TRANSNAV
http://www.transnav.eu
the International Journal
on Marine Navigation
and Safety of Sea Transportation
Volume 17
Number 1
March 2023
DOI: 10.12716/1001.17.01.25

# Evolving ECDIS: Concept Development Through Different Manufacturer Models Comparison

S. Žuškin, D. Brčić, M. Uroda & M. Strabić
*University of Rijeka, Rijeka, Croatia*

ABSTRACT: The Electronic Chart Display and Information Systems (ECDIS) became inevitable central navigational tool for effective voyage planning and voyage monitoring execution. Furthermore, each model comprises numerous navigational and other display components, each of them with its limitations, reliability and simplicity. This is also supported by the fact that there is a large number of approved manufacturer systems on the market. Apart from fulfilling the performance standards regulated by the International Maritime Organization (IMO), the system models differ significantly regarding handling, interface, and interpretation of data and information, therefore biasing the required knowledge and the purposefulness of the system.
The aim of this study is to determine navigators' response in ECDIS comparison of different manufacturer models to identify pros and cons of specific tasks, features and other navigational functions. The present work is based on international survey in form of questionnaire conducted among ECDIS stakeholders. Answers are presented and discussed, revealing certain shortcomings of specific manufacturer ECDIS system. On the other hand, the analyses show the significant advantages of each system, potentially leading to creation of the ideal system from the end-user's perspective. The proper configuration of ECDIS should standardise functions and display considering different types, and undoubtedly resolve a problematic issue as a consequence of numerous ECDIS models and their diversities.

## 1 INTRODUCTION

ECDIS is defined as a complex, safety-relevant software-based system with data fusion, integration and synergy as main features [1]. The purpose of the system is the reduction of the navigator's workload and ease and automation of navigation tasks, primarily voyage planning and conducting of the navigation venture. The system comprises hardware (PC, display and console), software (the ECDIS program and additional software) and data (charts, additional data and information) [2]. The essential system components are sensors providing mandatory data feed regarding the vessel's movement position and movement [3, 4]. The navigation information (the position of own vessel, and its movement over ground and through the water obtained from Electronic Position Fixing System (EPFS), gyrocompass, and speed log) placed on an appropriate suitable base (the Electronic Navigational Chart – ENC) represent the basis of the system operability. Together with mandatory navigation information, the full ECDIS display can be roughly divided in four main categories: cartographic (chart) data, environmental and other external related information, target tracking information received from radar equipment and AIS, and user-defined layers, such as routes, customized maps, additional sailing information etc. In Figure 1, relations between

permitted levels of information are presented with the final outcome on the navigator's display.

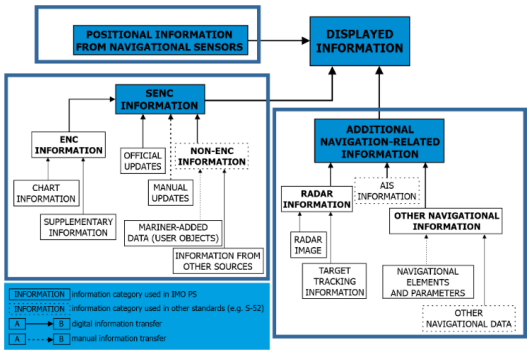


Figure 1. ECDIS display: Relations between information categories. Adapted, modified and supplemented on the basis of [5]

Table 1. Approved ECDIS models. Adopted from [9]

| Manufacturer/ Model | Approvals | A | M |
|---|---|---|---|
| Adveto/ECDIS 4000 | DNV/USCG | x | x |
| Alphatron/NaviSailor 4000 | CCS/DNV/RMRS | x | x |
| Highlander/HLD-ECDIS 1000 | CCS | x | |
| ChartWorld/eGlobe TM | DNV/USCG | x | x |
| ChartWorld/eGlobe G2 TM | DNV | x | x |
| Consilium/Consilium ECDIS | DNV | x | x |
| Danelec Marine/DM-800E | DNV | x | x |
| Furuno/FEA-2107&2807 | BSH | x | x |
| Furuno/FMD3200&3300 | ClassNK | x | x |
| GEM elettronica/ECD-700 | DNV | x | x |
| Headway/Headway ECDIS | GL | x | x |
| Hyunday e-MARINE/ e-Navigator | DNV/KR | x | x |
| Imtech/Seaguide | | | |
| Imtech/(W)ECDIS 4500 | | | |
| JRC/JAN-2000 | QinetiQ | x | x |
| JRC/JAN-901B | QinetiQ | x | x |
| JRC/JAN-701B | QinetiQ | x | x |
| Kelvin Hughes/Manta Digital Widescreen | QinetiQ/BSH | x | x |
| Kongsberg/K-Bridge | CCCS | x | x |
| Lilley&Gillie/Navmaster ECDIS | DNV/CCS/GL | x | x |
| Marine Tech/Bridge Mate ECDIS 900 | DNV | x | |
| Maris/ECDIS 900 | DNV | x | x |
| Martek Marine/iECDIS | | | |
| MECys/ECDIS | | x | |
| NAUDEQ/Master-DEQ 10/20 | BSH | x | x |
| OSI/OSI ECPINS | GL | x | x |
| PC MARITIME/Navmaster ECDIS | DNV/CCS/GL | x | x |
| Raytheon Anschutz/Synapsis | CCS | x | x |
| SAM Electronics/ECDIS Pilot Basic | BSH | x | x |
| SAM Electronics/ECDIS Pilot Platinum | BSH | x | x |
| Samsung/Naru 2000 (INS) | | x | |
| Seall/Seall ECDIS | DNV | x | x |
| SIMRAD/CS68 | DNV | x | x |
| SODENA/GECDIS | DNV/BV | x | |
| Northrop Grumman/VisionMaster FT | QinetiQ | x | x |
| TELKO/TECDIS | DNV | x | x |
| Tokyo KEIKI/ECDIS EC-8000/ 8500 | DNV | x | x |
| Totem Plus/Totem ECDIS | DNV | x | x |
| Transas/Navi-Sailor 4000 | DNV/CCS/RMRS | x | x |
| TRESCO/Navigis | | x | |

