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A Decade of ECDIS:
Analytical Review of the ECDIS Effect towards the Safety of Maritime Shipping

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المستخلص

يعد نظام الخرائط الإلكترونية على متن السفن أحد أحدث التعديلات التي نصت عليها المنظمة البحرية الدولية (IMO) في عام ٢٠٠٨ وقد طبق على نطاق واسع بحلول عام ٢٠١٢، وكان الغرض الرئيسي من استخدام الخرائط الإلكترونية هو الاستفادة من التكنولوجيا الحديثة للمساعدة في عملية تشغيل السفن للحصول على وردية ملاحية آمنة وخط سير آمن ورسو امن في الموانئ. بالإضافة إلى ذلك، فإن الخريطة الإلكترونية تسهل عملية التخطيط الملاحي للرحلة البحرية.

وبعد مرور عشر سنوات (٢٠١٢-٢٠٢٢). فان السؤال يطرح نفسه، هل يعتبر استخدام الخرائط الإلكترونية اضافة إيجابية نحو تشغيل أكثر اماناً للسفن، أم هو على العكس من ذلك، وانه قد أدى إلى زيادة الحوادث البحرية؟

بدأ الباحثون الدراسة بافتراض أن الخرائط الإلكترونية قد تكون سببًا لزيادة للحوادث البحرية وليس التقليل منها كما كان مرجو، ووجد الباحثون أن الإحصائيات الموجودة في أيدي الباحثين لم تكن مؤشرا على رأي قاطع. لذلك، استخدم الباحثون معيار الاستبيان كوسيلة للإحصاء الكمي كأداة بحثية للتعرف على رأي ورؤية ضباط الممشى لاستخدام الخرائط الإلكترونية خلال عقد من الزمن، ولتحديد ما إذا كان هناك حاجة إلى أي تطوير سواء في الإطار التشغيلي أو التعليمي.

كانت المنهجية المستخدمة في هذا البحث هي أسلوب التحليل النوعي للبيانات من خلال استبيان لمستخدمي الخرائط الإلكترونية المختلفين وقد أشار إلى أن المعدة محل البحث كان لها تأثير إيجابي غير مسبوق على سلامة الملاحة. اعتمد الاستبيان على ١٠ أسئلة مختلفة، ومع ذلك، اتفق جزء كبير على أن هناك مجالًا كبيراً للتطور في مجالات البرمجة والأجهزة وأجهزة الاستشعار الخارجية للمساهمة بفعالية في نظام الممشى المتكامل الفعال.

Abstract

The Electronic Charts Display Information System (ECDIS) on board ships is one of the latest amendments that have been stipulated by the International Maritime Organization (IMO) since 2008 and had been widely spread in 2012, and the main purpose of implementing the use of ECDIS was to use modern technology to help in operating ships to obtain a safe navigational watch and a safe approach and mooring in ports. Additionally, it facilitates voyage planning as an easy-to-use tool.

Hence, ten years passed (2012-2022). The question arose, was the use of ECDIS considered an improvement to the safe operation of ships, or, on the contrary, it led to an increase in marine accidents?

The authors initiated the study after the hypothesis that the ECDIS could be a major cause of marine accidents, and the authors found that the statistics in the hands of the researchers were not indicative of a conclusive opinion. Therefore, the researcher used the criterion of questionnaire as a means of quantitative statistics as a research tool to identify the opinion and vision of bridge seafarers for the use of ECDIS in a decade and to identify if any development is needed either in operational or educational sight.

The methodology used in this research was the qualitative analysis data method through a questionnaire for different ECDIS users and indicated that the equipment carried an unprecedented positive effect on the safety of navigation. The questionnaire was based on 10 different questions. Yet, a great fraction agreed that there is a massive room for improvement in the areas of software, hardware, and external sensors to effectively contribute to an efficient Integrated Bridge System.

1 Introduction

A decade ago, the primary and obligatory means of navigation were paper charts, which the navigator could rely on to plan her/his voyage, monitor route, and plot positions. Those duties required significant effort and professionalism from the navigator, especially during long voyages. On the other hand, Electronic Chart Systems (ECS) and ECDIS existed as navigational aids and were not yet obligatory used as primary navigation tools.

In 2008, the IMO began to implement the application of ECDIS on high-speed crafts, the real spread of the newly added equipment was in 2012 when newly built cargo ships were obligated to carry ECDIS on board. Accordingly, the compulsory implementation of ECDIS was specified according to the type and tonnage of each vessel where ECDIS should be used as the primary method of navigation in addition to an approved backup system depending upon the flag state preference, to be either a paper chart or to install another separate ECDIS and transform the vessel to a "paperless" ship. This change illuminated the privilege to have the ECDIS connected to all the navigational devices in the bridge as an integrated system to facilitate monitoring the data originating from all connected equipment.

In addition, to implement the installation of ECDIS on board almost all the existing vessels in addition to the newly built ones, the need presented itself for all operators to have undergone training, this training became compulsory according to the International Convention on Standards of Training, Certification, and Watchkeeping for Seafarers (STCW/78), so that they can deal with ECDIS correctly and safely (IMO, 2017).

Finally, concerns developed after a decade (2012-2022) about the ECDIS and its effectiveness as a reliable device used to play an effective crucial role to achieve safe navigation and the sufficiency of its development, and if ECDIS is good enough to rely on or if the ECDIS might need more development.

