad
  practice.

- When fog signals are transmitted manually from the transmitting ship, the
  receiving ship will get a visual and audible alarm along with navigational status
  and other details, but will not be able to hear electronically the fog signals
  transmitted by the transmitting ship on the sound speaker attached to the ECDIS
  on the receiving ship as in case of fog signals which are transmitted by automatic
  means.

- Similarly, in case of sound signals (Manoeuvring and warning signals) the
  receiving ship will get a visual and audible alarm along with navigational status
  and other details, but will not be able to hear the transmitted sound signal
  electronically on the sound speaker of the receiving ship.

- Since the system involves AIS, limitations of AIS such as variation in detection
  range depending upon traffic density in a particular area will affect the operation
  of the proposed model. For example, the pre-set range for detection of special
  navigational status as per the proposed model should not be more than detection
  range of AIS.
5. Chapter 5- Validation of the concept by expert opinion survey
In order to validate the developed concept, a survey was carried out to gather the opinion of experts from various sectors of the maritime field regarding the use and application of “Electronically exchanging ‘Day signals’, ‘Light signals’ and ‘Fog signals/Sound signals (Manoeuvring and warning signals)’ as required by COLREGs to provide easy, quick and reliable information to navigators to improve situational awareness, which shall subsequently enhance safety of navigation.” The survey included questionnaires sent by e-mails, and personal interviews. The questionnaire used for online responses is provided in Appendix 2. The same questions have been used as guiding questions for personal interviews. Ethical issues have been addressed according to the requirements of WMU.

5.1 Analysis of the responses obtained through questionnaires:

5.1.1 Profile of the participants
- **Number of participants:** 40
- **Number of nationalities:** 19
- **Job description of the participants:**
  - Maritime administrators
  - Vessel managers
  - Maritime education and training professionals
  - Master mariners
  - Navigating officers
  - Marine pilots
  - Coastguard officers
  - Navy officers.

92.5% of the total number of participants had seafaring experience, 20 % are presently sailing as master mariners and 20% presently sailing as other navigating officers. 37.5% are maritime administrators and 25% belong to the maritime education and training sector.
5.1.2 Findings:

- 82.5% of the participants testified that they were confident using AIS data. The majority comprising of 64.7% of the participants were confident due to the availability of updated static, dynamic and voyage related data, which they consider very useful. 26.5% of the participants considered AIS data to be reliable because most of the vessels (as required by SOLAS/ Local regulations) are equipped with AIS and transmit data pertaining to a vessel at regular intervals. 17.5% of the participants considered AIS data not to be reliable, of which 46.2% of the participants considered it to be unreliable due to the fact that transmitted data may not be absolutely correct due to incorrect manual or automatic inputs. 7.7% of the participants stated that at times AIS is switched off due to security reasons, which does not make it completely reliable for using it solely for navigational purposes.

- 90% of the participants considered the AIS information overlay on the ECDIS display enhances the situational awareness of the bridge team, of which 58.7% believed that this was due to the availability of various data on the same display and 38.2% of the participants considered that it facilitated in the easy crosschecking of AIS data with other sources of data.

- 45% of the participants considered that bridge team members are not fully aware of the limitations of AIS and ECDIS, the major causes being lack of proper training and sufficient experience. Whereas, 32.5% of the participants considered bridge team members are aware of the limitations of AIS and ECDIS, and 22.5% of the participants were unsure.

- 62.5% of the participants consider that inclusion of information such as ‘Day signals, Light signals and Fog signals/Sound signals’ (including fog/sound signals by sound speaker at the receiving vessel) as required by COLREGs on the ECDIS screen (Using AIS) will improve the situational awareness of the bridge team and subsequently improve the safety of navigation. The major causes argued by the participants were, it will reduce human error and will allow various information available at one place for appraising the situation.
20% of the participants considered the inclusion of the above-mentioned data will not be appropriate as it may lead to overreliance, and can confuse the OOW with excessive data. 17.5% of the participants were unsure about inclusion of the above-mentioned data.

- 62.5% of the participants considered that the inclusion of information such as ‘Day signals’, ‘Light signals’ and ‘Fog signals/Sound signals’ as required by COLREGs on the ECDIS screen (Using AIS) will allow the navigators to assess the traffic situation better and earlier irrespective of heavy weather and reduced/restricted visibility. 10% of the participants considered including the above-mentioned data will not help to assess traffic situation earlier during heavy weather and reduced/restricted visibility, and 27.5% of the participants were unsure about the inclusion of above-mentioned data.

56.4% of the participants contemplate including the above-mentioned data will be beneficial in areas of high traffic density, whereas, 17.9 % think otherwise, and 25.6% of the participants were unsure of its application in high traffic density areas.

- 75% of the participants consider that Vessel traffic service (VTS) and other vessels will benefit from the information such as correct navigational status of own vessel (automatic input from respective panels without human interference), which is independent of the erroneous input to the own vessel's AIS. They considered that it will help the VTS to organize traffic more effectively, and allow the VTS to inform traffic in any particular area about any vessel with special navigational status.

- 35% of the participants consider that above mentioned additional information could clutter the ECDIS screen. Most of them considered the standard size of the ECDIS display is not sufficient, whereas, 40% consider it otherwise, and 25% were unsure.

- 45% of the participants considered that inclusion of additional navigational data on the ECDIS screen might result in complacency or overreliance, which could
have consequential effects. Many participants emphasized on the fact that visual lookout cannot be substituted by any electronic aids.

5.2 Analysis of the responses obtained through personal interviews:

5.2.1 Profile of the participants

- Number of participants: 10
- Number of nationalities: 08
- Job description of the participants:
  - Maritime administrators
  - Master mariners
  - Maritime education and training professionals
  - Port Manager
  - Port State Control Officers
  - Navigating officers
- 90% of the total number of participants have seafaring experience.

5.2.2 Findings:

- All the participants consider the confident use of AIS data. Firstly, due to the availability of the updated static, dynamic and voyage related data which is very useful, and secondly, because most of the vessels (as required by SOLAS/Local regulations) are equipped with AIS and transmit data pertaining to the vessel at regular intervals.
- All participants consider that the AIS information overlay on the ECDIS display enhances the situational awareness of the bridge team, of which 70% believed that this was due to the availability of various data on the same display and 30% considered that it facilitated in the easy crosschecking of AIS data with other sources of data.
- 50% of the participants consider that bridge team members are not fully aware of the limitations of AIS and ECDIS, the causes being lack of proper training,
insufficient experience, and the different makes and models of the equipment. Whereas, 50% of the participants were unsure.

- 90% of the participants consider that inclusion of information such as ‘Day signals, Light signals and Fog signals/Sound signals’ as required by COLREGs on the ECDIS screen (Using AIS) will improve the situational awareness of the bridge team and subsequently improve safety of navigation. The reasons argued are, firstly, it will help to overcome the limitations of the conventional method of exchanging signals; and secondly, it will serve as an additional aid to help in the identification of vessels. 10% of the participants were unsure about the inclusion of the above-mentioned data.

- 90% of the participants consider that the inclusion of information such as ‘Day signals, Light signals and Fog signals/Sound signals’ as required by COLREGs on the ECDIS screen (Using AIS) will improve the navigators to assess the traffic situation better and earlier irrespective of heavy weather and reduced/restricted visibility. 10% of the participants were unsure about the inclusion of the above-mentioned data.

80% of the participants contemplate the inclusion of the above-mentioned data will be beneficial in areas of high traffic density, whereas, 20% of the participants were unsure of its application in high traffic density areas.

- 80% of the participants consider that VTS and other vessels will benefit from information such as correct navigational status of own vessel (automatic input from respective panels without human interference), which is independent of erroneous input to the own vessel's AIS. The reason being, that it will help to enhance the situational awareness of the VTS regarding special navigational status of vessels. 20% of the participants were unsure.

- 10% of the participants consider that above mentioned additional information could clutter the ECDIS screen. Whereas, 60% consider it otherwise, and 30% were unsure.

- 10% of the participants consider that inclusion of additional navigational data on the ECDIS screen might result in complacency or overreliance, which could have
consequential effects. 60% of the participants consider otherwise and 30% participants were unsure.

5.3 Compiled analysis and discussion of the survey:
The survey predominantly comprised of end users such as experienced master mariners and navigators, personnel from maritime administrations involved in implementation and enforcement mechanisms, and personnel involved in maritime education and training. The survey included participants from various nations and belonging to different regions of the world, having relevant quality experience. It is important to highlight that the survey allowed for a wide array of inputs due to diversity in the population of the participants.

5.4 Expert opinions regarding the enhanced integrated use of AIS and ECDIS:
The vast majority considered they were confident in using AIS data. Although, it was noted that many participants considered that the bridge team members are not fully aware of the limitations of AIS and ECDIS due to lack of proper training and insufficient experience, some believed it was due to different make and model of the systems. The probable solution is more regulated and intense shore-based and on-board training, besides the senior officers onboard needs to demonstrate the proper use of navigational instruments, and the data obtained from them, to the junior officers.