A – A.817(19). M – MSC.232(82)

Presented components imply additional ECDIS equipment elements. Besides mandatory sensors providing navigational information, majority of connected navigation bridge equipment provide with additional information. Besides the equipment, variety of databases provide with navigational and non-navigational information, such as tide tables, list of lights and other essential navigational publications. Apart from databases, additional software enables additional functionalities and possibilities, such as datum transformation, playback functions, functions related to charts (installation, update, purchase reports etc.). However, the primary system task is voyage appraisal, planning, execution and the monitoring of the vessel's progress. i.e. navigation.

Apart from system and data issues [1, 6, 7] recognized through years, the emphasis has been given on differences between ECDIS models. Although all approved systems meet Performance Standards defined in both system-related resolutions [2, 8], several dozen, approved models can be found on the global market (Table 1). Each system is characterised by its own features and handling principles, which, to a greater or lesser extent, differ from others. The mentioned can reflect negatively on the sole operation with the system, besides the defined ECDIS Education and Training (EET). The ECDIS Generic Training (EGT) is conceived as to ensure that navigators understand the system in the context of navigation, and to operate the system safely [1]. The ECDIS Equipment Specific Training (EST) refers to specific equipment. The EST emerged as a response to large number of ECDIS equipment from variety of manufacturers, where, apart the fulfilment of IMO Performance Standards, systems and their usage differ to a greater or lesser extent. This training remains the responsibility of a particular company [12, 13, 14]. The EST represents an industry standard, rather than formal regulation. The equipment specific training should ensure that the navigator improves its knowledge and especially skills, usage and handling with a specific, approved ECDIS model. Considering beforementioned variety of system models, the conduction of EST courses differs accordingly. Unlike the generic training, the EST can take form of a regular course, a ship-specific familiarisation, a computer-based training and cascade training [15], and it is less standardised than the EGT, referring, among other, to discrepancies in official existing requirements, training duration and means of conducting, etc. [16]. Regulated by IMO, ISM and STCW, both trainings are basic, and they refer primarily to existing and future navigational ranks. Also, both represent one-time training, with no further need for improvements in accordance in pace with technology, new features etc. Moreover, they are oriented towards the navigational rank in general, not the specific rank onboard. There is more system-related training designed for the other ECDIS stakeholders, with a different perspective and aspect. There is additional training referring to the further improvements and knowledge on the system, however those training is not mandatory and regulated as EGT and EST, and their achievement mostly depends on the individual rank.

Considering all above-mentioned statements and observations, a need for elaboration of different

ECDIS models as seen from the end-users int of view appears. The following chapter represents a research design description covering the whole research, after which this specific segment is introduced, referring to survey on different (and most frequent) models. The main features and system tasks were analysed within the handling with the system. Results are presented and discussed in the following chapter. The main findings are presented in the conclusion chapter, with possible guidelines for the continuation of the research.

## 2 THE RESEARCH DESIGN

### 2.1 *General features of the research methodology*

This research segment is based on ECDIS Concept Development (ECDIS CoDe) for increasing navigation safety and environment protection. The ECDIS CoDe relies on the previous research educational-scientific project ECDIS Experience, Handling and Opinion (ECDIS EHO), to which the Human-Machine Interface (HMI) segment followed. Previous achievements within the research [16, 17, 18, 19, 20, 21, 22, 23] have given the significant contribution considering growing changes in development of maritime technologies, especially in Maritime Education and Training (MET) referring to navigational information systems. Apart from mentioned, the previous research and respective results established a basis towards further development of concepts and capabilities of navigational information systems [24, 25, 26]. The wholesome research design is presented in Figure 2.