2 Historical background

In 1986 the North Sea Hydrographic Commission (NSHC) completed a study on the benefits and consequences of the development of ECDIS for Hydrographic Offices (HOs) (IHO, 2014). Following that study, and because of its impact, several manufacturers showed interest in being involved in the development of ECDIS. Meanwhile, the industry reached a point where it became essential for all related parties, Hydrographic Offices, mariners, National Shipping Authorities, and manufacturers, to have at least the first draft of the IHO and/or IMO guidance for both the Electronic Navigation Chart (ENC) and its display systems (IHO, 2014).

Consequently, ECDIS specifications' first draft was presented to IHO Member State Hydrographers at Monaco in May 1987 at the 13th International Hydrographic Conference, and it was distributed in an enormous figure to many other parties including National Shipping Authorities, Mariner Associations, and Marine Equipment Manufacturers, to receive their feedback regarding the draft (IHO,2014).

A year later, in November 1988, the Committee on ECDIS (COE) recognized the need for the presence of a common standard for Colors & Symbols. With the support of the Colors and Symbols Maintenance Working Group (CSMWG) specifications and guidelines for both chart symbols and colors were developed (IHO, 2014).

After three months, in January 1989, the IMO Safety of Navigation sub-committee integrated a common task with the Maritime Safety Committee (MSC) resulting in a recommendation recognizing the need to unify the symbols and colors for all navigational charts. Accordingly, they invited the Comité International Radio-Maritime (CIRM) and assigned the IHO to make a detailed technical proposal (IHO, 2014).

Simultaneously, the IMO/IHO Harmonizing group for ECDIS developed the Provisional Performance Standards (PPS), which was published in May 1989 by the IMO. Furthermore, a modified version of the PPS was prepared for industry convenience and was adopted in 1995 resulting in the production of IMO resolution Performance Standards for Electronic Chart Display and Information Systems (ECDIS) A.817 (19) (IHO, 2014).

Since this resolution had integrated many elements of the original IHO Specification. Therefore, for the time being, "Standard-52" (S-52) was considered the only standard that provides details of the hydrographic requirements for ECDIS PS (IHO, 2014).

In 2008, the Committee on Hydrographic Requirements for Information Systems (CHRIS) in its 20th meeting redesigned the S-52 to contain the modified IMO ECDIS PS, MSC.232 (82) with the correlated new International Electrotechnical Commission (IEC) 61174 Specification for ECDIS hardware test aiming towards the verification of compliance for ECDIS type approval. Finally, Edition 6 of S-52 was published, and the IMO PS ended up having only one standard which is the current resolution MSC.232 (82) (IHO, 2014).

Finally, to ensure that chart data provided by the chart suppliers to the end users maintained a high degree of security and to avoid the presence of any criminal activity that might affect the safe navigation of the vessel and thus affected the harmony in the operation of ECDIS, the IHO specified publication S-63 to ensure a secured ECDIS. This publication was updated in 2020 by the IHO and nominated as the IHO Data Protection scheme Edition 1.2.1 (IHO, 2020).

3 ECDIS International Standards

Three main parties participated in the regulations of ECDIS, namely the IMO, IHO, and IEC. All three organizations have established standards and publications for ECDIS to be an internationally approved maritime device, covering all three areas of software, hardware, and chart data.
The International regulative standards could be summarized as follows:

- **IMO standards:**
  - IMO Resolution A.817(19) Performance Standards for Electronic Chart Display and Information Systems (ECDIS), as amended.
  - IMO Resolution Msc.232(82) Adoption of The Revised Performance Standards for Electronic Chart Display and Information Systems (ECDIS).

- **IHO standards:**
  - S-52 (Specifications for Chart Content and Display Aspects of ECDIS).
  - S-57 (IHO Transfer Standard for Digital Hydrographic Data).
  - S-61 (Product Specification for Raster Navigational Charts (RNC)).
  - S-63 (IHO Data Protection Scheme).
  - S-64 (IHO Test Data Sets for ECDIS).

- **IEC standards:**
  - IEC 61174, ECDIS operational and performance requirements, methods of testing, and required test results.

The relationships among the International Organizations and working groups that have madeimportant contributions to the development of ECDIS are shown schematically in Figure 1.

