Research Article

The effect of the developing and changing electronic bridge equipment and electronic navigation charts on intelligent maritime transportation systems

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Abstract: It is seen that high technology and its products work to meet every stage and need of human life and navigational safety in the maritime sector. Electronic systems have been developed and are used today as a result of the search for alternatives to the well-known and approved classical methods used in safe navigation on the world's seas. Electronic systems are susceptible and more accurate than classical methods and significantly benefit maritime transport. Bridge electronic systems and infrastructures supporting its components also work with advanced technology products. In this context, electronic navigational charts - ENC, Electronic Chart Display Information systems - ECDIS and Automatic Information systems - AIS are undoubtedly the best examples. These and similar bridge and auxiliary devices ensure the safety of navigation on both national and international seas and oceans and cause a decrease in human error rates. This study mentions the positive effects of high-tech bridge navigation systems developed in the maritime sector on maritime transportation.

Key words: Maritime Transportation, S-57, ECDIS, Strategy of Maritime Management, Intelligent Maritime Transportation Systems.

Gelişen ve değişen elektronik köprüüstü ekipmanları ve elektronik seyir haritalarının akıllı deniz ulaşım sistemlerine etkisi

Özet: Denizcilik sektöründe yüksek teknoloji ve ürünlerinin insan yaşamının ve seyir güvenliğinin her aşamasını ve ihtiyacını karşılamak için çalıştığı görülmektedir. Elektronik sistemler, dünya denizlerinde güvenli seyirde kullanılan, bilinen ve onaylanmış klasik yöntemlere alternatif arayışları sonucunda geliştirilmiş ve günümüzde kullanılmaktadır. Elektronik sistemler, klasik yöntemlerden daha hassas ve güvenlirdir.Deniz taşımacılığına önemli ölçüde fayda sağlar. Köprüüstü elektronik sistemleri ve bileşenlerini destekleyen altyapılar da ileri teknoloji ürünlerle çalışmaktadır. Bu kapsamda elektronik seyir haritaları - ESH, Elektronik Harita Görüntüleme Bilgilendirme sistemleri - EHGBS ve Otomatik Bilgilendirme sistemleri - AIS şüphesiz en iyi örneklerdir. Bu ve benzeri köprüüstü ve yardımcı cihazlar hem ulusal hem de uluslararası denizlerde ve okyanuslarda seyir güvenliğini sağlamakta ve insan hata oranlarında azalmaya neden olmaktadır. Bu çalışma, denizcilik sektöründe geliştirilen yüksek teknolojili köprüüstü seyir sistemlerinin deniz taşımacılığına olumlu etkilerinden bahsetmektedir.

Anahtar Kelimeler: Deniz Taşımacılığı, S-57, EHGBS, Denizcilik Yönetimi Stratejisi Akıllı deniz ulaşım sistemleri.

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1. Introduction

It is known by surveys that more than 70% of the earth, which does not have a smooth form, is covered with water. It is known that more than 80% of the earth's population has lived by the sea throughout history and still today. It is known that more than 90% of the transportation activities carried out on earth in order to meet the endless needs of human beings are carried out by sea transportation. As a result of developing and changing technology, maritime transport and maritime transport elements are also affected. Maritime transport is essential in transporting almost all industries, raw materials, and products. Especially for maritime transport, IMO-International Maritime Organization serves the member countries and the world's seas at the stage of what should be the requirements for this purpose, first of all for safety in the seas; provides technical, legal, and educational support in written form.URL1.