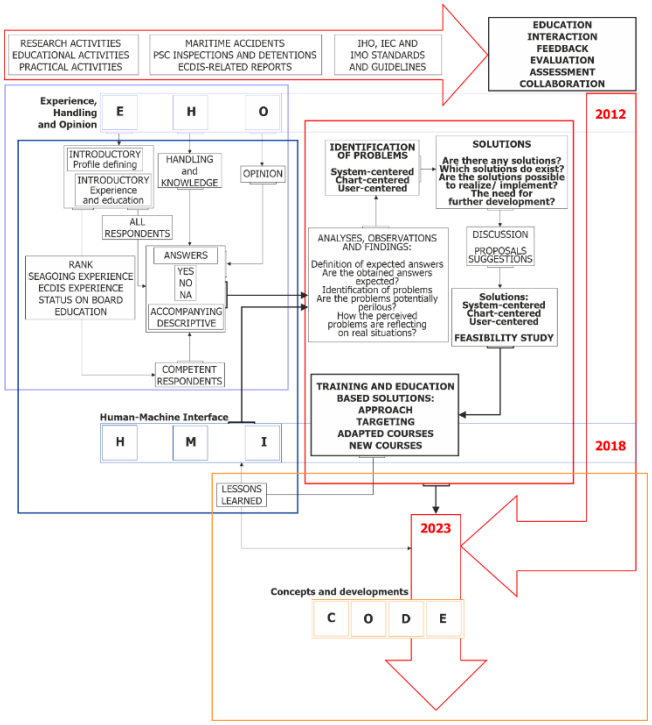


Figure 2. The general research methodology design with emphasis on the ECDIS CODE segment

The ECDIS CoDe research continuation refers to new electronic navigation information systems that nowadays have fundamentally replaced traditional navigational equipment. Navigational means have been changed due to complete use of ECDIS system as primary means of navigation together with marking of new navigational era approach. Possibilities of educational process improvements, but also potential safety risks and dangers resulting from improper handling with the system and insufficient knowledge were recognized. Furthermore, the ECDIS CoDe is a concept-based development project aiming to improve navigational safety and environmental protection through the development of new ECDIS main system functionalities: enhanced voyage planning and voyage monitoring together with development ECDIS system itself. In other words, the research purpose is based on innovative ECDIS concept development and system capabilities through the Integration Navigation System (INS) improvement. The initial step of ECDIS system concept development begins with ECDIS end-users and their system experience, handling level together with concrete opinion regarding improvement. The aim of this study is to determine navigators' response in ECDIS comparison of different manufacturer models to identify pros and cons of specific tasks, features and other navigational functions.

### 2.2 *ECDIS CoDe*

The research model of the ECDIS CoDe Methodology is based on international questionnaire distributed after ECDIS courses, through shipping companies and directly to international seafarers worldwide. The data were collected from the period from 2018 to 2022. In this research, the introductory questions have elaborated the respondents' navigational rank, seagoing and ECDIS experience, and status on board regarding ECDIS mandatory carriage requirements. These questions have been used to define the end-users' profiles which are participated in the international questionnaire. Furthermore, the following questions have been used in the research:

- State the ECDIS Manufacturer and model? (Abbreviated further as Q1)
- State the level of ECDIS usability for voyage planning with answer explanation? (Abbreviated further as Q2)
- State the level of ECDIS usability for voyage monitoring with answer explanation? (Abbreviated further as Q3)
- State the Level of ECDIS usability for manual corrections with answer explanation (daily e.g. Navtex corrections)? (Abbreviated further as Q4)
- State the Level of ECDIS usability for weekly manual corrections (e.g., ENC update)? (Abbreviated further as Q5)
- State the level of ECDIS usability for working with the chart (display category) with answer explanation? (Abbreviated further as Q6)
- State the level of ECDIS usability for working with the ECDIS display (e.g., moving cursor on the display) with answer explanation? (Abbreviated further as Q7)
- State the level of ECDIS usability for Line of position (LOP) with answer explanation? (Abbreviated further as Q8)
- State the level of ECDIS usability for additional information (e.g. communication and NO GO AREA) with answer explanation? (Abbreviated further as Q9)

The questions from Q2 to Q9 were analysed for the different ECDIS manufacturer from the collected international questionnaire results. The level of usability is presented in the rating scale from 1 to 5 as follows:

- 1 – very difficult to use,
- 2 – difficult to use,
- 3 – moderate to use,
- 4 – easy to use,
- 5 – very easy to use.

Besides the scale answers, a description answers have been introduced and elaborated in the results chapter.

## 3 RESULTS

As to date present, the international questionnaire was fulfilled by 187 respondents. After first filtering and excluding the respondents which are not directly related to the ECDIS system and carriage requirements on-board vessel, total number is 159 of active ECDIS end-users: 45 Masters, 39 Chief Officers (1st Officer), 45 Second Officers (2nd Officer), 27 Third Officers (3rd Officer), and 3 Others (2 Deck Cadets and 1 Superintendent). The ECDIS CoDe survey respondents is presented in the following Figure.

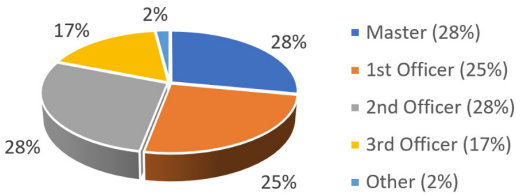


Figure 3. ECDIS CoDe survey respondents

Additionally, respondents with seagoing experience (in years) ranges from 0.4 (Deck Cadet) to 32 years (Master), with the mean value of 8.77 and standard deviation of 14 years. The respondents with ECDIS working experience is presented in the following Figure.