The majority of the participants considered the AIS data overlay on the ECDIS screen enhances situational awareness and hence the safety of navigation due to the availability of various types of information being on the same screen. This perhaps allows navigators to focus at the same place for various types of information without wasting time to look for details using various instruments. This also allows navigators to concentrate and assess any situation more effectively.

5.5 Electronically exchanging ‘Day signals’, ‘Light signals’ and ‘Fog signals/Sound signals’:
The majority of the participants considered the inclusion of day/light/ and fog/sound signals on the ECDIS screen (including fog/sound signals by the sound speaker at the
receiving vessel) will help to reduce human error and improve the situational awareness of the navigators. They stated that it would help to overcome the limitations of the conventional methods of exchanging signals, and the availability of such information at one place will help to appraise any situation better. Most of the participants concluded its effective application in heavy weather conditions, and reduced/restricted visibility conditions. A large number of participants also agreed that VTS will benefit by the establishment of such an exchange of information, which will subsequently assist in the efficient traffic organization.

Although some limitations were anticipated by the participants, such as, the cluttering of the ECDIS display, confusion due to excessive information, complacency, and overreliance on electronic aids. The enhanced new ‘Model’ is not intended to replace conventional methods of navigation such as visual navigation or radar navigation, which is imperative; it only serves as an additional means of crosschecking information. The navigator has the option to display additional information after getting a visual/audible alarm, but if he/she reckons it is not necessary, then the alarm could be just acknowledged. Hence, the navigator is not burdened by excessive information nor compelled to use the application.

Majority of the participants considered that it will take about one to two months for the bridge team to get adapted to the proposed application.

The views of the participants regarding the implementation and implications of establishing this application ranged from: need of upgrading the existing navigation components (example: ECDIS) contemplated to be used, need of sufficient and proper training, and change in the mindset of navigators to use modern navigational aids. Although many propounded that the cost of implementation and training could be a deterrent, the application need not be made mandatory, and this could be used as an excuse to reduce the number of crew members.
6. Chapter 6- The Design and Conduction of the simulation-based pilot study

6.1 Purpose of the Simulation experiment:

Simulation experiments were carried out using a desktop bridge simulator, with four participants. The objective was to carry out a spotlight pilot study in order to observe and to understand how the navigators assess navigational situations. The experiments specifically focused on analysing and identifying the factors and features the participants took into account to appraise the given situations. Basically, the experiments emphasized on studying how the participants used the available means to develop their situational awareness while navigating.

6.2 Experimental set-up and Simulation infrastructure:

The study was carried out in the MaRiSa (Maritime Risk and System Safety) simulator laboratory at the World Maritime University (WMU). The Desktop bridge simulator was used for the purpose of the simulation experiments. The simulator consisted a SOLAS compliant ship’s bridge and that contained all the basic instruments as required by SOLAS for ship-handling. The desktop ship handling simulator bridge provided a variable 135° view, and included basic navigational equipment, such as, ECDIS, Radar/ARPA with the integrated overlay of AIS information, interfaces of GPS, echo sounder, DOLOG, and other devices. It also comprised the controls for rudder, thrusters, and engine.

Figure 11- Experimental set-up for the simulation.
6.3 Profile of the participants

- Number of participants: 04
- Number of nationalities: 03
- Job description of the participants: All the participants were experienced seafarers with sailing experience as navigators, two of them served in the capacity of master mariner, one as chief officer and one as second officer onboard merchant vessels.

6.4 The Planning and Conduction of the Simulation experiments:

A total of eight simulation experiments were carried out; four were related to restricted visibility conditions and the other four related to good visibility conditions. Each simulation experiment spanned for about seven minutes. Each of the four participants took part in one restricted visibility condition experiment and one good visibility condition experiment. A questionnaire was served to the respective participant after completion of each experiment. The questionnaire comprised of two parts; Part-1 dealt with the questionnaire related to the scenario, whereas Part-2 consisted of the opinion of the participant about how the new ‘Model’ would work in the particular scenario.

An experimental study using simulation trials were planned and conducted. Two traffic scenarios with different compositions of vessel traffic and variations in the navigational status of the targets in the scenarios were created.

The chosen sea area was the passage of the Strait of Singapore with a container vessel (as characterized in the tables (5 and 10)).

The target vessels and their characteristics and navigational status are summarized in the following tables (5 and 10) as well.

Beside the different composition of the traffic, also the conditions of visibility were changed; one scenario with restricted visibility and the second with good visibility.
6.5 Scenario 1: Restricted visibility condition.

Description of the scenario:

**Time:** 2030 hrs, **Season:** Summer, **Sunrise:** 0642 hrs, **Sunset:** 1939 hrs.

**Weather conditions:**

Visibility: 0.2 nm, Heavy fog; Wind: 000 (T) X 20 Knots; Sea state: SS2 X Dir 180(T); Current: No current; Air temperature: 32.0 degree Celsius; Barometric pressure: 1030 hPa; Dew point: 31.2 degree Celsius; Cloudy sky.

**Details of Ownship and Targets:**

*Table 5- Scenario 1- Details of vessels.*

<table>
<thead>
<tr>
<th>Serial No.</th>
<th>Model Class</th>
<th>Model Type</th>
<th>Name</th>
<th>Call Sign</th>
<th>Length (m)</th>
<th>Beam (m)</th>
<th>Navigational Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Ownship</td>
<td>REF 221/100 CONT (Baltic)</td>
<td>Baltic Star</td>
<td>DQFS</td>
<td>217.5</td>
<td>32.2</td>
<td>Power driven vessel (Making way through water)</td>
</tr>
<tr>
<td>2</td>
<td>Traffic ship</td>
<td>Container Vessel</td>
<td>Seiki Maru</td>
<td>DGVS</td>
<td>208.0</td>
<td>29.8</td>
<td>Power driven vessel (Making way through water)</td>
</tr>
<tr>
<td>3</td>
<td>Traffic ship</td>
<td>Container Vessel</td>
<td>MOL Wish</td>
<td>DIDC</td>
<td>245.0</td>
<td>32.2</td>
<td>Power driven vessel (Making way through water)</td>
</tr>
<tr>
<td>4</td>
<td>Traffic ship</td>
<td>Cruisiner</td>
<td>Vela</td>
<td>UMWO 4</td>
<td>281.25</td>
<td>32.2</td>
<td>Vessel not under command</td>
</tr>
<tr>
<td>5</td>
<td>Traffic ship</td>
<td>MV Wilhelm Gust I off II</td>
<td>MV Wild Shark II</td>
<td>ST430</td>
<td>213.1</td>
<td>32.2</td>
<td>Vessel at anchor</td>
</tr>
<tr>
<td>6</td>
<td>Traffic ship</td>
<td>REF CONT (Seatrade)</td>
<td>Sea-horse</td>
<td>FLY02</td>
<td>213.1</td>
<td>32.2</td>
<td>Vessel at anchor</td>
</tr>
<tr>
<td>7</td>
<td>Traffic ship</td>
<td>REF TUG</td>
<td>Slim Fish</td>
<td>SF441</td>
<td>38.5</td>
<td>10.5</td>
<td>Vessel engaged in fishing</td>
</tr>
<tr>
<td>8</td>
<td>Traffic ship</td>
<td>REF TUG</td>
<td>Hope VI</td>
<td>HIK88</td>
<td>38.5</td>
<td>10.5</td>
<td>Vessel engaged in fishing</td>
</tr>
<tr>
<td>9</td>
<td>Traffic ship</td>
<td>Container Vessel</td>
<td>Star Eclipse</td>
<td>SECL6</td>
<td>245.0</td>
<td>32.2</td>
<td>Power driven vessel (Making way through water)</td>
</tr>
</tbody>
</table>
Experiments:

The section below provides the short characteristics of the individually conducted trials and a summary of the observations (Refer to Appendix 1 for other details of simulation experiments).

Experiment 1 (Scenario 1-Restricted visibility)

Initially the heading of ownship was 079 degrees and the speed was about 16.0 Knots. The vessel used radar (ARPA data was not used) and AIS data for identification of the targets and assessing the situation. No speed alteration was made by the own vessel during the course of the experiment. About five minutes later a large alteration to starboard, heading 093 degrees was made to pass astern of ‘Slim Fish’.

Table 6- Experiment 1 (Scenario 1-Restricted visibility).