Figure 1. *Different types of cargo ships (URL2).*

It has also created and developed the element of trade in the need for transportation due to national and international production and the resulting trade. Since the produced and to be transported cargoes are solid, liquid, gas, living, wheeled, particular types (project cargo) in different types and forms, it has led to the production and use of ship types with different types of warehouse structures. Therefore, the ships should be designed according to the transportation needs and equipped with navigational safety. While the ship has been equipped with safety and security principles since its construction, the critical equipment and devices on the bridge used for dispatch and management are essential for safety during navigation. Many devices of different types and functions work on the bridge for navigational safety. The systems provide maximum benefit to the captain and watchkeeping officers on the bridge in the management and administration and help to minimize the human error rate. Every step taken in maritime is made with laws, regulations, and directives and is used on all seas as a framework (Joseph and Dalaklis,2021), (Pawlovski,2017). Based on these principles, SOLAS-Safety of Life at Sea was first defined in 1974 according to the tonnage of ships (SOLAS,1974). Digital or vector-based chart display and information systems used in electronic navigation systems for ships' management and administration on bridges are essential to increase safety. The charts and nautical publications used are similar to IMO, and IHO International Hydrographic Organization works to produce maps and similar publications for the seas. In this way, charts and similar products are made according to the data obtained from reliable sources with the same standards on the same frame. There are places (natural or artificial) of very different depths and structures where ships/vessels are on the world's seas. These areas are formed by natural and artificial waterways or shallow waters and oceans. There are sea areas such as harbors, wharves, ports, docks, and piers, where ships/vessels load or unload passengers and cargo. However, each area is not at the depth where the ships can dock in the coastal areas, which are the places where the ships will dock/anchor. Depths are changed according to the needs of the ships in places where the depth is known naturally at the beginning. The aim here is definitely to increase the safety level of navigation and the ship's port entry-exit and cargo handling in ports. Despite all the safety, the narrow channel, strait crossings, and port and pier entrances, which should be given operational importance, are among the viewing areas that should be considered. The different lengths and tonnages of the ships can be described as the part of the underwater/sub-water part of the ship, which affects the safety in shallow waters in part called Draft in terminology. It is called the squat effect during the cruise and the instantaneous collapse of the ship (Zhang et al.,2019). This collapse effect has a more significant effect in shallow water and fresh waters, making the water withdrawal larger. National and International Hydrographic Departments, which work following IHO standards, make measurements at sea in order for the ship to navigate safely, but marine sciences should be mentioned here incredibly accurately. Marine Sciences, in general terms, consists of Hydrography (Bathymetry), Oceanography, Meteorology, and the final product, cartography (Usluer and Alkan, 2016).

1.1. Marine Sciences

According to the IHO definition, ***Hydrography (bathymetry)*** is working by applied sciences to survey and define the physical status of oceans, seas, coastal areas, lakes, and rivers. Hence with this survey data, the prediction of water or seas status change over time for the safety of navigation and environmental protection (IHO,2022).

Oceanography definition by NOAA (National Ocean Service-National Oceanic and Atmospheric Administration) Oceanography covers marine life and ecosystems, ocean circulation, plate tectonics and the geology of the seafloor, chemical, and physical properties of the ocean and seas (NOAA,2022). Also, oceanography has some valuable sub-divisions like chemical and physical oceanography, marine biology, etc.

Basically, ***Meteorology*** is the science of the atmosphere. Also, it studies for earth’s atmosphere and components of earth system science with survey temperature, wind, and precipitation that we observe and experience impact, and all are impacted on various scales (Usluer and Alkan, 2016).

Cartography is the transfer of the measurable earth onto the plane understandably and expressively. There are different ways. Today it is divided into two. It is classical, that is, transfer on paper and transfer to plane with digital, that is, electronic materials.

2. Electronic Navigation Systems

Bridge electronic navigation aids used on ships today work to increase the safety level of ships during navigation. The most known and widely used ones are ARPA Radar, Sonar/Echo Sounder, ECDIS, AIS, GNSS, DGPS, LORAN-C, EPIRB, SART, NAVTEX, IBS, and VDR, etc.

3. Electronic Navigation Charts

It has established its internal disciplines, which determine the standards required for producing hydrographic products used in the seas and is used in the national hydrographic offices of the maritime countries.

According to this;
B-Bathymetric Publications (Mainly related to GEBCO).
C-Capacity Building Publications
M-Miscellaneous Publications (including Basic Documents)
P-Periodic Publications
S-Standards and Specifications.

