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Original article

E-navigation Services for Non-SOLAS Ships *

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Abstract

It is clearly understood that the main benefits of e-navigation are improved safety and better protection of the environment through the promotion of standards of navigational system and a reduction in human error. In order to meet the expectations on the benefit of e-navigation, e-navigation services should be more focused on non-SOLAS ships. The purpose of this paper is to present necessary e-navigation services for non-SOLAS ships in order to prevent marine accidents in Korean coastal waters. To meet the objectives of the study, an examination on the present navigation and communication system for non-SOLAS ships was performed. Based on the IMO's e-navigation Strategy Implementation Plan (SIP) and Korea's national SIP for e-navigation, future trends for the development and implementation of e-navigation were discussed. Consequently, Electronic Navigational Chart (ENC) download and ENC up-date service, ENC streaming service, route support service and communication support service based on Maritime Cloud were presented as essential e-navigation services for non-SOLAS ships. This study will help for the planning and designing of the Korean e-navigation system. It is expected that the further researches on the navigation support systems based on e-navigation will be carried out in order to implement the essential e-navigation services for non-SOLAS ships.

Keywords: e-navigation, e-navigation service, navigational system, human error, non-SOLAS ships, Electronic Navigational Chart (ENC)

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I. Introduction

International Maritime Organization (IMO) has decided to introduce an e-navigation in order to improve safety of navigation and to reduce errors. In spite of the huge development of technologies in navigation and communication systems, there is a need to coordinate systems and more use of harmonized standards. 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” (IMO, 2009a). The Strategy Implementation Plan (SIP) was adopted at the 94th Maritime Safety Committee (MSC) meeting in 2014. According to the identified tasks and timelines for the implementation of prioritized e-navigation solutions, new standards and regulations will be developed until 2019. In Korea, the Ministry of Oceans and Fisheries (MOF) plans to perform the Research and Development (R&D) project on e-navigation from 2016 to 2020 to implement the national e-navigation strategy.

According to the IMO’s Strategy, the main benefits of e-navigation are expected to be improved safety and better protection of the environment through the promotion of standards of navigational system and a reduction in human error. In order to meet the expectations on the benefit of e-navigation, e-navigation services should be focused not only on ships which are complying with the International Convention for the Safety of Life at Sea (SOLAS), hereinafter referred to as 'SOLAS ships’, but also on non-SOLAS ships, such as coastal operating ships and fishing vessels.

According to the statistics, the most of marine accidents were occurred in fishing vessels and smaller ships under 100 Gross Tons (GT) in Korean coastal waters (KMST, 2014). In addition, the 88.4% of registered ships are fishing vessels and the 94.9% of registered ships are smaller ships under 100 GT. In this regard, it is crucial to establish a safety support system for non-SOLAS ships based on e-navigation in order to reduce marine accidents.

The purpose of this study is to present necessary e-navigation services for non-SOLAS ships in order to prevent marine accidents. To achieve the purpose of the study, a present shipboard navigation and communication systems of non-SOLAS ships were examined and findings were discussed in this paper. The present global status of the development and implementation of e-navigation were also discussed including Korean e-navigation project in order to forecast the future trends of e-navigation services for ships. In addition, the necessary navigational support services and communication services for smaller ships and fishing vessels were discussed through literature review.

This study will help for the planning and designing of the Korean e-navigation system. It is expected that the further researches on the navigation support systems based on e-navigation will be carried out in order to improve the navigation safety of non-SOLAS ships.

II. Navigation and Communication System of non-SOLAS Ships

To find out the problems in the coastal navigation surroundings, the present shipboard navigation and communication systems of non-SOLAS ships were examined in this section.

2.1. Navigation System

Shipboard navigational system of non-SOLAS ships are relatively poor in comparison with SOLAS ships which are carrying advanced navigational equipment in accordance with the provisions of SOLAS. Shipboard navigational systems and equipment for all ships are described in Regulation 19, Chapter V of SOLAS. Unless expressly provided otherwise, the chapter V shall apply to all ships on all voyages. However the Administration shall determine to what extent the provisions of regulations on carriage requirements for shipborne navigational systems and equipment do not apply to the domestic voyage ships and fishing vessels (IMO, 2009b).