<table>
<thead>
<tr>
<th>Vessel Name</th>
<th>Initial Course (degree)</th>
<th>Initial Speed (Knots)</th>
<th>Initial CPA</th>
<th>Initial TCPA</th>
<th>Final CPA</th>
<th>Final TCPA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baltic Star</td>
<td>192</td>
<td>15.0</td>
<td>1.2 nm</td>
<td>00:12:00</td>
<td>1.6 nm</td>
<td>00:05:30</td>
</tr>
<tr>
<td>Seiki Maru</td>
<td>079</td>
<td>18.0</td>
<td>691 m</td>
<td>00:14:49</td>
<td>1142 m</td>
<td>unreachable</td>
</tr>
<tr>
<td>MOL Wish</td>
<td>257</td>
<td>02.0</td>
<td>788 m</td>
<td>00:13:48</td>
<td>1.1 nm</td>
<td>00:06:19</td>
</tr>
<tr>
<td>Vela</td>
<td>258</td>
<td>00.0</td>
<td>1.8 nm</td>
<td>00:12:59</td>
<td>1.1 nm</td>
<td>00:07:35</td>
</tr>
<tr>
<td>MV Wild Shark II</td>
<td>358</td>
<td>0.0</td>
<td>2.2 nm</td>
<td>00:10:19</td>
<td>1.7 nm</td>
<td>00:05:25</td>
</tr>
<tr>
<td>Seahorse</td>
<td>000</td>
<td>0.0</td>
<td>269 m</td>
<td>00:11:15</td>
<td>1154 m</td>
<td>00:03:37</td>
</tr>
<tr>
<td>Slim Fish</td>
<td>355</td>
<td>4.0</td>
<td>2.4 nm</td>
<td>00:07:34</td>
<td>2.6 nm</td>
<td>Unreachable</td>
</tr>
<tr>
<td>Hope VI</td>
<td>000</td>
<td>2.0</td>
<td>1849 m</td>
<td>00:07:54</td>
<td>1.3 nm</td>
<td>00:00:46</td>
</tr>
<tr>
<td>Star Eclipse</td>
<td>260</td>
<td>12.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Observation: Firstly, the participant did not use ARPA data for collision avoidance, instead he completely relied on AIS data. Secondly, considering the visibility conditions the participant did not consider to reduce the speed of the vessel. Finally, the participant did not try to identify the navigational status of the targets in the vicinity, and neither did he account for the fog signals.

Experiment 2 (Scenario 1-Restricted visibility)
Initially the heading of ownship was 079 degrees and SOG was 16.0 Knots. The vessel used radar (ARPA) and AIS data for the identification of targets and assessing the situation. After about two minutes the speed was reduced to 14.3 knots, heading 073 degrees and making good a course of 74.9 degrees. Further, about two minutes later the speed was reduced to 12.5 knots and the vessel altered to port, heading 067 degrees. Finally, the vessel reduced the speed to about 11.0 knots and made a bold starboard alteration, heading 104 degrees to pass astern of ‘Slim Fish’.

<table>
<thead>
<tr>
<th>Vessel Name</th>
<th>Initial Course (degree)</th>
<th>Initial Speed (Knots)</th>
<th>Initial CPA</th>
<th>Initial TCPA</th>
<th>Final CPA</th>
<th>Final TCPA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baltic Star</td>
<td>079</td>
<td>16.0</td>
<td>1.1 nm</td>
<td>00:12:26</td>
<td>1.0 nm</td>
<td>00:10:47</td>
</tr>
<tr>
<td>Seiki Maru</td>
<td>079</td>
<td>15.0</td>
<td>609 m</td>
<td>00:17:07</td>
<td>742 m</td>
<td>Unreachable</td>
</tr>
<tr>
<td>MOL Wish</td>
<td>257</td>
<td>02.0</td>
<td>713 m</td>
<td>00:14:14</td>
<td>1.1 nm</td>
<td>00:10:01</td>
</tr>
<tr>
<td>Vela</td>
<td>358</td>
<td>0.0</td>
<td>1.9 nm</td>
<td>00:13:20</td>
<td>1.1 nm</td>
<td>00:12:41</td>
</tr>
<tr>
<td>MV Wild Shark II</td>
<td>000</td>
<td>2.0</td>
<td>2.2 nm</td>
<td>00:10:40</td>
<td>1.7 nm</td>
<td>00:09:48</td>
</tr>
<tr>
<td>Seahorse</td>
<td>355</td>
<td>4.0</td>
<td>199 m</td>
<td>00:11:43</td>
<td>1504 m</td>
<td>00:06:10</td>
</tr>
<tr>
<td>Slim Fish</td>
<td>000</td>
<td>2.0</td>
<td>2.4 nm</td>
<td>00:08:09</td>
<td>2.6 nm</td>
<td>Unreachable</td>
</tr>
<tr>
<td>Hope VI</td>
<td>260</td>
<td>12.0</td>
<td>1804 m</td>
<td>00:08:24</td>
<td>1.2 nm</td>
<td>00:01:53</td>
</tr>
</tbody>
</table>

Table 7- Experiment 2 (Scenario 1-Restricted visibility).
Observation: The participant did consider reducing speed, but altered to port for a target forward of her beam. Afterwards, he made a bold alteration to starboard to pass astern of the vessel engaged in fishing. If the speed was reduced by a larger amount at an early stage he could have got more time to assess the situation. Further, he did not try to identify the navigational status of the targets in the vicinity, and neither did he account for the fog signals.

Experiment 3 (Scenario 1-Restricted visibility)
Initially the vessel headed 079 degrees with a speed of 16.0 Knots. The vessel started to reduce speed gradually almost maintaining the same heading. After about two minutes it commenced altering to starboard and headed 098 degrees with a speed of about 12.0 Knots in order to pass astern of ‘Slim Fish’. At the end of the experiment the vessel headed 081 degrees at a speed of 12.7 Knots.

Table 8- Experiment 3 (Scenario 1-Restricted visibility).

<table>
<thead>
<tr>
<th>Vessel Name</th>
<th>Initial Course (deg)</th>
<th>Initial Speed (Kts)</th>
<th>Initial CPA</th>
<th>Initial TCPA</th>
<th>Final CPA</th>
<th>Final TCPA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baltic Star</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Seiki Maru</td>
<td>192</td>
<td>15.0</td>
<td>1.1 nm</td>
<td>00:12:33</td>
<td>1824 m</td>
<td>00:07:20</td>
</tr>
<tr>
<td>MOL Wish</td>
<td>079</td>
<td>18.0</td>
<td>548 m</td>
<td>00:15:25</td>
<td>1006 m</td>
<td>unreachable</td>
</tr>
<tr>
<td>Vela</td>
<td>257</td>
<td>02.0</td>
<td>654 m</td>
<td>00:14:28</td>
<td>1382 nm</td>
<td>00:10:05</td>
</tr>
<tr>
<td>MV Wild Shark II</td>
<td>358</td>
<td>0.0</td>
<td>1.9 nm</td>
<td>00:13:31</td>
<td>1.5 nm</td>
<td>00:10:09</td>
</tr>
<tr>
<td>Seahorse</td>
<td>000</td>
<td>0.0</td>
<td>2.3 nm</td>
<td>00:10:48</td>
<td>1.9 nm</td>
<td>00:06:54</td>
</tr>
<tr>
<td>Slim Fish</td>
<td>355</td>
<td>4.0</td>
<td>179 m</td>
<td>00:11:57</td>
<td>1118 m</td>
<td>00:06:43</td>
</tr>
<tr>
<td>Hope VI</td>
<td>000</td>
<td>2.0</td>
<td>2.4 nm</td>
<td>00:08:22</td>
<td>2.7 nm</td>
<td>00:01:35</td>
</tr>
<tr>
<td>Star Eclipse</td>
<td>260</td>
<td>12.0</td>
<td>1771 m</td>
<td>00:08:30</td>
<td>1.2 nm</td>
<td>00:02:13</td>
</tr>
</tbody>
</table>

Observation: The manoeuvre conducted by the participant was prudent, as he assessed the situation early and gradually reduced the speed of the vessel, this allowed him time
for assessing the situation better. Except, he did not use the available means to ascertain the navigational status of vessels in the vicinity. He did not consider the fog signals either.

**Experiment 4 (Scenario 1-Restricted visibility)**

The initial heading and speed of own vessel was 079 degrees and 16.0 Knots respectively. After two minutes the speed was gradually reduced to 14.3 Knots, heading about 072 degrees. Further speed was reduced and the vessel altered more to port. Finally, the vessel commenced swinging to starboard with a speed of about 9.0 Knots with the objective of passing astern of ‘Slim Fish’. By the end of the experiment the own vessel headed 095 degrees with a speed of 7.7 Knots.