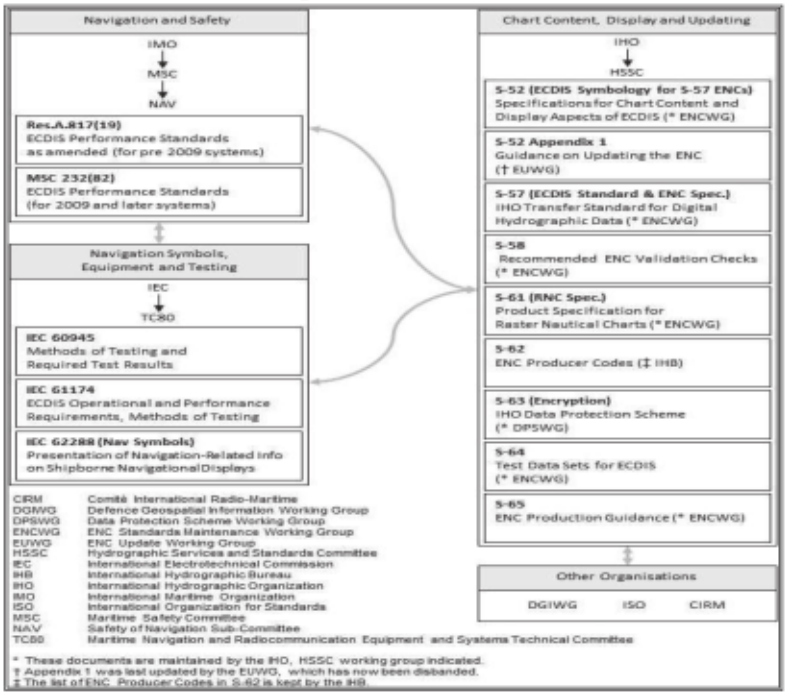

Figure 1: International Organizations involved in ECDIS Standardization. Source :(IHO, 2014).

As shown in figure 1, the efforts involved in producing a safe operating system for ECDIS was the fruitful performance for 14 working bodies to reach the end to the device seafarers were able to use smoothly on board their vessels (IHO, 2014).

4 Safety of Life at Sea Convention (SOLAS) Requirements for the Carriage of ECDIS

To add any new requirement in an IMO convention, a process of procedural steps should be made for these amendments to take effect, and a predefined percentage of ratifying member States should sign in favor of that new amendment. Starting from that point, SOLAS chapter five *"Safety of Navigation"* stipulated the new requirements for the carriage of ECDIS in regulation 19/2.1.4 to all ships as follows:

"All ships, irrespective of size, shall have nautical charts and nautical publications to plan and display the ship's route for the intended voyage and to plot and monitor positions throughout the voyage. An electronic chart display and information system (ECDIS) is also accepted as meeting the chart carriage requirements' (IMO, 2020).

Consequently, SOLAS classified vessels into two categories, a new ship, and an existing ship. Furthermore, the vessels were classified into three types according to their line of work: Passenger Ships, Tanker Ships, and Cargo Ships. Each type was limited for implementation by their Gross Tonnage (GT) Capacity, as shown in figure 2.

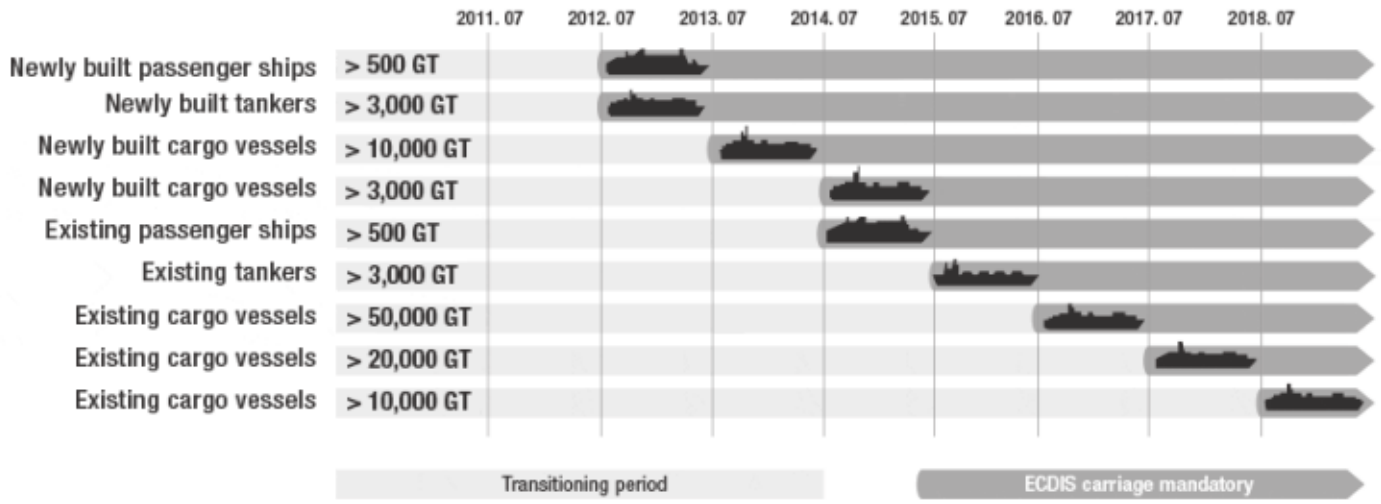

Figure 2: SOLAS Requirements for the Carriage of ECDIS. Source: (Furuno Electric Co., LTD, 2014).

As shown in figure 2; the existing ship is the vessel where her keel in the shipyard was laid before the assigned date and the newly built vessel is the vessel where its keel was laid after the assigned date.

5 Development of ECDIS

Corresponding to the implementation process for an Integrated Bridge System (IBS) to operate ECDIS, the global organizations related to the maritime industry gathered their forces and developed their requirements in various standards to develop the ECDIS.

Electronic Navigation or E-Navigation is a new hypothesis in marine navigation defined as the harmonized collection, integration, exchange, presentation, and analysis of marine information on board and ashore by electronic means to enhance berth-to-berth navigation and related services for safety and security at sea and protection of the marine environment (IMO, 2009).