According to the Ship Safety Act and Fishing Vessels Act in the Republic of Korea, ships operating in near-coastal zone regardless of their size and fishing vessels less than 20 meters in length do not have to carry nautical charts to plot and monitor ship's position for their navigable area. Moreover, smaller ships less than 12 meters in length and fishing vessels less than 10 GT do not have to have means of obtaining ship's position information and heading information. Global Positioning System (GPS) is applicable only to fishing vessels which are fitted with radio equipment. On the other hands, GPS plotters are widely used in non-SOLAS ships for convenience reasons. However, the use of unapproved electronic chart data with an unapproved GPS plotter is dangerous because of the reliability of the equipment and chart data. In addition, the chart data installed in GPS plotters is mostly not up-to-dated properly (MOF, 2015a).

Because nautical charts are essential for safe navigation together with the means of position fixing, SOLAS requires all ships, irrespective of size, to carry nautical charts to plan and display the ship's route for the intended voyage, also to plot and monitor positions throughout the voyage. Ship's position information is achieved by Global Navigational Satellite Systems (GNSS), terrestrial systems or radio navigation systems. However, position information is useless without nautical charts to plot on it.

Table 1: Carriage Requirements for Navigation Equipment of Non-SOLAS Ships

Ships \ Navigation Equipment			Nautical Chart	GPS	Magnetic Compass	Radar	Gyro Compass
Non-Fishing Vessels	Less than 12m in length	Near-coastal zone	×	×	×	×	×
		Coastal zone	○	×	×	×	×
	12m or over in length	Near-coastal zone	×	above 500GT	×	above 100 GT	×
		Coastal zone	○	above 20 GT	above 500 GT	above 100 GT	above 500 GT
Fishing Vessels	Less than 10 GT		×	○	×	×	×
	10 GT or over	Less than 20m	×	○	×	×	×
		20m or over	○	○	×	×	×
		24m or over	○	○	○	×	×
		35m or over	○	○	○	○	×
		45m or over	○	○	○	○	○

The carriage requirements for shipborne navigational systems and equipment for non-SOLAS ships are as shown in Table 1. In addition to the navigational equipment, ship position transmitter has become compulsory to carry for the most fishing vessels. According to the Fishing Vessels

Act, Class-A AIS (Automatic Identification System), Class-B AIS, MF (Medium Frequency)/HF (High Frequency) radio, mobile phone, satellite communication equipment and TRS (Trunked Radio Service) are admitted as a ship position transmitter (MOF, 2015c).

2.2. Shipboard Communication System

The carriage requirements of radio equipment for non-SOLAS ships are described in Ship Safety Act and Fishing Vessels Act as shown in Table 2. Ships navigating in coastal area and fishing vessels of 5 GT and upwards are carrying VHF (Very High Frequency) DSC (Digital Selective Calling) and MF/HF DSC radio equipment for communication and distress purpose. In practically, VHF radio telephone is widely used for communication with other ships and VTS (Vessel Traffic Service) centers. A language barrier exists between non-SOLAS ships and SOLAS ships.

Table 1 : Carriage Requirements for Radio Equipment of non-SOLAS Ships

	Ships by Operating Areas and/or Size		Communication Equipment
Non-Fishing Vessels	Coastal Area (within approx. 20 nautical miles)	300 GT and upward	VHF^{DSC}, NAVTEX, EPIRB, SART, 2-way VHF
		Less than 300 GT, international voyages	VHF^{DSC}, MF/HF^{DSC} , EPIRB
		Less than 300 GT, domestic voyages	VHF ^{DSC}, EPIRB
	Near-coastal Area (within port or harbour areas)	2 GT and upward	VHF ^{DSC}
		Less than 2 GT	-
Fishing Vessels	Ships engaged on international voyages		VHF ^{DSC}/RT, MF/HF ^{DSC}, EPIRB, NAVTEX, 2-way VHF
	24m and upward in length		VHF^{DSC}/RT, MF/HF, EPIRB
	Less than 24m in length	5 GT and upward	VHF ^{DSC}/RT, MF/HF, (MF or 27MHz Radio)
		2 – 5 GT	VHF^{DSC}/RT (Radiotelephony)
		less than 2 GT	-

As shown in Table 2, small ships of less than 2 GT are not fitted with radio equipment. There are no means of communication and information exchange among the ships without radio equipment.