*Table 9- Experiment 4 (Scenario 1-Restricted visibility).*

<table>
<thead>
<tr>
<th>Vessel Name</th>
<th>Initial Course (degree)</th>
<th>Initial Speed (Knots)</th>
<th>Initial CPA</th>
<th>Initial TCPA</th>
<th>Final CPA</th>
<th>Final TCPA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baltic Star</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Seiki Maru</td>
<td>192</td>
<td>15.0</td>
<td>1.1 nm</td>
<td>00:12:26</td>
<td>681 m</td>
<td>00:09:21</td>
</tr>
<tr>
<td>MOL Wish</td>
<td>079</td>
<td>18.0</td>
<td>609 m</td>
<td>00:17:07</td>
<td>568 m</td>
<td>unreachable</td>
</tr>
<tr>
<td>Vela</td>
<td>257</td>
<td>02.0</td>
<td>713 m</td>
<td>00:14:14</td>
<td>1620 nm</td>
<td>00:15:34</td>
</tr>
<tr>
<td>MV Wild Shark II</td>
<td>358</td>
<td>0.0</td>
<td>1.9 nm</td>
<td>00:13:20</td>
<td>1.3 nm</td>
<td>00:20:24</td>
</tr>
<tr>
<td>Seahorse</td>
<td>000</td>
<td>0.0</td>
<td>2.2 nm</td>
<td>00:10:40</td>
<td>1.8 nm</td>
<td>00:15:51</td>
</tr>
<tr>
<td>Slim Fish</td>
<td>355</td>
<td>4.0</td>
<td>199 m</td>
<td>00:11:43</td>
<td>1715 m</td>
<td>00:09:29</td>
</tr>
<tr>
<td>Hope VI</td>
<td>000</td>
<td>2.0</td>
<td>2.4 nm</td>
<td>00:08:09</td>
<td>2.5 nm</td>
<td>Unreachable</td>
</tr>
<tr>
<td>Star Eclipse</td>
<td>260</td>
<td>12.0</td>
<td>1804 m</td>
<td>00:08:24</td>
<td>1.0 nm</td>
<td>00:02:59</td>
</tr>
</tbody>
</table>

**Observation:** The participant did not significantly reduce the speed at an early stage and further he decided to alter course to port. He had to make a large alteration to
starboard and largely reduce the speed to avoid a collision situation. He did not check
the navigational status of the targets in vicinity and also did not consider the fog
signals.

6.6 Scenario 2: Good visibility condition.

Description of the scenario:


Weather conditions:

Visibility: 15.0 nm, clear; Wind: 000 (T) X 30 Knots; Sea state: SS4 X Dir 180(T);
Current: No current; Air temperature: 32.0 degree Celsius; Barometric pressure: 1030
hPa; Dew point: 31.2 degree Celsius; Cloudy sky.

Details of Ownship and Targets:

Table 10- Scenario 2- Details of vessels.

<table>
<thead>
<tr>
<th>Serial No.</th>
<th>Model Class</th>
<th>Model Type</th>
<th>Name</th>
<th>Call Sign</th>
<th>Length (m)</th>
<th>Beam (m)</th>
<th>Navigational Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Own-ship</td>
<td>REF 221/100 CONT(Baltic)</td>
<td>Baltic Star</td>
<td>DQFS</td>
<td>217.5</td>
<td>32.2</td>
<td>Power driven vessel (Making way through water)</td>
</tr>
<tr>
<td>2</td>
<td>Traffic ship</td>
<td>Cruiseline</td>
<td>WMU Vela</td>
<td>RDE04</td>
<td>281.25</td>
<td>32.2</td>
<td>Power driven vessel (Making way through water)</td>
</tr>
<tr>
<td>3</td>
<td>Traffic ship</td>
<td>Container Vessel</td>
<td>MSC Europe</td>
<td>ER4AS</td>
<td>334.0</td>
<td>42.8</td>
<td>Vessel constrained by her draught (Not displaying day signals)</td>
</tr>
<tr>
<td>4</td>
<td>Traffic ship</td>
<td>Merchant Training Ship</td>
<td>Mumbai Trader</td>
<td>MMTC</td>
<td>90.0</td>
<td>16.8</td>
<td>Power driven vessel (Making way through water)</td>
</tr>
<tr>
<td>5</td>
<td>Traffic ship</td>
<td>REF TUG</td>
<td>Sprotte I</td>
<td>RiMD6</td>
<td>38.5</td>
<td>10.5</td>
<td>Vessel engaged in fishing</td>
</tr>
</tbody>
</table>
### Experiments:

**Experiment 1 (Scenario 2-Good visibility)**

Initially own vessel was heading 047 degrees with a speed of 14.0 Knots. No significant changes in speed and/or course were made until the vessel ‘MSC Europe’ came very close on the port bow. Own vessel altered to port to pass astern of ‘MSC Europe’, but couldn’t avoid a very close quarters situation.

---

#### Table 11- Experiment 1 (Scenario 2-Good visibility).

<table>
<thead>
<tr>
<th>Vessel Name</th>
<th>Initial Course (degree)</th>
<th>Initial Speed (Knots)</th>
<th>Initial CPA</th>
<th>Initial TCPA</th>
<th>Final CPA</th>
<th>Final TCPA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baltic Star</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WMU Vela</td>
<td>238</td>
<td>14.0</td>
<td>1481 m</td>
<td>00:06:23</td>
<td>1527 m</td>
<td>00:00:00</td>
</tr>
<tr>
<td>MSC Europe</td>
<td>138</td>
<td>14.0</td>
<td>61 m</td>
<td>00:07:13</td>
<td>189 m</td>
<td>00:00:08</td>
</tr>
<tr>
<td>Mumbai Trader</td>
<td>052</td>
<td>07.0</td>
<td>490 m</td>
<td>00:07:09</td>
<td>599 m</td>
<td>unreachable</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>----------------</td>
<td>-----</td>
<td>-----</td>
<td>--------</td>
<td>----------</td>
<td>----------</td>
<td>------------</td>
</tr>
<tr>
<td>Sprotte I</td>
<td>332</td>
<td>05.0</td>
<td>309 m</td>
<td>00:10:58</td>
<td>1356 m</td>
<td>00:05:04</td>
</tr>
<tr>
<td>MOL Wish</td>
<td>062</td>
<td>13.0</td>
<td>2.7 nm</td>
<td>00:14:53</td>
<td>2.9 nm</td>
<td>unreachable</td>
</tr>
<tr>
<td>Sprotte II</td>
<td>324</td>
<td>0.0</td>
<td>1.1 nm</td>
<td>00:10:28</td>
<td>711 m</td>
<td>00:07:16</td>
</tr>
<tr>
<td>Hercules</td>
<td>328</td>
<td>05.0</td>
<td>151 m</td>
<td>00:09:21</td>
<td>801 m</td>
<td>00:03:22</td>
</tr>
<tr>
<td>Nopower</td>
<td>329</td>
<td>0.0</td>
<td>1816 m</td>
<td>00:08:29</td>
<td>1101 m</td>
<td>00:02:51</td>
</tr>
<tr>
<td>Mahatma</td>
<td>047</td>
<td>16.0</td>
<td>396 m</td>
<td>00:19:36</td>
<td>683 m</td>
<td>00:00:09</td>
</tr>
<tr>
<td>LT Cortesia</td>
<td>048</td>
<td>14.0</td>
<td>1298 m</td>
<td>01:02:40</td>
<td>1584 m</td>
<td>unreachable</td>
</tr>
</tbody>
</table>

**Observation:** The participant did not consider identifying the navigational status of the targets in the vicinity using all the available means. ‘MSC Europe’ was a ‘vessel constrained by her draught’, not displaying her day signals, but the AIS transmission (which included navigational status) of ‘MSC Europe’ was working correctly. The participant did not check the navigational status in the AIS of ownship, rather than assuming it to be a power driven vessel. He did not consider reducing speed, and altered to port when ‘MSC Europe’ was too close on the port bow. He also did not use any sound signals (Manoeuvring and warning signals) to alert ‘MSC Europe’, or to know her intention.

**Experiment 2 (Scenario 2-Good visibility)**
Initially own vessel headed 047 degrees with a speed of 14.0 Knots. It gradually commenced reducing speed and altering to starboard. It headed about 056 degrees steaming with a speed of about 11.5 Knots. Further alteration of the course to starboard was made and the speed was reduced to 6.1 Knots to avoid a close quarters situation with ‘MSC Europe’.
Table 12- Experiment 2 (Scenario 2-Good visibility).