Since ECDIS is the only system that could be considered as a central system for presenting different information capable of satisfying the end user needs and fulfilling the requirements for E-navigation through the integration between all such navigational equipment (Bistrovića & Komorčec, 2014). Therefore, ECDIS should be made compatible with E-navigation by inserting changes in all related operational standards for targeted equipment. Also, it may include developing some functions to achieve the concept of IBS to produce sharable information between ships and shore (Bistrovića & Komorčec, 2014).

Additionally, IHO had the S-100 (Universal Hydrographic data model) which should eventually replace the established IHO Transfer Standard for Digital Hydrographic Data S-57, allowing the usage of chart images, for instance; classification of the seabed, high-density bathymetry, 3D data, dynamical ECDIS and online updates (IHO, 2010).

Moreover, the maritime Industry may use S-100 as the new E-Navigation tool used for exchanging data between own vessel, other vessels, and ashore, not to mention the capability for analyzing and facilitating the decision-making process. Furthermore, the international standard format for route exchange from IMO facilities the ability to share routes between ship and shore at route planning and execution phases to enhance the safety of navigation at sea. (CIRM, 2020).

Although all ECDIS can operate using ENC on both modes of S-57 and S-100 and should run smoothly for the entire operation. Unfortunately, till now it is not mandatory on-board ships (IHO, 2018).

Figure 3 explains the latest technology available for reaching a smooth data exchange between ship and shore following the E-Navigation mode including the participation between satellite systems for positioning and cloud storage with VTS stations and remote control stations on land supported by the AIS data from all surrounding vessels to each at the end to the integrated navigational system performing with the optimum use of all on board and in the sea and on land resources (Sushchinskii & Rodionov, 2022).

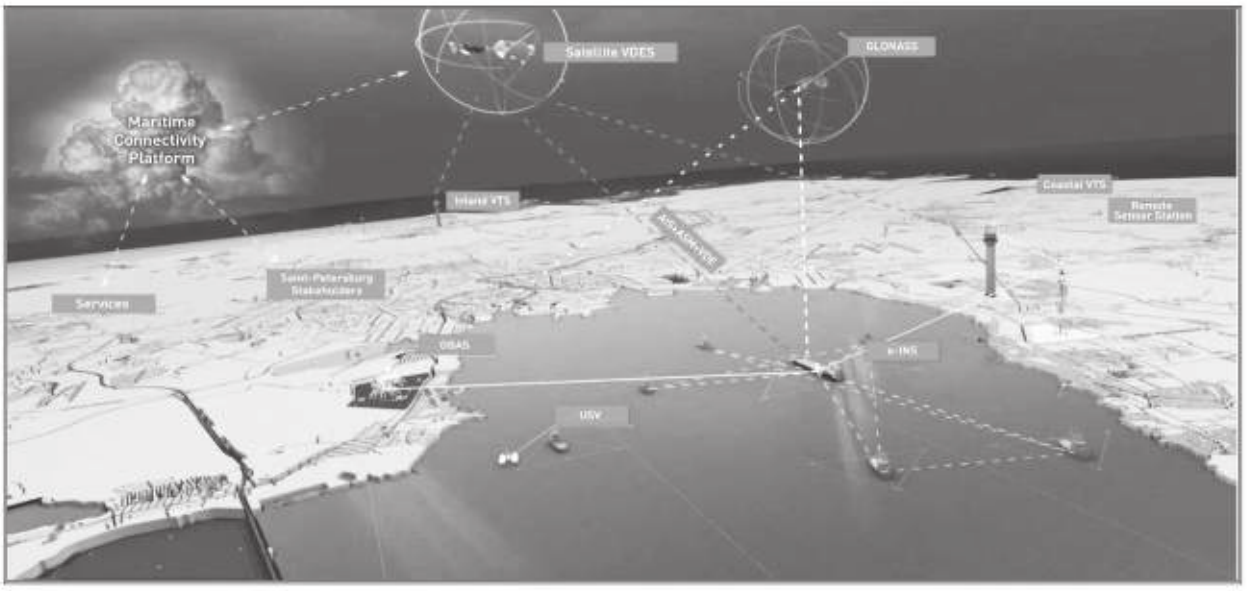

Figure 3: exchange information between ships and shore using E-navigation. Source: (Sushchinskii & Rodionov, 2022).

It is worth mentioning that there are serious intentions for the standardization of the interface of all types of ECDIS (S-Mode Display) allowing operators to easily familiarize themselves with different ECDIS models when changing between ships during different contracts/companies without the need for type-specific training (Patraiko, 2017).

Finally, with all this mutation in the technology related to E-navigation, the maritime industry needed to adapt especially from the human factor perspective by applying a new method of training to cope with the industry development (IAMU, 2019). On the other hand, E-Navigation should support the implementation of the first three degrees identified by the IMO for the Marine Autonomous Surface Ship (MASS).

6 Training for ECDIS

ECDIS operators should complete the mandatory courses according to the STCW/78 convention as amended to be competent in maintaining a safe navigational watch during the use of ECDIS functions (IMO, 2017).

There are two types of training according to the level of operators. The first type is the operational level STCW training competency according to table A-II/1 as shown and covered in figures 5 and 6. The second type is the management level training as per STCW table A-II/2 as shown in figure 4.

However, all of these courses are focusing on the minimum international requirements for ECDIS functions but still, type-specific training is not obligatory for ECDIS to issue a certificate of competency (COC) which demonstrates the reality of the presence of different types of ECDIS in the industry (IMO, 2017).