III. Development of e-navigation

3.1. IMO's Strategy Implementation Plan (SIP)

The SIP presents the list of tasks and specific timelines for the implementation of prioritized e-navigation solutions during the period from 2015 to 2019. The SIP focuses on the five prioritized e-navigation solutions which are emphasizing the efficient transfer of marine information between all appropriate users (ship-ship, ship-shore, shore-ship and shore-shore) and the promotion of the workable use of the information and data onboard. During the development of the SIP, a number of tasks have been identified in order to continue the further development and implementation of e-navigation (IMO, 2014a).

As a part of the implementation of the SIP, Guidelines on Human Centred Design (HCD) and Guidelines on Usability Testing, Evaluation and Assessment (U-TEA) of e-navigation systems are under development as key elements for improved, harmonized and user-friendly bridge design. HCD employs the methods of U-TEA, the results of which drive a formal feedback loop in the design stages to ensure usability and continued safety. The fundamental to HCD is the collection of user feedback through systematic and formalized U-TEA. U-TEA enables extended use of standardized and unified symbology for relevant bridge equipment (IMO, 2014b).

3.2. Korea's Strategy Implementation Plan

Realizing the importance of navigation safety of non-SOLAS ships in the Korean coastal waters as discussed in section II of this paper, the government of Korea has decided to establish the e-navigation system. Taking into account the ship navigation surroundings in Korean coastal waters, MOF set up the national strategy plan for the development and implementation of e-navigation in 2013 (MOF, 2013). Following the governmental decision making process, Korea's e-navigation Strategy Implementation Plan (SIP) has been finalized in 2015. Korea's SIP focuses on the e-navigation services for non-SOLAS ships based in the Maritime Service Portfolios (MSPs) of IMO as shown in Figure 1.

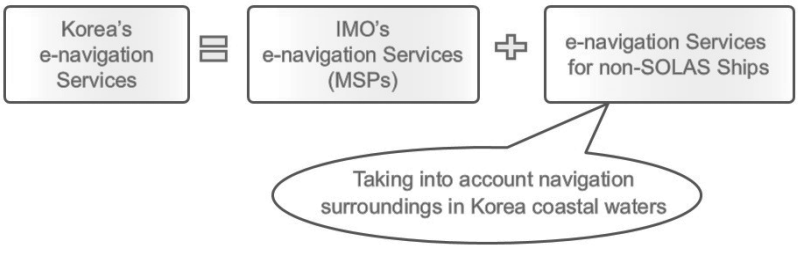

Figure 1: Concept of Korea's e-navigation

Source: K. An (2015), p.49.

The project for the development and implementation of Korean e-navigation was selected as an appropriate program qualified for the national R&D project. As a part of policy making process, the Feasibility Study on National R&D Program was performed in 2014 by the Korea Institute of Science and Technology Evaluation and Planning (KISTEP) under the supervision of the Ministry of Strategy and Finance (MOSF). The Korea's SIP provides a framework for the development and implementation of e-navigation in Korea. According to the Korea's SIP, the project will be performed from 2016 to 2020 with approximately 114 million USD of government budget (MOF, 2015b). The project has three strategies, namely the development of core technologies of e-navigation services, the expansion of infrastructure and the development of e-navigation standards in IMO's SIP.

Firstly, the core technologies of e-navigation services include the technology for situational awareness of maritime traffic and response to navigational hazard based on real-time traffic monitoring system together with ship position information. It also includes the technologies for

risk assessment for the identified navigational hazard. The developed technologies will be applied to the e-navigation services for non-SOLAS.