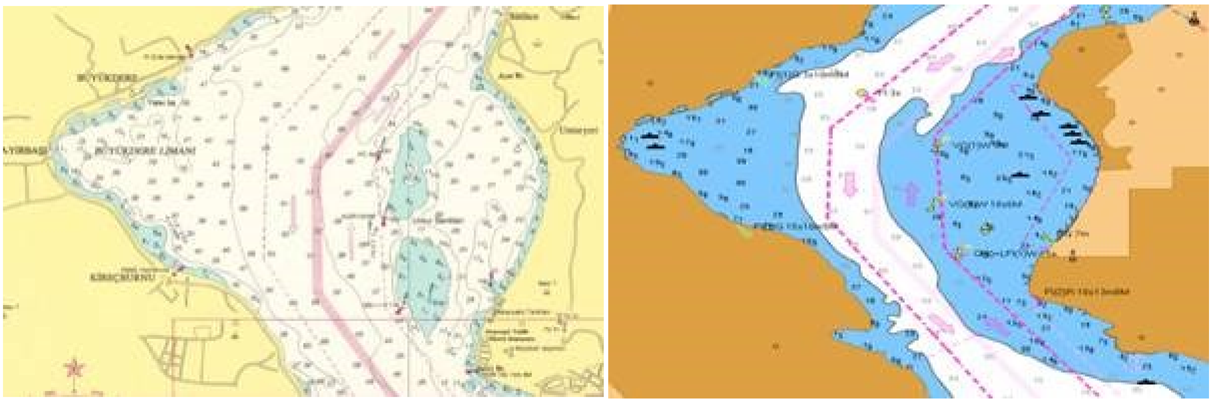
***Table 1**. Hydrographic production standards*

	Descriptions
S-4	Regulations for International (INT) Charts and Chart Specifications of the IHO
S-5A	Standards of C.ompetence for Category "A" Hydrographic Surveyors
S-5B	Standards of Competence for Category "B" Hydrographic Surveyors
S-8A	Standards of Competence for Category "A" Nautical Cartographers
S-8B	Standards of Competence for Category "B" Nautical Cartographers
S-11	Guidance for the Prep. and Maint. of Int.(INT) Chart and ENC Sch. and Cat. of INT Charts
S-12	Standardization of List of Lights and Fog Signals (June 2004 - Corrections to June 2006)
S-23	Limits of Oceans and Seas (1953). Sheet maps 1, 2 and 3
S-32	Hydrographic Dictionary
S-44	IHO Standards for Hydrographic Surveys
S-49	Standardization of Mariners' Routeing Guides
S-52	Specifications for Chart Content and Display Aspects of ECDIS
S-53	Joint IMO/IHO/WMO Manual on Maritime Safety Information
S-57	IHO Transfer Standard for Digital Hydrographic Data
S-58	ENC Validation Checks
S-60	User´s Handbook on Datum Transformations involving WGS 84
S-61	Product Specification for Raster Navigational Charts (RNC)
S-62	List of IHO Data Producer Codes
S-63	IHO Data Protection Scheme
S-64	IHO Test Data Sets for ECDIS
S-65	ENCs: Production, Maintenance and Distribution Guidance
S-66	Facts about Electronic Charts and Carriage Requirements
S-67	Mariners' Guide to Accuracy of Depth Information in Electronic Navigational Charts (ENC)
S-97	IHO Guidelines for Creating S-100 Product Specifications
S-99	Operational Procedures for the Org. and Managem of the S-100 Geospatial Inf. Registry
S-100	IHO Universal Hydrographic Data Model - S-100 based Product Specifications
S-101	ENC Product Specification
S-102	Bathymetric Surface Product Specification
S-111	Surface Currents Product Specification
S-121	Maritime Limits and Boundaries Product Specification
S-122	Marine Protected Areas
S-123	Marine Radio Services
S-127	Marine Traffic Management
S-129	Under Keel Clearance Management

S codes show all standards. The standards that should be emphasized and known on the digitalized bridge are primarily s-52, s-57, s-63, and s-100.