The second type is the operational level training as per STCW table A-II/2 as shown in figures 5 and continued in figure 6 which includes the same functions but with different level of operation.

Table A-II/2 *(continued)*

Function: Navigation at the management level *(continued)*

Column 1	Column 2	Column 3	Column 4
Competence	**Knowledge, understanding and proficiency**	**Methods for demonstrating competence**	**Criteria for evaluating competence**
Maintain safe navigation through the use of information from navigation equipment and systems to assist command decision making **Note:** Training and assessment in the use of ARPA is not required for those who serve exclusively on ships not fitted with ARPA. This limitation shall be reflected in the endorsements issued to the seafarer concerned	An appreciation of system errors and thorough understanding of the operational aspects of navigational systems Blind pilotage planning Evaluation of navigational information derived from all sources, including radar and ARPA, in order to make and implement command decisions for collision avoidance and for directing the safe navigation of the ship The interrelationship and optimum use of all navigational data available for conducting navigation	Examination and assessment of evidence obtained from approved ARPA simulator and one or more of the following: .1 approved in-service experience .2 approved simulator training, where appropriate .3 approved laboratory equipment training	Information obtained from navigation equipment and systems is correctly interpreted and analysed, taking into account the limitations of the equipment and prevailing circumstances and conditions Action taken to avoid a close encounter or collision with another vessel is in accordance with the International Regulations for Preventing Collisions at Sea, 1972, as amended
Maintain the safety of navigation through the use of ECDIS and associated navigation systems to assist command decision making **Note:** Training and assessment in the use of ECDIS is not required for those who serve exclusively on ships not fitted with ECDIS. This limitation shall be reflected in the endorsements issued to the seafarer concerned	Management of operational procedures, system files and data, including: .1 navtex procurement, licensing and updating of chart data and system software to conform to established procedures .2 system and information updating, including the ability to update ECDIS system versions in accordance with vendor's product development .3 create and maintain system configuration and backup files .4 create and maintain log files in accordance with established procedures .5 create and maintain route plan files in accordance with established procedures .6 use ECDIS log book and track history functions for inspection of system functions, alarm settings and user responses Use ECDIS playback functionality for passage review, route planning and review of system functions	Assessment of evidence obtained from one of the following: .1 approved in service experience .2 approved training ship experience .3 approved ECDIS simulator training	Operational procedures for using ECDIS are established, applied and maintained Actions taken to minimize risk to safety of navigation

Figure 4: STCW ECDIS training tables A-II/2 management levels. Source: (IMO,2017)

Table A-II/1 *(continued)*

Function: Navigation at the operational level *(continued)*

Column 1	Column 2	Column 3	Column 4
Competence	**Knowledge, understanding and proficiency**	**Methods for demonstrating competence**	**Criteria for evaluating competence**
Use of ECDIS to maintain the safety of navigation **Note:** Training and assessment in the use of ECDIS is not required for those who serve exclusively on ships not fitted with ECDIS. This limitation shall be reflected in the endorsements issued to the seafarer concerned	Navigation using ECDIS Knowledge of the capability and limitations of ECDIS operations, including: .1 a thorough understanding of Electronic Navigational Chart (ENC) data, data accuracy, presentation rules, display options and other chart data formats .2 the dangers of over-reliance .3 familiarity with the functions of ECDIS required by performance standards in force Proficiency in operation, interpretation, and analysis of information obtained from ECDIS, including: .1 use of functions that are integrated with other navigation systems to optimize installation, including proper functioning and adjustment to desired settings .2 safe monitoring and adjustment of information, including own position, sea area display mode and orientation, chart data displayed, route monitoring, user-created information layers, contacts (when interfaced with AIS and/or radar tracking) and radar overlay functions (when interfaced) .3 confirmation of vessel position by alternative means .4 efficient use of settings to ensure conformance to operational procedures, including alarm parameters for anti-grounding, proximity to contacts and special areas, completeness of chart data and chart update status, and backup arrangements .5 adjustment of settings and values to suit the present conditions	Examination and assessment of evidence obtained from one or more of the following: .1 approved training ship experience .2 approved ECDIS simulator training	Monitors information on ECDIS in a manner that contributes to safe navigation Information obtained from ECDIS (including radar overlay and/or radar tracking functions, when fitted) is correctly interpreted and analysed, taking into account the limitations of the equipment, all connected sensors (including radar and AIS where interfaced), and prevailing circumstances and conditions Safety of navigation is maintained through adjustments made to the ship's course and speed through ECDIS-controlled track-keeping functions (when fitted) Communication is clear, concise and acknowledged at all times in a seamanlike manner

Table A-II/1 *(continued)*

Function: Navigation at the operational level *(continued)*

Column 1	Column 2	Column 3	Column 4
Competence	**Knowledge, understanding and proficiency**	**Methods for demonstrating competence**	**Criteria for evaluating competence**
Use of ECDIS to maintain the safety of navigation *(continued)*	.6 situational awareness while using ECDIS including safe water and proximity of hazards, set and drift, chart data and scale selection, suitability of route, contact detection and management, and integrity of sensors		

Figures 5&6: STCW ECDIS training tables A-II/1 operational level. Source: (IMO,2017)

Consequently, operators should require extra training to be familiar with the type or model of ECDIS available on board their vessel, to achieve that, numerous methods could be established, for

example, the companies might draft a bilateral agreement with the onboard ECDIS manufacturer to deliver onboard training, or by sending the officers to training centers equipped with the required ECIDS Model. However, sending officers for type-specific training can be harder for fleets that have a wide range of ECDIS models, and officers will still require a brief period of onboard familiarisation when dealing with ship-specific installations (Chhabra, 2014).