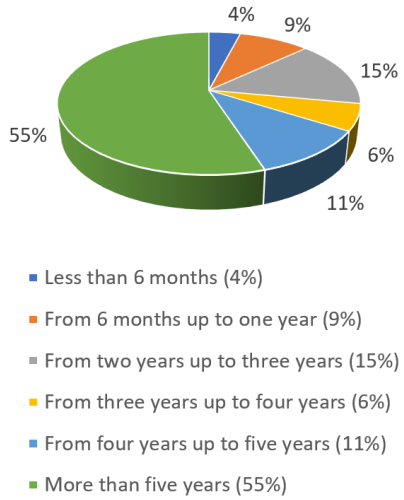


Figure 4 Survey respondents with ECDIS working experience

Eventually, more than half of the ECDIS CoDe survey respondents have ECDIS working experience onboard vessel. After defining the end-users' profiles which are participated in the international questionnaire, the following cornerstone questions were elaborated. The share of answer on question Q1 is presented in the following Figure and Table, respectively.

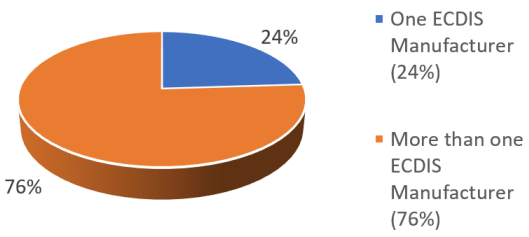


Figure 5. Share of respondents

Among all the survey respondents with ECDIS working experience, 76 % has a working experience on more than one ECDIS model. These results classification is desirable when comparing several ECDIS manufacturer models. The following table represents the results regarding different ECDIS manufacturers and models stated in the international survey.

Table 2 ECDIS Manufacturers and models considering Q1

| ECDIS Manufacturer | Respondents |
|---|---|
| Furuno (FMD 3300) | 61 |
| JRC (JAN-9201) | 43 |
| Transas -Wärtsilä (Navi-Sailor 4000) | 39 |
| Kongsberg (K-Bridge) | 24 |
| Sam Electronics - Wärtsilä NACOS Platinum | 22 |
| Sperry (VisionMaster Sperry Marine) | 24 |
| Other | 19 |

According to the survey results, participants mostly dealing with Furuno, JRC and Transas - Wärtsilä (Navi-Sailor 4000). ECDIS Manufacturers with less than 10 participants in survey participation ware not observed for this research (stated as Other). Other ECDIS manufacturers which are noticed in the survey results are MARIS, Kelvin Hughes, Raytheon Anschütz and Chartworld.

### 3.1 *Survey results for ECDIS manufacturer Furuno (FMD 3300)*

According to the survey results, ECDIS manufacturer Furuno (FMD 3300) has 61 respondents. The results are presented in the following Figure.

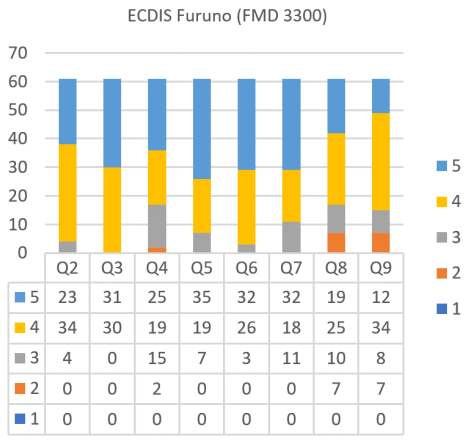


Figure 6. End-user results regarding ECDIS Furuno handling

Additionally, by analysing the survey results in the following table the Average value and Mode for the ECDIS Furuno is presented.

Table 3. Average value and Mode from survey results for the ECDIS Furuno

| Furuno | Q2 | Q3 | Q4 | Q5 | Q6 | Q7 | Q8 | Q9 |
|---|---|---|---|---|---|---|---|---|
| Average value | 4.31 | 4.51 | 4.10 | 4.46 | 4.48 | 4.34 | 3.92 | 3.84 |
| Mode | 4 | 5 | 5 | 5 | 5 | 5 | 4 | 4 |

According to the end-user results, ECDIS Furuno is very user-friendly ECDIS manufacturer for handling. The best function according to the usability is based on one of the primary ECDIS function: voyage monitoring (Q3), then weekly corrections related to the ENC updating together with Admiralty Information Overlay - AIO (Q5) and working with the ENC chart for adjusting safety parameters and display category (Q6). Additional information or User charts regarding Navigational and communicational additional information (e.g., NO GO AREA) is in category Easy to use while in other models this function is higher rated according to the participants result. The overall average value for this model is 4.24.

### 3.2 *Survey results for ECDIS manufacturer JRC (JAN-9201)*

According to the survey results, ECDIS manufacturer JRC (JAN-9201) has 43 respondents. The results are presented in the following Figure.