3.1. S-52 Definitions

According to IHO definitions, S-52 provides specifications and guidance regarding issuing and updating Electronic Navigational Charts (ENC) and their display in ECDIS. Basically and primarily, paper chart data could use transformed to ENC.



Paper Chart ENC

Figure 2. *The same area shows both on paper and ENC (SHODB,2022).*

3.2. S-57 Definitions

S-57 is the standard of the data format used to transfer vector and digital hydrographic data between hydrographic offices. So it takes the chance for distribution to manufacturers, mariners, and other data users. By S-57 ENC production meeting these specifications, hydrographic offices will ensure that all electronic charts contain all the chart information that is necessary for safe navigation.

3.3. S-63 Definitions

According to the IHO definitions, S-63 describes the recommended standard for protecting ENC information. Also, S-63 defines security constructs and operating procedures. S-63 standard covers three essential areas Piracy protection, Selective Access, and Authentication. It could help prevent unauthorized use of data by encrypting the ENC information, restricting access to ENC information to only those cells that a customer has been licensed for, and providing assurance that the ENC data has come from approved sources (Admiralty,2022).

3.4. S-100 Definitions

By IHO definition; The S-100 Standard is being a framework document that is intended for the development of digital products and services for hydrographic, maritime, and GIS communities. Also, S-100 comprises multiple parts that are based on the geospatial standards developed (IHO,2022). The S-100 provides an advanced hydrographic geospatial data standard capable of supporting hydrographic digital data and sources. It reinforces this principle with international standardization; mainly, it is fully compatible with ISO-19100 series geospatial standards. Its main goal is to support a wide range of digital data sources, products, and customers related to hydrography. Thus, high-density bathymetry, seafloor classification, marine GIS, etc. It enables the development such as new applications (URL4).

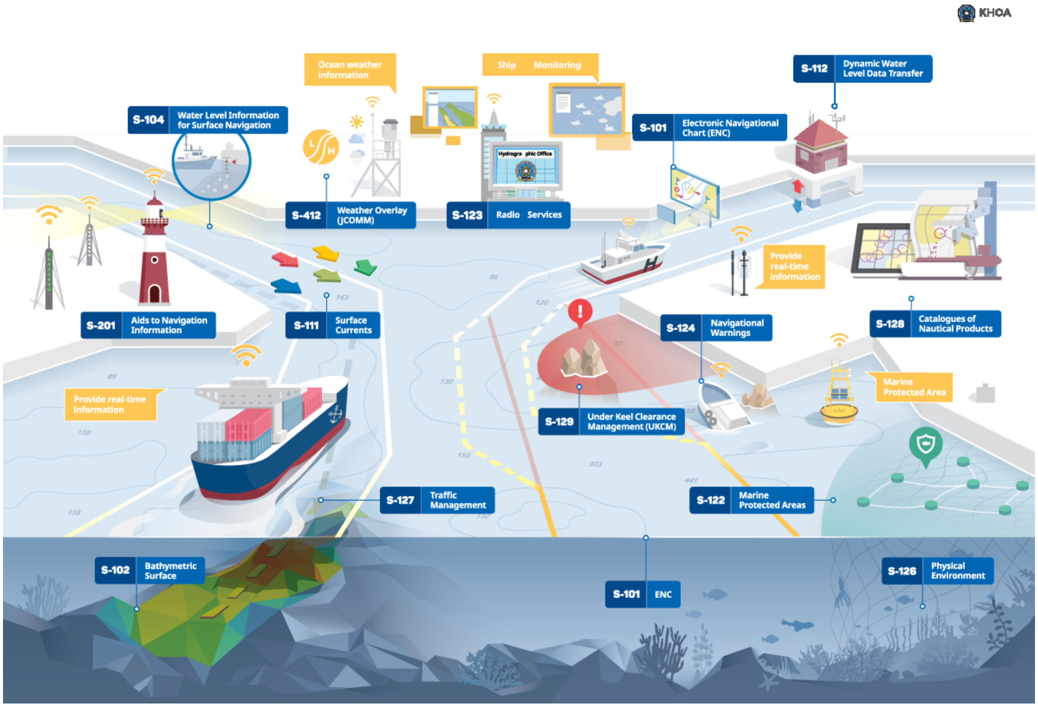


Figure 3.S-100 and sub information circle (IHO,2022).