Companies' accountability to ensure the proper delivery of the type-specific training was based on the responsibility assigned to them according to the International Safety Management (ISM) Code (Section 6) to ensure their bridge officer's familiarity with the onboard ECDIS. This responsibility was delegated also to the Master on board representing his company to ensure familiarity for all ECDIS users on board. The most understandable process of familiarisation with onboard ECDIS functions is to read the onboard user manual with evidence of proof by a signature on the management system to ensure that the ECDIS users had read the manual and are familiar with the ECDIS in question (Chhabra, 2014).

7 Accidents related to ECDIS

In this section, the authors checked the probability of having ECDIS as the primary cause of a ship's accident, the statistical data used in this study are based on the grounding accidents investigation reports published by the following bodies:

- Marine Accident Investigation Branch (MAIB),
- The Federal Bureau of Maritime Casualty Investigation (BSU).
- The Marine Safety Investigation Unit (MSIU).
- The Dutch Safety Board (DSB).

There was a record of a total of 80 grounding accidents in the period from 2008 to 2018; after analyzing the recorded accidents it was noticed that in 22 cases the probability of finding more than one reason for the accident related to ECDIS and ENC has been spotted and illustrated in Figure 7. The Y-axis represents the number of cases, and the X-axis represents the years. Additionally, we categorized the incidents/accidents into three types: Less Serious – Serious - Very Serious (Turna & Ozturk, 2019).

For further explanation, "very serious" are marine casualties resulting in the complete loss of the vessel or big harm to the environment or loss of life. Where "Serious" refers to marine incidents to vessels not big enough to be "very serious" and includes for instance fire, collision, grounding, heavy weather damage, and suspected hull defect, affecting the ship's performance and leading to an unseaworthy vessel. In addition to the consequences of pollution or inappropriate towage. Lastly, "less serious" are marine incidents that do not qualify to be "very serious" or "serious" (Turna & Ozturk, 2019).

Following that reason, a total of 22 grounding cases have been classified as follows (Ships and Offshore Structures, 2019).

- 2 very serious accidents
- 18 serious accidents
- 2 less serious accidents

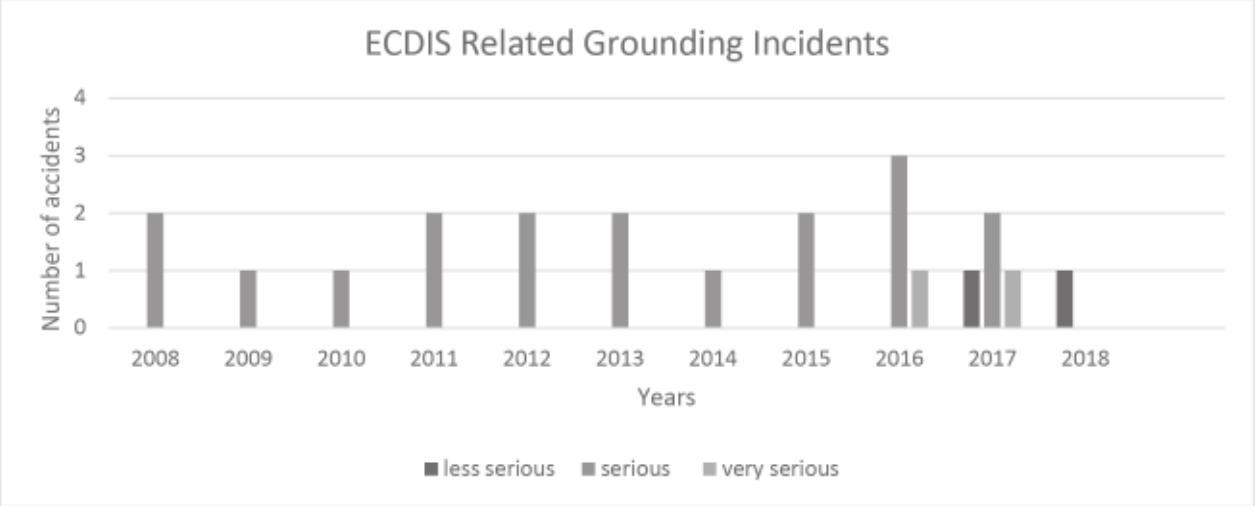

Figure 7: Statistics for grounding accidents related to ECDIS from 2008 to 2018. Source: (Turna & Ozturk, 2019).

Forthcoming from the fact shown in figure 5 that the indicators to the records for the three measuring elements, the author identified the discrepancies in all of them over the years which leads the authors to follow the track of a quantitative questionnaire as a survey involving a random sample of bridge competencies as a mean for measuring the hypotheses involving the implementation of the ECDIS and its link to be considered as a major cause for accidents. (Turna & Ozturk, 2019).