Secondly, a digital communication system and an e-navigation operation system will be established as a digital infrastructure. The digital communication system is a key for the implementation of e-navigation. It will consist of digitalized GMDSS (Global Maritime Distress and Safety System) and LTE–M (Long Term Evolution for Maritime). The digitalized communication system will be developed based on the existing GMDSS for SOLAS ships, such as AIS Application Specific Messages (AIS-ASM) and VHF Data Exchange System (VDES). AIS-ASM transmitted in binary format will be increasingly used to digitally communicate maritime safety information between participating vessels and shore stations. Together with AIS-ASM, VDES will have a significant beneficial impact on the maritime information services including Aids to Navigation and VTS in the future.

Apart from the GMDSS technologies, LTE-M enables smaller ships which have not fitted with radio equipment to communicate and exchange data within 100km in coastal waters from the shore. LTE-M has the ability to manage fast-moving mobiles and supports multi-cast and broadcast streams. It is expected that LTE-M will improve the safety of smaller ships and fishing vessels significantly. Thanks to the high-speed data networks, non-SOLAS ships can use an ENC streaming service to monitor the ship's position by the internet connection at sea. Figure 2 shows the maritime communications in e-navigation system. The Maritime Cloud will be established to exchange data and information between ships with different communication system. For instance, a ship with LTE-M can communicate with GMDSS ship through the Maritime Cloud system.

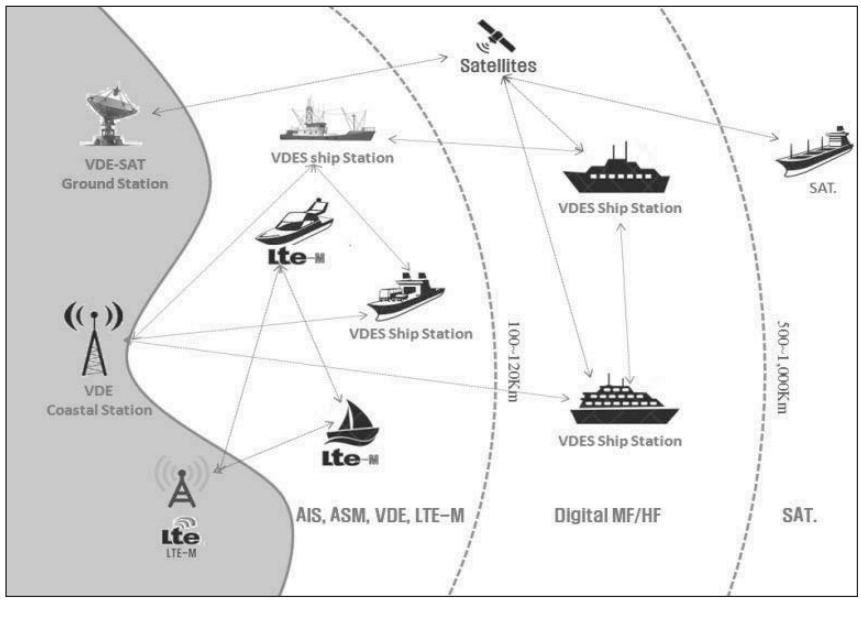

Figure 2: E-Navigation Communication Systems

Source: Source: K. An (2015), p.113.

The e-navigation operation system will include central and regional operation centre(s), big-data system of marine information, ship position information, information exchange, maritime

cloud system and data back-up system. The e-navigation operation system will consist as shown in Figure 3.