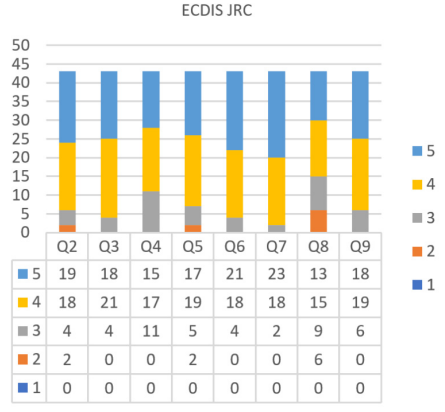


Figure 7. End-user results regarding ECDIS JRC handling

Additionally, by analysing the survey results in the following table the Average value and Mode for the ECDIS JRC (JAN-9201) is presented.

Table 4. Average value and Mode from survey results for the ECDIS JRC

| JRC | Q2 | Q3 | Q4 | Q5 | Q6 | Q7 | Q8 | Q9 |
|---|---|---|---|---|---|---|---|---|
| Average value | 4.26 | 4.33 | 4.09 | 4.19 | 4.40 | 4.49 | 3.81 | 4.28 |
| Mode | 5 | 4 | 4 | 4 | 5 | 5 | 4 | 4 |

According to the end-user results, ECDIS JRC is also one of the user-friendly ECDIS manufacturer for handling. The best function according to the usability is based on working with ECDIS display (Q7) (moving cursor on the ENC Chart and main Menu) together with easy access to the required position with ETA calculation. Also, working with the ENC chart for adjusting safety parameters and display category (Q6) has a high rate. LOP category (Q8) is in lower usability category Easy to use while in other models this function is more rated according to the participants result. According to the participants comments in the survey, LOP function has a few more unnecessary clicks in this system. The overall average value for this ECDIS manufacturer model is 4.23.

### 3.3 *Survey results for ECDIS manufacturer ECDIS Wärtsilä Transas Navi-Sailor 4000*

According to the survey results, ECDIS manufacturer ECDIS Wärtsilä Transas Navi-Sailor 4000 has 39 respondents. The results are presented in the following Figure.

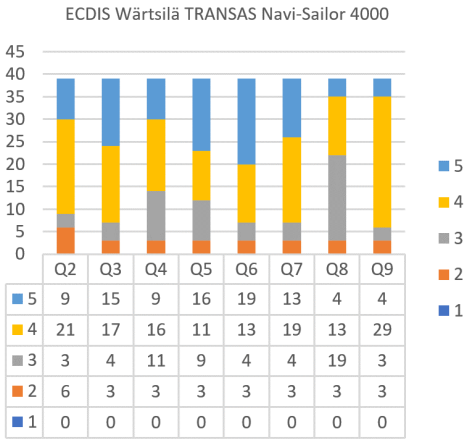


Figure 8. End-user results regarding ECDIS Wärtsilä Transas Navi-Sailor 4000

Additionally, by analysing the survey results in the following table the Average value and Mode for the ECDIS Wärtsilä Transas Navi-Sailor 4000 is presented.

Table 5. Average value and Mode from survey results for the ECDIS Wärtsilä Transas Navi-Sailor 4000

| Wärtsilä Transas | Q2 | Q3 | Q4 | Q5 | Q6 | Q7 | Q8 | Q9 |
|---|---|---|---|---|---|---|---|---|
| Average value | 3.85 | 4.13 | 3.79 | 4.03 | 4.23 | 4.08 | 3.46 | 3.87 |
| Mode | 4 | 4 | 4 | 5 | 5 | 4 | 3 | 4 |

According to the end-user results, ECDIS Wärtsilä Transas Navi-Sailor 4000 is not in the top class regarding level of usability. Mainly, improvement should be considered regarding Line of Position for manually position fixing (Q8). Due to complexity, for determine manually fix position more time and accuracy is needed especially for younger end-users. Furthermore, lower rate of usability is noted regarding manual corrections (Q4). The manual correction complexity is noted for Navtex corrections and Temporary and Preliminary Notices (T&Ps). According to the survey results the main strength lies in ECDIS usability for working with the ENC chart and safety parameters adjustment (Q6). The overall average value for this ECDIS manufacturer model is 3.93.

### 3.4 *Survey results for ECDIS manufacturer Kongsberg*

According to the survey results, ECDIS manufacturer Kongsberg has 24 respondents. The results are presented in the following Figure.

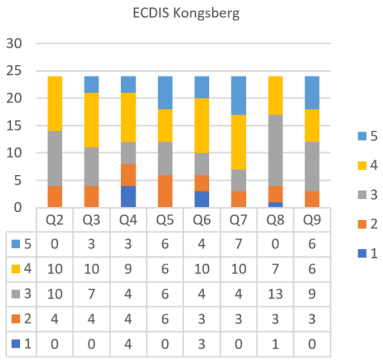


Figure 9. End-user results regarding ECDIS Kongsberg

Additionally, by analysing the survey results in the following table the Average value and Mode for the ECDIS Kongsberg is presented.