8 Questionnaire

A questionnaire is a research instrument that consists of a set of questions or other types of prompts that aims to collect information from a respondent. A research questionnaire is typically a mix of close-ended questions and open-ended questions. Such questions offer the respondent the ability to elaborate on their thoughts. Research questionnaires were developed in 1838 by the Statistical Society of London. The data collected from a data collection questionnaire can be both qualitative as well as quantitative in nature. A questionnaire may or may not be delivered in the form of a survey, but a survey always consists of a questionnaire. (QuestionPro, 2022)

The questionnaire related to our research was distributed to people in direct and frequent involvement with ECDIS, whether onboard ships or ashore (companies, training centers, equipment distributors). The questionnaire contained the following questions: -

Q1. Do you think the presence of ECDIS reduced the number of accidents?

The authors set this question to measure the effect of using ECDIS concerning the number of accidents from the operator's point of view.

Q2. Do you think the presence of ECDIS facilitates the job of the bridge before and during sailing?

The purpose is to clarify if the ECDIS is considered a useful navigation tool on the bridge and if it is helpful more than the paper chart for bridge operations at all stages.

Q.3 Do think the ECDIS requires more options to be added?
The authors set this question to analyze if the ECDIS functions/options are sufficient/reliable to achieve safe navigation or need more options.

Q.4 Do you prefer to use the ECDIS or the paper chart?
The authors set this question to verify if the ECDIS existence as a navigation tool is better than the paper chart or if the paper chart is still the most comfortable tool for use by the operators.

Q.5 Do you prefer to have another ECDIS as a backup or the paper chart?
The authors asked this question to identify the preferred backup system because while using ECDIS as a primary navigation tool and according to the requirements; it is compulsory to have a backup arrangement then the question opened the area for volunteers to identify their tendencies either towards paper chart or secondary ECDIS.

Q.6 Do you think that using ECDIS in S-Mode will be more "user-friendly" than using different models of ECDIS?
The authors set this question to clarify when manufacturers of ECDIS make standardization for the interface of ECDIS display, does it make it easier for operators to transfer from one model to another without needing time for type-specific training or familiarization or not?

Q.7 Do you think that the mandatory sensors connected to ECDIS (Satellite Positioning Fixing System, Speed & Distance Measuring Device, & Gyro Compass) are sufficient to achieve safe navigation, or do other sensors needed to be added mandatory?
The authors set this question to estimate the minimum requirements for the number and function of sensors that should be connected to the ECDIS and if current requirements are sufficient to depend on for ECDIS use in navigation or if ECDIS needs more sensors.

Q.8 To the best of your knowledge, are there any administrations/companies that do not apply ECDIS carriage requirements?
The authors set this question to identify the deficiencies of administrations or companies in the application of international carriage requirements.

Q.9 to the best of your knowledge, does the vector charts library (ENC) cover all sailing areas globally?
We set this question to track the sailing areas which are not covered by vector charts, and whether we still need Raster charts or paper charts for the uncovered areas.

Q.10 Do you think that ECDIS training requirements in its current status are sufficient for safely operating the equipment?

We set this question to know what additional requirements need to be added to STCW compulsory training courses to raise the level of safety to operate the equipment.

The sample used in this survey was a total of (92) volunteers divided into bridge officers with various positions from second mates, chief mates, and Masters, with different ranges of ages and work on board diverse types of vessels or involved in the management of several types of ships but with a previous career for work at sea as navigating officers.
The results of that survey could be summarized that 92.4 % (64.1 % agree and 28.3 % strongly disagree) believed that ECDIS reduced the number of accidents. Also, 97.8 % (54.9 % agree and 42.9 % strongly agree) believed that ECDIS facilitates the job of the bridge team before and during sailing. Where 46.2 % (27.5 % agree and 18.7 % strongly agree) asked for more options to be added as suggested in Table I with a total of 4 suggestions.

Table 1: ECIDS options to be added as extracted from the questionnaire

Item	Suggestion
1	Search and rescue patterns
2	Target prediction
3	Navigation warnings and forecast
4	Secure online updating

Source: (Author)

Additionally, 98.9 % preferred to use the ECDIS over the paper chart and 45.7 % preferred a secondary ECDIS as a backup, and 42.4 % preferred a secondary ECDIS as a backup with paper charts. At the same time, 85.7 % (67 % agree and 18.7 % strongly agree) preferred to use the S-Mode and 59.4 % (39.6 % agree and 19.8 % strongly agree) requested more sensors to be connected to the ECDIS as suggested in Table II below with a total of 3 suggestions.

Table II: ECDIS added sensors as extracted from the questionnaire

Item	Suggestion
1	AIS
2	Anemometer
3	Echo Sounder

Finally, according to the implementation requirements for the ECDIS, it was logged that 33.8 % (25 % agree and 8.8 % strongly agree) were in favor that the vector charts were covering all navigable sea areas, according to their vessel's coverage and operating areas. In addition, 78.3 % (53.3 % agree and 25 % strongly agree) requested extra training requirements for ECDIS.