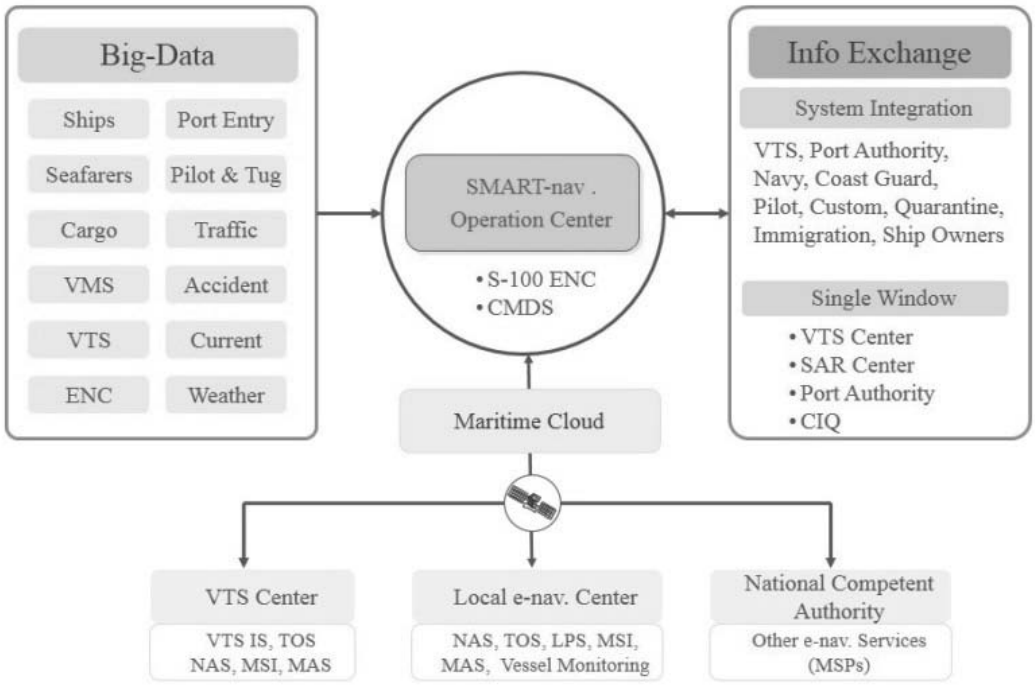

Figure 3: E-navigation Operation System

Source: K. An (2015), p..56.

Lastly, the development of standards or guidelines for Software Quality Assurance (SQA), S-mode (Standard mode for navigational equipment), Maritime Cloud and S-100 ENC will be performed under the Korea's e-navigation SIP. The project will be led by MOF and managed by KIMST (Korea Institute of Marine Science and Technology Promotion. MOF will cooperate with the Ministry of Science, ICT and Future Planning and Ministry of Industry and Trade.

IV. E-navigation Services for Non-SOLAS Ships

In this section, the essential e-navigation services for non-SOLAS ships were discussed based on the findings as discussed in section II. The results of examination of shipboard navigation and communication systems for non-SOLAS were reviewed to draw essential e-navigation services for non-SOLAS ships. Considering problems that are encountered in non-SOLAS ships, the navigation and communication system of non-SOLAS ships should be supported by e-navigation services. In this context the e-navigation services for non-SOLAS ships would be navigation support services, communication support services and safety information services. The navigation support services are intended to help smaller ships which are not fitted with basic navigational equipment, such as GPS, magnetic/gyro compass and nautical charts.

4.1. ENC Download and ENC Up-date Service

ENC download service provides the approved ENC data through internet connection. It enables mariners to install ENC data in the shipboard chart plotter by themselves. In non-SOLAS ships, it is practically impossible to use paper charts and publications because of up-date related problem and inconvenience. It is convenience to use electronic charts for mariners to plan and display the ship's route for the intended voyage and to plot and monitor positions which are obtained from GPS throughout the voyage. The chart plotters are widely used to plot and track the ship's position on the display. For economic reason, it is impossible to carry ECDIS in non-SOLAS ships.

In order to facilitate the wide use of ENC in non-SOLAS ships, it is important to improve the performance standards for the chart plotter. The chart plotter for non-SOLAS ships should be approved by the government in accordance with national laws and regulations. The chart plotter also should have means of obtaining position and heading information. In addition, the communication network will be connected in the chart plotter to exchange data and information with shore centre and other ships. ENC up-date should be performed automatically through the maritime communication network according to the Notice to Mariners which are published by the Hydrographic Authority. The communication network might be digitalized GMDSS or LTE-M according to the choice of users. It is estimated that approximately 60,000 non-SOLAS ships are going to use the ENC download and ENC up-date service.

4.2. ENC Streaming Service

ENC streaming service is intended to support smaller ships, fishing vessels and leisure boats which are not fitted with chart plotter. In the ENC streaming service, it is expected that the portable display unit will be used instead of fixed chart plotter. The mariner does not have to download or install the ENC data. The chart information will be displayed through streaming which sent from shore support centre. In the chart streaming system, the chart up-date service is not necessary. The ship position and route information will be plotted and tracked on ENC display together with ship's heading information. The portable display unit should have means of obtaining position and heading information. The LTE-M network should be connected in the portable display unit to connect into internet and shore data centre. It is estimated that approximately 30,000 smaller ships, fishing vessels and leisure boats will be the target of ENC streaming service. The ENC service is based on the ship's position information.