Table 6. Average value and Mode from survey results for the ECDIS Kongsberg

| Kongsberg | Q2 | Q3 | Q4 | Q5 | Q6 | Q7 | Q8 | Q9 |
|---|---|---|---|---|---|---|---|---|
| Average value | 3.25 | 3.50 | 3.13 | 3.50 | 3.38 | 3.88 | 3.08 | 3.63 |
| Mode | 3-4 | 4 | 4 | 2-5 | 4 | 4 | 3 | 3 |

According to the survey results, ECDIS Kongsberg has a lower level of general usability. In other words, the manufacturer system is not user-friendly regarding usage interface organisation which consists of too many textboxes. According to the end-users this unintuitive system demands additional attention and practice for smooth handling. Furthermore, lower rate of usability is noted regarding Line of Position for manually position fixing (Q8). Also, significant complexity in system handling is related to the ECDIS usability for manual corrections (Q4). The overall average value for this ECDIS manufacturer model is 3.42.

### 3.5 *Survey results for ECDIS manufacturer Wärtsilä SAM Platinum*

According to the survey results, ECDIS manufacturer Wärtsilä SAM Platinum has 22 respondents. The results are presented in the following Figure.

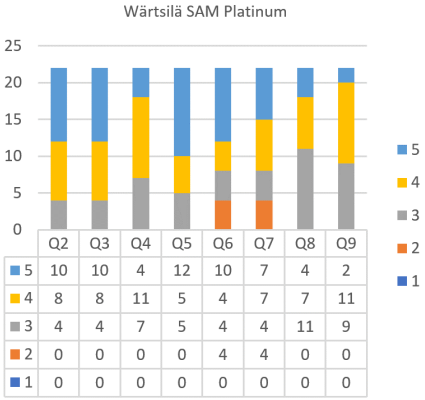


Figure 10. End-user results regarding ECDIS Wärtsilä SAM Platinum

Additionally, by analysing the survey results in the following table the Average value and Mode for the Wärtsilä SAM Platinum is presented.

Table 7. Average value and Mode from survey results for the ECDIS Wärtsilä SAM Platinum

| Wärtsilä SAM | Q2 | Q3 | Q4 | Q5 | Q6 | Q7 | Q8 | Q9 |
|---|---|---|---|---|---|---|---|---|
| Average value | 4.27 | 4.27 | 3.86 | 4.32 | 3.91 | 3.77 | 3.68 | 3.68 |
| Mode | 5 | 5 | 4 | 5 | 5 | 5-4 | 3 | 4 |

According to the survey results, ECDIS Wärtsilä SAM Platinum is not in the top-class regarding level of usability. Mainly, improvement should be considered regarding Line of Position for manually position fixing (Q8) and additional information or User charts (Q9) regarding navigational and communicational additional information (e.g., NO GO AREA). Also, the complexity is noted when plotting Navtex corrections on the ENC chart. Also, the survey results show that the main strength lies in ECDIS usability for weekly manual corrections (Q5) (e.g., ENC update). Furthermore, ECDIS main function, i.e. voyage planning is also user-friendly for handling and leading navigation. The overall average value for this ECDIS manufacturer model is 3.97.

### 3.6 *Survey results for ECDIS manufacturer VisionMaster Sperry Marine*

According to the survey results, ECDIS manufacturer VisionMaster Sperry Marine has 24 respondents. The results are presented in the following Figure.

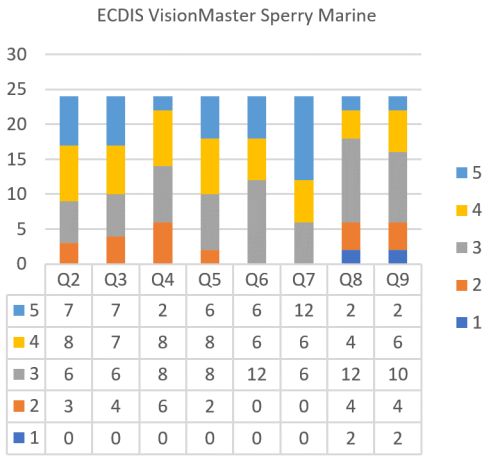


Figure 11. End-user results regarding ECDIS VisionMaster Sperry Marine

Additionally, by analysing the survey results in the following table the Average value and Mode for the Wärtsilä SAM Platinum is presented.

Table 8. Average value and Mode from survey results for the ECDIS VisionMaster Sperry Marine

| Sperry Marine | Q2 | Q3 | Q4 | Q5 | Q6 | Q7 | Q8 | Q9 |
|---|---|---|---|---|---|---|---|---|
| Average value | 3.79 | 3.71 | 3.25 | 3.75 | 3.75 | 4.25 | 3.00 | 3.08 |
| Mode | 4 | 5-4 | 3-4 | 3-4 | 3 | 5 | 3 | 3 |

According to the survey results, ECDIS VisionMaster Sperry Marine has a lower level of general usability. Mainly, improvement should be considered regarding Line of Position for manually position fixing (Q8) and additional information or User charts (Q9) regarding navigational and communicational additional information (e.g., NO GO AREA). Furthermore, the ECDIS main display and interface organisation represent a high level of usability for end-users. The overall average value for this ECDIS manufacturer model is 3.57.