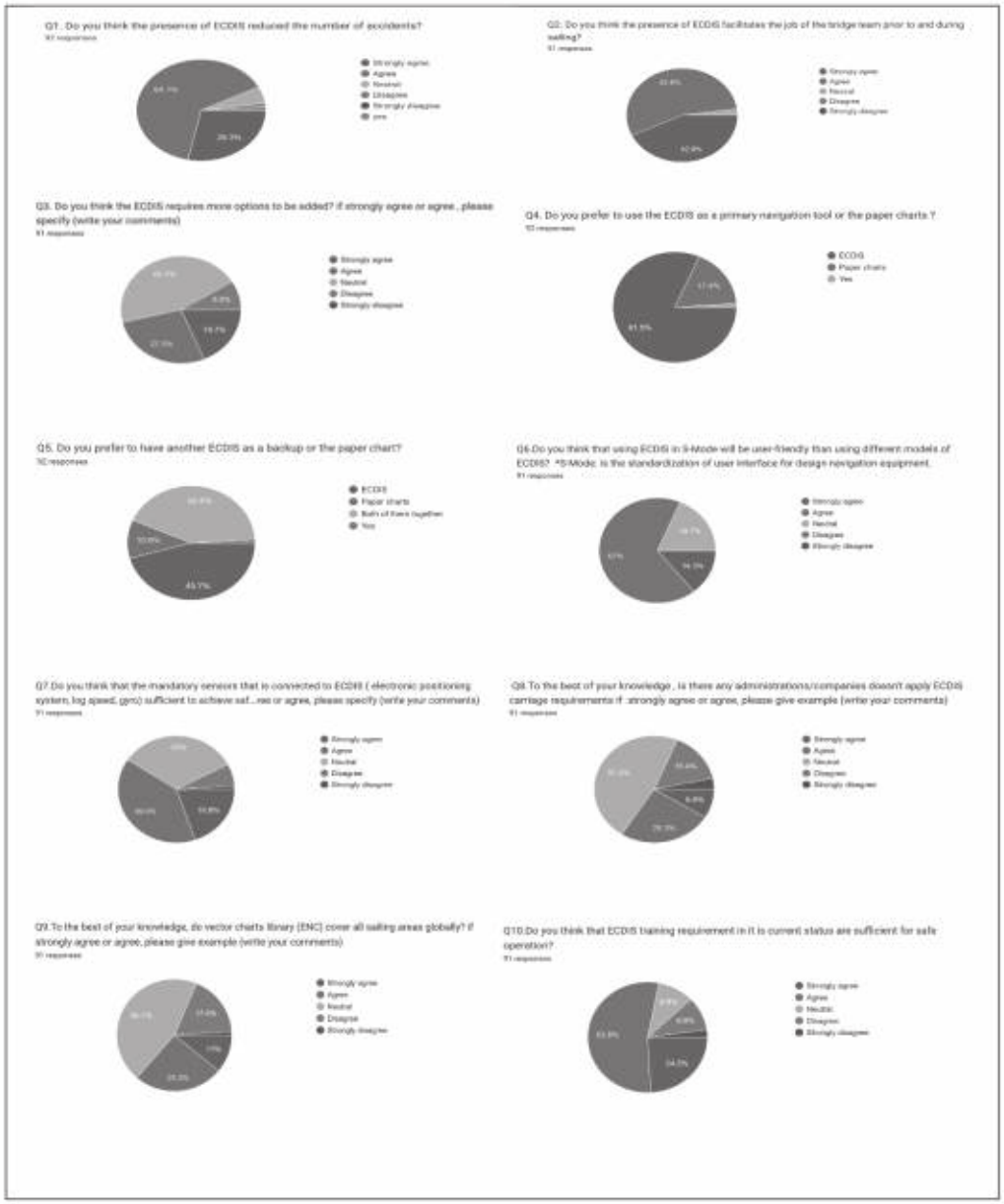

Figure:8 Questionaire Statistics
Source: (Author)

Referring to figure 8, it identifiess the results of the questionnaire in the form of ten statistical pie charts with different variables colored to indicate the results of the survey.

9 Discussion

Discussing the results from the survey was that the majority of results agreed that ECDIS reduced the number of accidents and facilitates the job of the bridge team before and during sailing. The ECDIS preferred to be used over the paper charts. Additionally, the ECDIS vector charts covered most of the navigable sea areas. However, the presence of ECDIS was satisfactory for most of the

volunteers in that survey, but more options were preferred to be applied and implemented for the ECDIS such as the programmed search and rescue patterns.
In addition, the S-Mode was identified as a beneficial approach to unify the cognitive and technical skills of end users with recommendations for extra training requirements for ECDIS due to different manufacturers with different software in the market.

10 Conclusion

It has been evident that any new addition to the Maritime Industry suffers a period of uncertainty in its purpose and a lot of miss-haps in its application before the Maritime community gains its benefits, ECDIS is no exception. ECDIS had been used onboard ships and training centers since its outbreak in 2012, allowing 10 years of building up exposure experience, highlighting errors, and thus developing as a result.
The questionnaire carried out by the authors of this review reflected the opinions of a sample of direct users of ECDIS, with a majority convinced that the equipment carried an unprecedented positive effect on the safety of navigation. Yet, a great fraction agreed that there is a massive room for improvement in the areas of software, hardware, and external sensors to effectively contribute to an efficient Integrated Bridge System.
This review captured the attention of Academia to the importance of constant review of newly added navigation equipment, especially those of direct effect on the safety of Shipping. The topic still in need of further studies using data may not be out for publication yet but surely will benefit the regulators to best develop ECDIS in the future.

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