<table>
<thead>
<tr>
<th>Vessel Name</th>
<th>Initial Course (degree)</th>
<th>Initial Speed (Knots)</th>
<th>Initial CPA (m)</th>
<th>Initial TCPA</th>
<th>Final CPA</th>
<th>Final TCPA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baltic Star</td>
<td>WMU Vela</td>
<td>238</td>
<td>14.0</td>
<td>1481 m</td>
<td>00:06:23</td>
<td>1.2 nm</td>
</tr>
<tr>
<td></td>
<td>MSC Europe</td>
<td>138</td>
<td>14.0</td>
<td>61 m</td>
<td>00:07:13</td>
<td>579 m</td>
</tr>
<tr>
<td></td>
<td>Mumbai Trader</td>
<td>052</td>
<td>07.0</td>
<td>490 m</td>
<td>00:07:09</td>
<td>1050 m</td>
</tr>
<tr>
<td></td>
<td>Sprotte I</td>
<td>332</td>
<td>05.0</td>
<td>309 m</td>
<td>00:10:58</td>
<td>1.1 nm</td>
</tr>
<tr>
<td></td>
<td>MOL Wish</td>
<td>062</td>
<td>13.0</td>
<td>2.7 nm</td>
<td>00:14:53</td>
<td>3.3 nm</td>
</tr>
<tr>
<td></td>
<td>Sprotte II</td>
<td>324</td>
<td>0.0</td>
<td>1.1 nm</td>
<td>00:10:28</td>
<td>1.3 nm</td>
</tr>
<tr>
<td></td>
<td>Hercules</td>
<td>328</td>
<td>05.0</td>
<td>151 m</td>
<td>00:09:21</td>
<td>1636 m</td>
</tr>
<tr>
<td></td>
<td>Nopower</td>
<td>329</td>
<td>0.0</td>
<td>1816 m</td>
<td>00:08:29</td>
<td>1101 m</td>
</tr>
<tr>
<td></td>
<td>Mahatma</td>
<td>047</td>
<td>16.0</td>
<td>396 m</td>
<td>00:19:36</td>
<td>1441 m</td>
</tr>
<tr>
<td></td>
<td>LT Cortesia</td>
<td>048</td>
<td>14.0</td>
<td>1298 m</td>
<td>01:02:40</td>
<td>336 m</td>
</tr>
</tbody>
</table>

**Observation:** Although prudent action of reducing speed and altering course to starboard was carried out, the participant was not aware of the navigational status of the vessels in the vicinity and did not use the available means to ascertain this.

**Experiment 3 (Scenario 2-Good visibility)**

Initially own ship steered 047 degrees with 14.0 Knots. After about four minutes the vessel reduced the speed to about 11.0 Knots and commenced altering to starboard. Further speed reduction was made and the speed was brought down to 8.0 Knots, heading 054 degrees by the end of the experiment.
Table 13- Experiment 3 (Scenario 2-Good visibility).

<table>
<thead>
<tr>
<th>Vessel Name</th>
<th>Initial Course (degree)</th>
<th>Initial Speed (Knots)</th>
<th>Initial CPA</th>
<th>Initial TCPA</th>
<th>Final CPA</th>
<th>Final TCPA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baltic Star</td>
<td>WMU Vela</td>
<td>238</td>
<td>14.0</td>
<td>1487 m</td>
<td>00:06:23</td>
<td>1747 m</td>
</tr>
<tr>
<td></td>
<td>MSC Europe</td>
<td>138</td>
<td>14.0</td>
<td>67 m</td>
<td>00:07:13</td>
<td>260 m</td>
</tr>
<tr>
<td></td>
<td>Mumbai Trader</td>
<td>052</td>
<td>07.0</td>
<td>484 m</td>
<td>00:07:09</td>
<td>246 m</td>
</tr>
<tr>
<td></td>
<td>Sprotte I</td>
<td>332</td>
<td>05.0</td>
<td>302 m</td>
<td>00:10:58</td>
<td>875 m</td>
</tr>
<tr>
<td></td>
<td>MOL Wish</td>
<td>062</td>
<td>13.0</td>
<td>2.7 nm</td>
<td>00:15:09</td>
<td>3.0 nm</td>
</tr>
<tr>
<td></td>
<td>Sprotte II</td>
<td>324</td>
<td>0.0</td>
<td>1.1 nm</td>
<td>00:10:28</td>
<td>1417 m</td>
</tr>
<tr>
<td></td>
<td>Hercules</td>
<td>328</td>
<td>05.0</td>
<td>145 m</td>
<td>00:09:21</td>
<td>736 m</td>
</tr>
<tr>
<td></td>
<td>Nopower</td>
<td>329</td>
<td>0.0</td>
<td>1808 m</td>
<td>00:08:29</td>
<td>480 m</td>
</tr>
<tr>
<td></td>
<td>Mahatma</td>
<td>047</td>
<td>16.0</td>
<td>382 m</td>
<td>00:19:45</td>
<td>130 m</td>
</tr>
<tr>
<td></td>
<td>LT Cortesia</td>
<td>048</td>
<td>14.0</td>
<td>1278 m</td>
<td>01:15:22</td>
<td>1.0 nm</td>
</tr>
</tbody>
</table>

Observation: Significant speed alteration was carried out late, when ‘MSC Europe’ was very close and no effort was made to ascertain the intention of this vessel. The participant did not consider the navigational status of any vessel in the vicinity while taking action.

Experiment 4 (Scenario 2-Good visibility)

Initially own vessel headed 047 degrees with a speed of about 14.0 Knots. No significant changes in speed and/or course were made until the vessel ‘MSC Europe’ came very close on the port bow. The speed was reduced to about 11.0 Knots, but was not sufficient to avoid a close quarters situation by the end of the experiment.
**Table 14- Experiment 4 (Scenario 2-Good visibility).**

<table>
<thead>
<tr>
<th>Vessel Name</th>
<th>Initial Course (degree)</th>
<th>Initial Speed (Knots)</th>
<th>Initial CPA</th>
<th>Initial TCPA</th>
<th>Final CPA</th>
<th>Final TCPA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baltic Star</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WMU Vela</td>
<td>238</td>
<td>14.0</td>
<td>1485 m</td>
<td>00:06:38</td>
<td>1747 m</td>
<td>unreachable</td>
</tr>
<tr>
<td>MSC Europe</td>
<td>138</td>
<td>14.0</td>
<td>124 m</td>
<td>00:07:28</td>
<td>260 m</td>
<td>00:01:07</td>
</tr>
<tr>
<td>Mumbai Trader</td>
<td>052</td>
<td>07.0</td>
<td>536 m</td>
<td>00:08:18</td>
<td>246 m</td>
<td>00:14:19</td>
</tr>
<tr>
<td>Sprotte I</td>
<td>332</td>
<td>05.0</td>
<td>203 m</td>
<td>00:11:53</td>
<td>875 m</td>
<td>00:06:25</td>
</tr>
<tr>
<td>MOL Wish</td>
<td>062</td>
<td>13.0</td>
<td>2.9 nm</td>
<td>00:01:18</td>
<td>3.0 nm</td>
<td>unreachable</td>
</tr>
<tr>
<td>Sprotte II</td>
<td>324</td>
<td>0.0</td>
<td>1.2 nm</td>
<td>00:11:17</td>
<td>1417 m</td>
<td>00:04:50</td>
</tr>
<tr>
<td>Hercules</td>
<td>328</td>
<td>05.0</td>
<td>61 m</td>
<td>00:10:06</td>
<td>736 m</td>
<td>00:03:59</td>
</tr>
<tr>
<td>Nopower</td>
<td>329</td>
<td>0.0</td>
<td>1841 m</td>
<td>00:09:09</td>
<td>480 m</td>
<td>00:04:40</td>
</tr>
<tr>
<td>Mahatma</td>
<td>047</td>
<td>16.0</td>
<td>432 m</td>
<td>00:12:40</td>
<td>130 m</td>
<td>00:01:08</td>
</tr>
<tr>
<td>LT Cortesia</td>
<td>048</td>
<td>14.0</td>
<td>unreachable</td>
<td></td>
<td>1.0 nm</td>
<td>unreachable</td>
</tr>
</tbody>
</table>

**Observation:** The participant did not consider the navigational status of vessels in the vicinity for acting to avoid collision. He considered ‘MSC Europe’ as a power driven vessel, and assumed that it would alter course to port and join the Traffic separation scheme. He tried to communicate with ‘MSC Europe’ by using VHF, but there was no reply. He did not use any sound signals (Manoeuvring and warning signals) to alert the vessel or to know her intention.
6.7 Analysis and discussion:

- All the participants considered that it is necessary to identify the navigational status of target vessels in the vicinity in case of restricted visibility, as it will assist them in taking appropriate action.

However, it was observed that none of the participants were aware of the navigational status of the targets in the vicinity. Neither did they make any effort to use the AIS to identify the navigational status of the targets. Although as per COLREGs, while acting in restricted visibility conditions by radar alone requires the determination of whether a target is forward or abaft the beam of own vessel, but with additional available means such as AIS could be used to identify the navigational status of targets which could perhaps assist in taking appropriate action to avoid collision.

In the case of scenario-2, good visibility, the vessel constrained by her draught did not display the appropriate day signals, none of the participants were aware of the navigational status of that vessel, because they did not use AIS to identify the navigational status of the vessels in the vicinity. This subsequently led to dangerous situation for some participants.

- None of the participants accounted for the fog signals, and no participant used the sound signals (Manoeuvring and warning signals) to alert surrounding traffic or to ascertain their intentions.