## 4 CUMULATIVE RESULTS AND DISCUSSION

The survey analysis shows pros and cons of each manufacturer ECDIS system through the statistical Average value. The following table shows the cumulative results, the manufacturers comparison, regarding established questions in the survey (Q2-Q9). These results also represent a concept development through different manufacturer model's comparison.

Table 9. Average value of ECDIS Manufacturers regarding survey question analysis

| ECDIS manufacturer | F | J | T | K | SA | Sp |
|---|---|---|---|---|---|---|
| Q2 (Voyage planning) | 4.31 | 4.26 | 3.85 | 3.25 | 4.27 | 3.79 |
| Q3 (Voyage monitoring) | 4.51 | 4.33 | 4.13 | 3.50 | 4.27 | 3.71 |
| Q4 (Manual corrections – Navtex) | 4.10 | 4.09 | 3.79 | 3.13 | 3.86 | 3.25 |
| Q5 (Weekly corrections – ENC update) | 4.46 | 4.19 | 4.03 | 3.50 | 4.32 | 3.75 |
| Q6 (chart settings and display category) | 4.48 | 4.40 | 4.23 | 3.38 | 3.91 | 3.75 |
| Q7 (ECDIS display with interface) | 4.34 | 4.49 | 4.08 | 3.88 | 3.77 | 4.25 |
| Q8 (LOP) | 3.92 | 3.81 | 3.46 | 3.08 | 3.68 | 3.00 |
| Q9 (additional information's/ user charts) | 3.84 | 4.28 | 3.87 | 3.63 | 3.68 | 3.08 |
| Average value | 4.24 | 4.23 | 3.93 | 3.42 | 3.97 | 3.57 |

F – Furuno, J – JRC, T – Transas, K – Kongsberg, SA – SAM, Sp – Sperry

According to the survey question analysis and average value regarding usability level for different ECDIS manufacturer, the list is as follows:

13. Furuno (FMD 3300) – AVG 4.24,
14. JRC (JAN-9201) – AVG 4.23,
15. SAM ELECTRONICS - Wärtsilä NACOS Platinum – 3.97,
16. Transas -Wärtsilä (Navi-Sailor 4000) – 3.93,
17. Sperry (VisionMaster Sperry Marine) – 3.57,
18. Kongsberg (K-Bridge) – 3.42.

From statistical point of view, all six ECDIS manufacturers have usability value more than average. However, first stage level of usability according to the end-user's survey results refer to Furuno and JRC, second stage level of usability refer to SAM ELECTRONICS and Transas, and third stage level of usability refer to Sperry and Kongsberg.

Furthermore, ECDIS Furuno has the first stage level of usability mostly in all survey questions (categories). The result of average value is lower only regarding ECDIS display with interface and textbox organisation (Q7), and additional information's/user charts usability for communicational and navigational additional information (Q9). However, ECDIS manufacturer JRC has these two questions (categories) in a first level of usability. Consequently, the ideal system from the end-user's perspective is a merge between the Furuno and JRC.

## 5 CONCLUSION

The ECDIS system greatly facilitated maritime navigation and had a significant impact on improving the safety, reliability and efficiency of navigation. Due to its exceptional features, today's navigators make faster, more accurate and more precise decisions that are crucial for safe navigation. However, although the ECDIS system is nowadays primary means of navigation, it should be remembered that it is only a system that is there to help end users (OOWs and masters) in making correct and timely decisions, but not to replace them. Therefore, it is extremely important that each ECDIS end-user is familiar with the ECDIS system, with sufficient knowledge, proper

training level and adequate skill for timely and correctly actions.

The survey results created an ideal system from the end-user's perspective which is an ECDIS system merge between the Furuno and JRC. These results also represent a concept development through different manufacturer model's comparison. For future development, proper configuration of ECDIS could standardise functions and display considering different types, and undoubtedly resolve a problematic issue as a consequence of numerous ECDIS models and their diversities.

To remain competitive, an ECDIS system manufacturers constantly expand their system, without concerning that the system is already congested with additional options, applications, and features, which half of them are very rare used. This leads to unnecessary handling difficulties for the end-user at sea. Furthermore, instead of adding new options, ECDIS manufacturers should focus on improving primary functions which are necessary and every day in use.

## ACKNOWLEDGEMENTS

This study has been financially supported by the University of Rijeka under the Faculty of Maritime Studies projects. Authors are grateful to all the officers of the navigational watch for their time and willingness for the fulfilment of the survey, discussions and their opinions. Authors believe that their answers have an immense significance for the appropriateness of the research deliverables. Additionally, congratulations to a wonderful friend and colleague David and his beloving Barbara. May the years ahead be filled with lasting joy!

## REFERENCES

[1] International Maritime Organization (IMO), 2017. MSC.1/Circ.1503 Rev.1: ECDIS – Guidance for good practice. London: IMO.

[2] International Maritime Organization (IMO), 2006. MSC.232(82): Adoption of the revised performance standards for Electronic Chart Display and Information Systems (ECDIS). London: IMO.

[3] Weintrit, A., 2009. The Electronic Chart Display and Information System (ECDIS): An Operational Handbook. London: CRC Press.