4.3. Routeing Support Service

The routeing support service provides the recommendation for best ship's route taking into account weather and maritime traffic. This service is intended to support the ship in trouble with navigation system. The routeing support service might be provided in the dense foggy weather on demand from ships. The system will support the ship's navigation with information for bearing and distance to the destination or next waypoints on the route.

4.4. Communication Support Service based on Maritime Cloud

Since the mobile communication networks (LTE-M) will be used in maritime communication together with existing GMDSS, the Maritime Cloud is necessary to enable seamless information exchange between various systems and across different physical communication links. The Maritime Cloud consists of standards, infrastructure and service reference implementations. The concept of Maritime Cloud is shown in Figure 4.

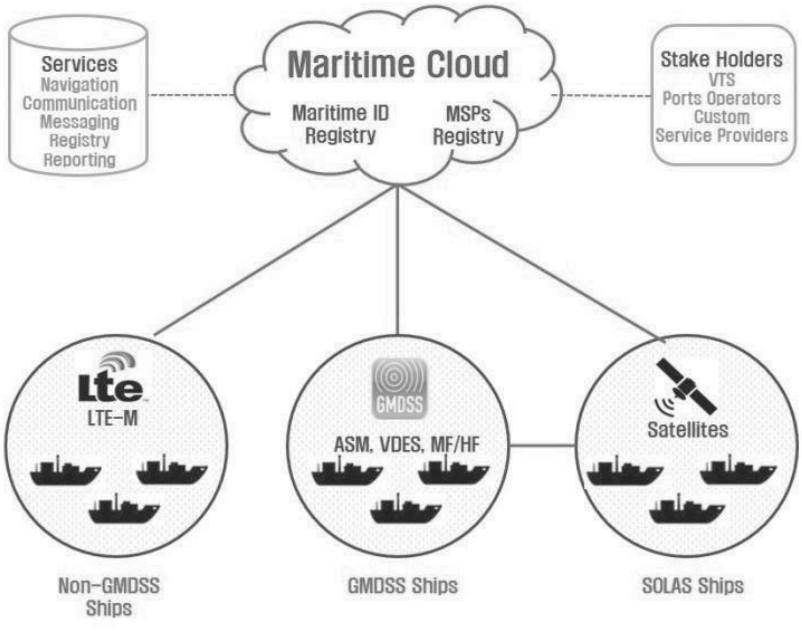

Figure 4: Concept of Maritime Cloud

Source: K. An (2015), p.110.

V. Conclusions

It is clearly understood that e-navigation will help to improve the safety of navigation. The main benefits of e-navigation are expected to be improved safety and better protection of the environment through the promotion of standards of navigational system and a reduction in human error. According to the IMO's SIP of e-navigation, various standards and guidelines will be developed in the near future. In addition, technologies and e-navigation services will be developed under the national strategy of Korea's e-navigation.

It is recognized that e-navigation services should be focused not only on SOLAS ships but also on non-SOLAS ships in order to meet the expectations on the benefit of e-navigation. This study examined the present navigation and communication system of non-SOLAS ships based on relevant laws and regulation to draw the findings. As a result, it is found that non-SOLAS ships are operating in poor navigation surroundings compared with SOLAS ships. Taking into account the status of the development and implementation of IMO's SIP and national strategy for e-

navigation in Korea, the essential e-navigation services for non-SOLAS ships were discussed in this paper. Finally, it is proposed that the e-navigation services for non-SOLAS ships would be navigation support services, communication support services and safety information services.

This study will help for the planning and designing of the Korean e-navigation system which will focus on the e-navigation services for non-SOLAS ships. In order to realize the e-navigation services for non-SOLAS ships, the navigational support system should be established in Korean e-navigation operation system. In this respect, further study on the development of navigational support system for non-SOLAS ships would be needed in the future.

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