The diligent use of fog signals as per COLREGs Rules 19 and 35 were not complied with. Fog signals serves as one of the most important means to identify targets, but no participant was concerned about the fog signals (IMO, Convention on the International Regulations for Preventing Collisions at Sea, 1972).

As per COLREGs Rule 34, various manoeuvring and warning signals are required to be sounded, but no participant used them. These signals are useful tools to communicate intentions among vessels, and such signals are intended to reduce the chances of misunderstandings in relation to the actions taken by vessels to avoid collision (IMO, Convention on the International Regulations for Preventing Collisions at Sea, 1972).
None of the participants were aware of which target was transmitting what kind of fog signals. When many targets are sounding signals, it obviously becomes cumbersome to identify which vessel is sounding the signal, especially in the case of restricted visibility. The enhanced new ‘Model’ will be a useful tool to identify which target is sounding what signal.

75% of the participants considered that during heavy traffic conditions it is not feasible to check the navigational status of individual targets in the vicinity. This is often mainly due to an insufficient bridge team composition, due to lesser number of crew members. Generally, the duty officer is overburden with various tasks, including visual lookout, radar lookout, record keeping, monitoring traffic, monitoring various controls etc.

The new ‘Model’ through its alarm mechanism can aid the navigator to identify targets with special navigational status on the ECDIS without him/her to check targets individually on the AIS.

All the participants agreed that deployment of the suggested ‘Concept/Model’ for the integrated presentation of the navigational status will:

- help the bridge team to identify targets early, correctly, quickly, and easily.
- improve the situational awareness of the bridge team.
- be a useful tool for collision avoidance.
- reduce/ eliminate human error.

6.8 Conclusions from the pilot study of the simulation experiment
In this spotlight study of the experiments to validate the suggested concept for integration of enhanced AIS features it has been exemplarily shown that there is seemingly a gap between the data provision and its use in the almost real conditions of the simulation experiment. It was observed that the participants (all experienced navigators) assessed the situations and made decisions depending only on parameters such as CPA/TCPA, target range, and relative courses. Even though the simulations study is far from being representative and surely will need further confirmation, there
seems to be a clear need for an improved presentation of the essential information as the navigational status for the purpose of collision avoidance. This pilot study can be used as basis for further more systematic and comprehensive simulation-based research to further improve and proof the concept. The limited amount of time for this dissertation was one of the main constraints to further extent this pilot study. However, the methodological approach including the developed and implemented scenarios can be used for more detailed and sophisticated studies.
7. Chapter 7- Case Studies
In order to further validate the need for enhanced information presentation a survey of accident investigation reports has been carried out. The objective for the identification of relevant case studies was to demonstrate the application of anticipated potential of the proposed new and enhanced concept/model.

7.1 Case 1

- Incident: Collision.
- Location: 6nm south of Dungeness (United Kingdom).
- Date: 24 March, 2012.
- Details of ships involved:

1) Name: M.V. Spring Bok.
   Gross tonnage: 12113.

2) Name: Gas Arctic.
   Gross tonnage: 2985.

- Brief description of the incident:

Environmental conditions- Wind: NE x 3, Sea State: Slight, Tidal stream: NE x 1 knot, Visibility: Generally, less than 3 nautical miles with fog patches.

Vessel ‘Spring Bok’ traded between the Caribbean and north-west Europe. It was employed in a dedicated liner service and was a refrigerated general cargo vessel. The vessel was coasting Europe from the 20 March. It sailed out from the port of Rotterdam on the 24 March before the incident took place. The master of the vessel took over the bridge watch as the OOW at 0700, and adjusted the radar settings as per his convenience, the radar was fitted with ARPA. At 0844, he reported to the coastguard on VHF while the vessel was approaching Dover, of the visibility being 200 metres, the vessel was sailing at 22.4 Knots and the required fog signals was not sounded. Many other vessels were present in the vicinity, but the master of Spring Bok manually
acquired only one of the closest targets and exhibited its details on the radar display. At 0900, he reported the coastguard of the visibility, which improved to more than 4 cables at that time, the lookout was removed at this point. Ship’s position was not fixed at regular intervals. At 0937, the master acquired a target on the radar at a range of about 6.5 nautical miles directly ahead of own vessel. The target vessel was identified as ‘Gas Arctic’ on the AIS, but the target details was not exhibited on the radar display. At 0955, a report of visibility conditions for the Dover Straits was broadcasted by the coastguard, as per the report the visibility in the area where Spring Bok was present at that time was about 1.5 nautical miles. Immediately prior to the incident the master of Spring Bok was engaged in conversation with the supernumeraries on the bridge. At 1014, the master suddenly noticed Gas Arctic visually, which was extremely close and the vessels collided.

LPG tanker ‘Gas Arctic’, which traded within north-west European waters was heading from Immingham to Portland. It was in ballast condition. The vessel had a defect on her gyro-compass repeater system, which restricted the use of ARPA functions on the radars. Flag State’s and classification society’s dispensations were issued, which allowed the ship to remain in service, provided the defect was fully rectified within one month. Risk assessment was carried out for the defect and countersigned by all bridge watchkeeping officers. 3/O (Third officer) was on bridge watch and observed a target on the radar about 6 nautical miles astern, he identified the target vessel on the AIS as ‘Spring Bok’. At 0950, numerous fishing vessels were noticed by the OOW, he altered the course of the ship by about 5 degrees to starboard to pass clear of the nearest fishing vessel by 0.4nm. At 1000, the OOW observed Spring Bok about 3 nautical miles astern with a CPA of zero. He neither tried to communicate with Spring Bok, nor did he take any action to avoid collision with it. He was under the impression that Spring Bok being the overtaking vessel will take action and will keep clear. The 3/O was plotting the position of own vessel on the chart at regular intervals. At 1012, the master of Gas Arctic, who was working one deck below the bridge noticed Spring Bok very close and ran to the bridge, he put the vessel on hand-
steering and put wheel hard-to-port. The vessels collided as Gas Arctic was swinging to port (MAIB, 2012).

- **Observation:**
  1) Both the vessels did not sound fog signals as required by COLREGs in conditions of restricted visibility.
  2) The master of Spring Bok, who was on the bridge watch lost situational awareness as he was involved in conversation prior to the incident with the supernumeraries on the bridge. He also failed to appraise risk of collision after detecting the target vessel (Gas Arctic) on the radar screen.
  3) The OOW of vessel Gas Arctic, was engrossed in manoeuvring through heavy fishing traffic, and assumed Spring Bok to take action as it was the overtaking vessel. He also did not continuously monitor Spring Bok.
  4) The ARPA of vessel Gas Arctic was unusable due to a technical defect in the gyro-compass repeater system.
  5) Proper lookout was not kept by both vessels as required by COLREGs.

- **What possibly could have happened if the ‘Model’ was employed in both vessels?**
  1) Both the ships would have been alerted by the audible and visible alarm at their pre-set specified range on their ECDIS display. This would be irrespective of the operation of ARPA. It would have warned the 3/O of Gas Arctic, and would have certainly enhanced situational awareness of the OOWs of both ships. A prudent selection of range relating to the proposed model could have also assisted the 3/O of Gas Arctic to determine the fishing vessels that were of immediate concern.
  2) Had the ships sounded fog signals as required by COLREGs, both ships could have exchanged the fog signals electronically.
7.2 Case 2
Source: Directorate General of Shipping, India (Casualty Circular No.03/2015).

- Incident: Collision.
- Location: Port approaches on the east coast of India (Note: Name of the port not mentioned in the report).
- Date: 07 August, 2013.
- Details of ships involved:
  Vessel “A”: Bulk carrier.
  Vessel “B”: Oil tanker.

(Note: Names and other detailed ship particulars not mentioned in the report).

- Description of the incident:
  Environmental conditions-Visibility was low, and drizzle/light rain.
  On 07th August, 2013 Vessel “A” arrived at the port and was instructed to wait at the anchorage for her berthing turn. At 2100 hrs on the same day the port control instructed the vessel to pick up anchor and proceed to the pilot station that was approximately 3 miles off the breakwater. At 2142 hrs the vessel heaved up the anchor and proceeded at a speed of about 4-6 knots. The Master noticed an echo on the radar almost right ahead but could not see anything. At about 2159 hrs the chief officer, who was in the forward station reported an unlit vessel ahead and asked the master to alter course to port. The master ordered ‘hard over’ to port side, but the vessel came in contact with vessel “B”, which was an anchored unlit tanker (DGS, 2015).

- Observation:
  1) The report does not mention in details about the navigational equipment the vessels carried, but it is certain that vessel “B” failed to exhibit signals as per COLREGs.
  2) The investigation revealed that vessel “B” was in lay-off and was undermanned.
• **What possibly could have happened if the ‘Model’ was employed in both vessels?**

1) If the anchored vessel “B” exhibited proper anchored vessel signals, that is, light and sound signal then vessel “A” could have been alerted of vessel “B” on its ECDIS screen. It is important to note that had this kind of incident took place during daytime and vessel “B” failed to exhibit the day signal, then also vessel “A” could have identified the navigational status of vessel “B”.