[4] Weintrit, A. 2018a. Accuracy of bathymetric data in electronic navigational charts. Sci. J. Marit. Univ. Szczec. 55 (127), 60-69. doi: 10.17402/302

[5] International Hydrographic Organization (IHO), 1997. Glossary of ECDIS-related terms. Ed. 3.0. Monaco: IHO.

[6] Weintrit, A., Stawicki, K., 2008. Operational requirements for Electronic Chart Display and Information Systems (ECDIS). Risk of overreliance on ECDIS. Transp. Probl. 3 (2), 67 - 74.

[7] International Hydrographic Organization (IHO), 2014. IHO Report on the Results of the ECDIS Survey Conducted by BIMCO and Denmark. Monaco: IHO.

[8] International Maritime Organization (IMO), 1995. A.817(19): Performance standards for Electronic Chart Display and Information Systems (ECDIS). London: IMO.

[9] eMaritime Group (2021). Approved ECDIS systems. Available online: http://www.ecdisregs.com/approved-ecdis-systems/, accessed 2 February 2022.

[10] International Maritime Organization (IMO), 2010. International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW), with amendments. London: IMO.

[11] International Maritime Organization (IMO), 2012. MC 1.27: Operational use of Electronic Chart Display and Information System. London: IMO.

[12] International Maritime Organization (IMO), 2017. STCW.7/Circ.24: Guidance for Parties, Administrations, Port State control authorities, recognized organizations and other relevant parties on the requirements of the STCW Convention, 1978, as amended. London: IMO.

[13] Weintrit, A., Kopacz, P., Bak, A., Uriasz, J., Naus, K., 2012. Polish approach to the IMO Model Course 1.27 on operational use of ECDIS. Annu. Navig. 19(2), pp. 155-170.

[14] International Maritime Organization (IMO), 2016. The International Safety Management (ISM) Code. London: IMO.

[15] Brčić, D., Žuškin, S., Valčić, S., Rudan, I., 2019. ECDIS transitional period completion: Analyses, observations and findings. WMU J. Marit. Aff 18 (2), 359-377. doi: 10.1007/s13437-019-00173-z

[16] Car, M,. Tominac Coslovich, S., Brčić, D., Žuškin, S., 2021. Cross section of ECDIS education and training worldwide and in the Republic of Croatia: Relations between programs and user perceptions. TransNav Int. J. Mar. Navig. Saf. Sea Transp. 9 (3), 317-326. (in press)

[17] Car, M., Vujičić, S., Žuškin, S., Brčić, D., 2019. Human Machine Interface: Interaction of OOWs with the ECDIS system. In: Proceedings of the 1st International Conference of Maritime Science & Technology – Naše More 2019. UNIDU. pp. 74-85.

[18] Brčić, D., Žuškin, S., 2018. Towards paperless vessels: A Master's perspective. Journal of Maritime & Transportation Sciences 55 (1), 183-199. doi: 10.18048/2018.00.12

[19] Brčić, D., Kos, S., Žuškin, S., 2016. Partial structural analysis of the ECDIS EHO research: The handling part. In: Proceedings of the 24nd International Symposium on Electronics in Transport. ISEP. 8 p.

[20] Žuškin, S., Brčić, D., Kos, S., 2016. Partial structural analysis of the ECDIS EHO research: The safety contour. In: Proceedings of 7th International Conference on Maritime Transport. UPC. pp. 246-262.

[21] Šakan, D., Žuškin, S., Brčić, D., Valčić, S., 2019. Analysis of Primary Position Validation in ECDIS system. In: Advances in Marine Navigation and Safety of Sea Transportation: Proceedings of 13th International Conference on Marine Navigation and Safety of Sea Transportation. Leiden: CRC Press. pp. 5-15.

[22] Brčić, D., Kos, S., Žuškin, S., 2015. Navigation with ECDIS: Choosing the proper secondary positioning source. TransNav Int. J. Mar. Navig. Saf. Sea Transp. 9 (3), 317–326. doi: 10.12716/1001.09.03.03

[23] Car, M., Brčić, D., Žuškin, S., Svilicic, B., 2020. The Navigator's Aspect of PNC Before and After the ECDIS Implementation: Facts and Possible Implications Towards Navigation Safety Improvement. J. Mar. Sci. Eng. 8 (11), 842, 12 p. doi: 10.3390/jmse8110842

[24] Kristić, M., Žuškin, S., Brčić, D., Valčić, S., 2020. Zone of Confidence Impact on Cross Track Limit Determination in ECDIS Passage Planning. J. Mar. Sci. Eng. 8 (8), 566, 12 p. doi: 10.3390/jmse8080566

[25] Kristić, M., Žuškin, S., Brčić, D. & Car, M. (2021). The partial analysis of the ECDIS EHO research: The Port State Control. Nase more 68 (2), 93-101. doi: 10.17818/NM/2021/2.5

[26] Žuškin S., Brčić D., Valčić S., 2017. ECDIS Possibilities for BWE Adoption. TransNav Int. J. Mar. Navig. Saf. Sea Transp. 11 (3), 477-482. doi:10.12716/1001.11.03.13