2) Since there were poor visibility conditions, had both vessels sounded the required fog signals, it could have been exchanged electronically and would have alerted and improved the situational awareness of the OOWs of both the vessels.

7.3 **Case 3**

**Source:** Japan Transport Safety Board (MA2015-03).

- Incident: Collision.
- Location: Sea southeast of Kinkazan, Ishinomaki, Miyagi Prefecture.
- Date: 23 June, 2013.
- Details of ships involved:
  1) Name: NOCC OCEANIC.  
     Gross tonnage: 58250.
  2) Name: YUJIN MARU No. 7.  
     Gross tonnage: 19.

- **Description of the incident:**

  Environmental Conditions - Wind: 10m/s, Wave height: Approximately 1m, Visibility: Poor and heavy showers.

  NOCC OCEANIC, a car carrier was enroute for Balboa port; and YUJIN MARU No.7, and a fishing vessel was heading towards the fishing grounds. The third officer was the OOW on NOCC OCEANIC and a deckhand was on watch on the fishing vessel. The OOW on NOCC OCEANIC noticed rain at around 09:15 hrs,
and observed thick clouds approaching from the forward port side. By 09:30 hrs visibility had deteriorated drastically to the extent that the bow mast couldn’t be seen. The radar screen on NOCC OCEANIC was obscured by echo of the clouds, which caused difficulty in recognizing other ships. The sound of rain impaired the OOW from hearing any other sound. There was no information displayed for other ships from the AIS on the ECDIS. The OOW on NOCC OCEANIC thought there were no other targets around and sailed ahead without using the fog signals. It was only after the Japan Coast Guard intervened and instructed NOCC OCEANIC to stop and requested its VDR data, that they knew about the incident. The deckhand on the fishing vessel also observed clouds on its radar. He sat on the floor, leaned against the rear wall and kept watch with a blind sector of 45 degrees starboard caused by the wall. The crew of YUJIN MARU No. 7 realized the occurrence of the incident by feeling the impact of a collision. The fishing vessel’s crew all fell down into the water and survived using an inflatable life-raft, they were rescued by another vessel. However, besides some scratches on the NOCC OCEANIC’s hull, the master of the fishing vessel couldn’t be found (JTSB, 2015).

- **Observation:**
  1) The proper signals were not exhibited as per COLREGs.
  2) The proper lookout was not kept by both vessels.
- **What possibly could have happened if the ‘Model’ was employed in both vessels?**
  1) Even if the fishing vessel did not have ECDIS onboard, it had AIS and exhibited the signals as required by COLREGs. The OOW of the car carrier would have been alerted and the OOW could have identified and recognized the presence of a fishing vessel in the vicinity.
    (Kindly note that transmitting vessel do not require to have ECDIS for the functioning of the Model.)
  2) If the car carrier had exhibited the appropriate signals as per COLREGs and the fishing vessel also had ECDIS and AIS onboard, the watchkeeper on the fishing vessel could also have been alerted.
7.4 Case 4
Source: Danish Maritime Accident Investigation Board.

- Incident: Collision.
- Location: North Sea, 4 nm off Hirtshals.
- Date: 01 July, 2015.
- Details of ships involved:
  1) Name: NECKER HIGHWAY.
     Gross tonnage: 9233.
  2) Name: ORION, AS 28.
     Gross tonnage: 5.6.
- Description of the incident:
  Environmental conditions- Good visibility, clear weather conditions, 98% of full moon and twilight conditions.
  NECKER HIGHWAY, a vehicle carrier was enroute from Malmo, Sweden to Emden, Germany. The second officer was on watch, and the Able-bodied seaman was not on the bridge and was engaged in cleaning activities elsewhere during the watch. ORION was engaged in fishing, displaying required signals as per COLREGs. ORION, was a small fishing vessel with one person onboard. It was equipped with an echo-sounder, radar, GPS and chart plotter, but it was not fitted with AIS. NECKER HIGHWAY was fitted with ECS which was an ECDIS, had two radars and an AIS as well. Both vessels were unaware of the presence of the other vessel and subsequently failed to appraise the risk of collision. The skipper of ORION felt the impact of the collision that occurred at 2327 hrs. ORION sank and the skipper was rescued at about 2350 hrs. On the other hand, OOW of NECKER HIGHWAY received a VHF-DSC call sent by ORION many times but ignored. NECKER HIGHWAY was informed by DMAIB of the incident on 02 July, 2015 (DMAIB, 2015).

- Observation:
  1) Both vessels failed to keep proper lookout and lacked situational awareness.
2) In NECKER HIGHWAY the OOW was alone on the bridge watch.
3) During twilight identifying targets is difficult.

- **What possibly could have happened if the ‘Model’ was employed in both vessels?**
  1) If ORION had AIS fitted on it, NECKER HIGHWAY could have been easily alerted of ORION’s navigational status, that is, engaged in fishing. It would have improved the situational awareness of the OOW.
  2) If ORION was equipped with ECDIS along with AIS, both vessels could have been alerted by the presence of the other vessel, the situational awareness of both vessels would have improved.
  3) As it becomes difficult for the navigators to identify targets during twilight, the Model could help navigators to identify targets easily and correctly.

7.5 Case 5
**Source: Isle of Man Ship Registry (CA102).**

- Incident: Collision.
- Location: Buoy channel north of Fynshoved.
- Date: 02 December, 2006.
- Details of ships involved:
  1) Name: British Cygnet.
     Gross tonnage: 63462.
  2) Name: Vera.
     Gross tonnage: 3999.
- **Description of the incident:**

  Environmental conditions-Wind: SW x Force 5-6, Sea State: approximately 1 metre, Visibility: greater than 5 miles, Tidal current: 1-1.5 knots setting to the north.

  At the time of collision British Cygnet, an oil tanker was steaming on a South-westerly course with the master, OOW (second officer) and pilot on the bridge. The vessel was on the northern part of the buoyed channel and had a draft of 9 metres. It was on manual
steering and engines ready for an immediate manoeuvre. Vera, a containership engaged in feeder services had the second officer alone on the bridge, initially steering almost southerly course and then attempting to enter the buoyed channel from its southern entrance. Unable to make it through the southern entrance, OOW of Vera decided to navigate north, outside the eastern boundary of the channel and then head back towards deepwater channel. In doing so, it headed towards British Cygnet which was on a south-westerly course inside the channel. British Cygnet was unsure of Vera’s intention and sounded five short blasts in accordance with COLREGs regulation 34(d); the pilot also tried to call Vera on VHF, but the call went unanswered. The pilot and the master tried to conduct some manoeuvres to avoid a collision, but it was too late as the vessels collided at 1138 hrs. No pollution or injuries were reported (Isle of Man Ship Registry Casualty Investigation Report No. CA102, 2006).

• Observations:

1) The investigation suggest that British Cygnet could have exhibited the signals of the vessel constrained by her draught.

2) The second officer of Vera recalls sound signal made by British Cygnet, but could not recall how many blasts were sounded.

3) British Cygnet’s speed of 15 knots drawing a draft of 9 metres in a channel of depth 15 metres was considered excessive.

• What possibly could have happened if the ‘Model’ was employed in both vessels?

1) Had British Cygnet exhibited the signal of the vessel constrained by her draught, Vera could have been alerted on its ECDIS screen by a visual and audible alarm. Had British Cygnet failed to display the day signal physically, but had the model in place, or had this situation occurred in restricted visibility conditions, the special navigational status of the vessel could have been communicated electronically.

2) Signals required by COLREGs, such as “five short blasts” could be exchange electronically by using the model.
The selected cases demonstrate the potential advantage of improving situational awareness and reducing human error by the introduction of the proposed enhanced model for the exchange of additional navigational information.
8. Chapter 8- Conclusion

The main emphasis of this research was to investigate the potential contribution of “Electronically exchanging ‘Day signals (shapes), ‘Light signals’, and Fog signals/Sound signals (Manoeuvring and warning signals)’ as required by COLREGs by using AIS and ECDIS” to assist in collision avoidance, and hence enhancing safety of navigation.

The research was carried out with the help of online questionnaires, personal interviews, simulation experiments and a series of selected case studies of real accidents. The results seem to widely support the concept and purpose of the research to integrate and visualize AIS information on the navigational status in a more sophisticated way. The key opinions obtained during the research was upgrading in the existing navigation components (example: ECDIS) contemplated to be used for the enhanced ‘Model’, and the need of sufficient and proper training of the seafarers who will be using this ‘Model’.

The underlying questions of this research were answered as follows:

- What leads to collision incidents/accidents?

  There are various factors that can contribute to any collision incident, but one very important factor is the lack of situational awareness of the bridge team members. From the research, it is evident that the lack of situational awareness was one of the major causes of collision incidents. Being aware of the importance of navigational status of target vessels while acting for collision avoidance, navigators often overlook it, or do not use the available means to crosscheck such details.

- Can addition of technological advancements assist to improve situational awareness?

  The results of the research testify that technological developments such as the proposed ‘Model’ could help to create a better situational awareness among the bridge team members, especially in critical navigational conditions, provided it is implemented prudently along with proper training.
• Is it only the human element that is responsible for incidents/accidents, or there exist a gap between human element and technology, which can be bridged by technological advancements?
  The research suggests that navigational equipment have limitations, but the human operating the equipment shall judge its reliability in the prevailing conditions and shall use the available means to crosscheck essential navigational data. Technology can obviously aid the navigator to access the situation in a more enhanced fashion.
• Can ‘Automatic Identification System (AIS)’, and ‘Electronic Chart Display and Information System (ECDIS)’ be used more effectively to enhance the safety of navigation?
  The research supported the fact that AIS and ECDIS could be used more efficiently, but the seafarers must be trained sufficiently to understand and appreciate the limitations of AIS and ECDIS.
• Will change in the existing provisions hinder safety of navigation?
  The research suggest that deployment of the ‘Model’ will enhance safety of navigation and assist to alleviate the problem of human error.

8.1 Scope for further research:

The research carried out for this dissertation was time bound and limited data was used for the analysis. The use of advanced simulators, and involving more qualified participants would certainly help in refining the results of the research. The analysis of technical feasibility remains as a broad opportunity for further research. This could be achieved by the involvement of technicians and engineers. The research could be expanded by conducting economic assessment for employing the proposed new ‘Model’, that is, a cost benefit analysis could be done. A risk assessment for the implementation of such additional application could stand out to be valuable. These are among a few directions in which the research can be augmented, which will assist to enhance maritime safety.

Parts of this research will be used for presentation at upcoming conference. Paper abstracts are submitted and under review.
References


http://www.nautinst.org/filemanager/root/site_assets/forums/fatigue_forum/mca_the_human_element_a_guide_to_human_behaviour_in_the_shipping_industry.pdf


Appendix 1- Simulator experiments
Experiment 1- Restricted visibility (Commencement of experiment)
Experiment 1- Restricted visibility (Completion of experiment)
Experiment 2 - Restricted visibility (Commencement of experiment)
Experiment 2- Restricted visibility (Completion of experiment)
Experiment 3- Restricted visibility (Commencement of experiment)
Experiment 3- Restricted visibility (Completion of experiment)
Experiment 4- Restricted visibility (Commencement of experiment)
Experiment 4- Restricted visibility (Completion of experiment)
Experiment 1-Good visibility (Commencement of experiment)
Experiment 1-Good visibility (Completion of experiment)
Experiment 2-Good visibility (Commencement of experiment)
Experiment 2-Good visibility (Completion of experiment)
Experiment 3-Good visibility (Commencement of experiment)
Experiment 3-Good visibility (Completion of experiment)
Experiment 4-Good visibility (Commencement of experiment)
Experiment 4-Good visibility (Completion of experiment)
Appendix 2- Questionnaire (used for survey(online) and personal interview)

Enhancing Safety of Navigation by incorporation of additional data by Automatic Identification System

This is a brief survey to gather views and opinions to support a dissertation which will research if and how Safety of Navigation could be enhanced by incorporation of additional data by using Automatic Identification System. Your contribution to this survey is very important and highly appreciated. The questionnaire is anonymous and all information will be analysed and presented in aggregate. Responding to the questionnaire should take no more than 30 minutes. Thank you very much for your interest and for your response.

* Required

Section 1 of 2

1. Email address *

2. Full name *

3. Gender *
Mark only one oval.
☐ Male
☐ Female

4. Nationality *

________________________

5. Age (Years)

________________________

6. Job description *

________________________
Mark only one oval.
☐ Maritime Administration
☐ Maritime Training and education
☐ Other: __________________________

7. Name of Organization (Full name)

________________________

8. Do you have Seafaring experience? *

________________________
Mark only one oval.
☐ Yes
☐ No

9. Presently sailing in which capacity? * Mark only one oval.
☐ Master
☐ Chief officer
☐ Second officer
☐ Third officer
☐ Other: __________________________
10. If currently not sailing, do you have previous sailing experience? Mark only one oval.
   ○ Yes
   ○ No

11. Total experience as a seafarer (Years) *
    ______________________

12. Total experience as a seafarer in current capacity (Years) *
    ______________________

13. Total experience in other maritime related job besides seafaring (Years) (Please mention the job and respective years of experience) *
    ______________________
    ______________________
    ______________________

14. Any other profession related information
    ______________________
Enhancing Safety of Navigation by incorporation of additional data

by Automatic Identification System

Section 2 of 2

1. Do you feel confident to use "Automatic Identification System (AIS)" data? * Mark only one oval.
   
   ○ Yes
   
   ○ No

1.1. If yes, please state why?  
   Mark only one oval.
   
   ○ Availability of updated static, dynamic and voyage related data which is very useful.
   
   ○ Most of the vessels (as required by SOLAS/ Local regulations) have AIS and transmits data pertaining to the vessel at regular interval.
   
   ○ Other:

1.2. If “no”, please state why?  
   Mark only one oval.
   
   ○ Many vessels, which are not required by any regulations may not be fitted with AIS.
   
   ○ Transmitted data may not be absolutely correct due to wrong automatic input from one or more equipment, or wrong manual input of some data.
   
   ○ AIS may be switched off due to security reasons.
   
   Other:

2. Do you think AIS details overlaid on the ECDIS display enhances situational awareness of the OOW and the bridge team? * 
   
   Mark only one oval.
   
   ○ Yes
☐ No
☐ Not sure

2.1 If “yes”, please state why?

Mark only one oval.

☐ Availability of various information on the same screen.
☐ Cross check AIS data with other resources.
☐ Other:

________________________

2.2 If “no”, please shortly explain?

________________________

3. Do you think all the bridge team members are well aware with the limitations of AIS and ECDIS? *

Mark only one oval.

☐ Yes
☐ No
☐ Not sure

3.1 If "yes", please state why?

________________________

3.2 If "no", please state why?

________________________

3.3 Other comments?

________________________

________________________

________________________
4. Do you think that inclusion of information such as Sound (Manoeuvring and warning signals)/Light/Day signals (As per COLREGs) on the ECDIS screen (Using AIS) will improve the situational awareness of the bridge team and will improve the safety of navigation? *

Mark only one oval.

☐ Yes
☐ No
☐ Not sure

4.1 If “yes”, please state why


4.2 If “no”, please state why?


5.1 Do you reckon that inclusion of data such as Sound (Manoeuvring and warning signals)/Light/Day signals (As per COLREGS) on the ECDIS screen (Using AIS) will allow the navigators to assess the traffic situation better and earlier irrespective of heavy weather and reduced/restricted visibility? *

Mark only one oval.

☐ Yes
☐ No
☐ Not sure

5.2 Do you reckon that inclusion of data such as Sound (Manoeuvring and warning signals)/Light/Day signals (As per COLREGS) on the ECDIS screen (Using AIS) will assist the navigators in areas of high traffic density?

Mark only one oval.

☐ Yes
☐ No
☐ Not sure
5.3 Kindly state any other comments?

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

6. Will VTS/other vessels benefit from information such as navigational status of own vessel (automatic input from respective panels without human interference) which is independent of erroneous input to the own vessel's AIS? *

Mark only one oval.

☐ Yes
☐ No
☐ Not sure

6.1) If "yes", please state why?

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

6.2) If "no", please state why?

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

7. Do you consider that such information will clutter the ECDIS screen (Note: information of a particular target can be selected by the OOW, any special navigational status will be supplemented by a visual/audible alarm)? *

Mark only one oval.

☐ Yes
☐ No
☐ Not sure

7.1) If “yes”, please state why?

_________________________________________________________

_________________________________________________________

_________________________________________________________

8. Do you think that the OOW or the bridge team will be distracted from keeping a vigilant visual lookout due to availability of electronic information (overreliance)? *

Mark only one oval.

☐ Yes

☐ No

☐ Not sure

8.1) If “yes”, please state why?

_________________________________________________________

_________________________________________________________

_________________________________________________________

9. How much time will the bridge team members take to get adapted to these information, as per your opinion? (In months)

__________________________

10) What will be the limitations/challenges in training and education in regard to the intended outcome of the dissertation on "Enhancing Safety of Navigation by incorporation of additional data by Automatic Identification System"? *
11) Please indicate your views regarding implementation/implications and training/education in regards to the objective of the dissertation on "Enhancing Safety of Navigation by incorporation of additional data by Automatic Identification System"?