4. Electronic Navigation Charts on developing Bridge

According to the IHO's e-navigation definition, the harmonized data collection, integration, data exchange, all kind of productions presentation, and real-time analysis of navigational/marine information about the vessel onboard and ashore by electronic means to enhance berth to berth navigation and related services for navigational safety and both seafarers and vessel security at sea and protection of the marine environment.

Figure 4. *New design and high-tech bridge systems (URL5).*

The bridge, which is equipped with changing and developing technology products, affects the officer on the watch and the ship's safety at a high level. On the other hand, E-Navigation combines and operates integrated high-tech navigation aids.

Thus, the rate of human error is reduced, the safety level of navigation increases, and it causes more reliable movement at sea and in port periods. Today's technology allows navigation by combining unmanned marine vessels with e-navigation and equipment. An IMO initiative designed and launched in 2005 to increase navigational safety, e-navigation, onboard navigation systems, Shoreside vessel traffic information management, Ship-to-ship-, ship-to-shore, and shore-to-shore communication infrastructure. It designs and implements progress in three key areas (Burmeister et.al,2014).

The ECDIS device used for E-Navigation, on the other hand, allows the watchkeeping officer who is on the watching shift on the bridge to use the ENC operating in a vector base and logic approved by the manufacturer hydrographic offices at a high level of confidence on which all instant data can be displayed for safe navigation. Also, the ENC goes through the stages that can become usable on ships, considering the principles in the diagram in Fig.5 below.

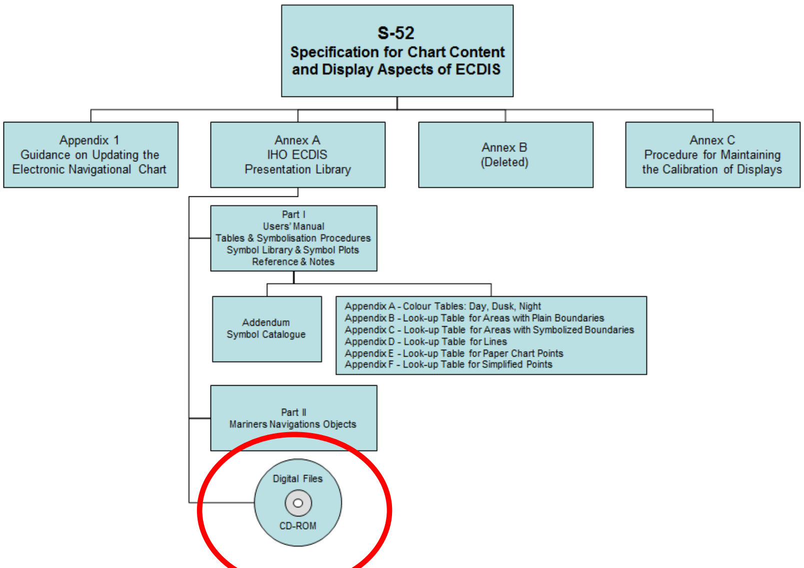


***Figure 5**. Diagram of presentation library usage as a graphic file while producing the ENC.*

Hard-copy ENC maps enclosed in red circles, thanks to their easy-to-carry and easy-to-use electronic structure, have been created by considering the paper map production features and containing all the information on the paper map. It appears as a product where users can question all areas and shapes. This hard copy arriving on the vessels' bridge has named the ENC - Electronic Navigation Chart, which is transmitted to the end-user after the S-57 vector representation data structure conforming to the S-52 production standards is encrypted with the S-63 data protection standards. All these standards ensure that the officer of the watch on the bridge uses meaningful projections of the real-world surface of the plane electronically and is prepared with accurate information. The possibilities provided to the user go beyond the classical methods and provide the opportunity to query any point or object on the map following the standards.

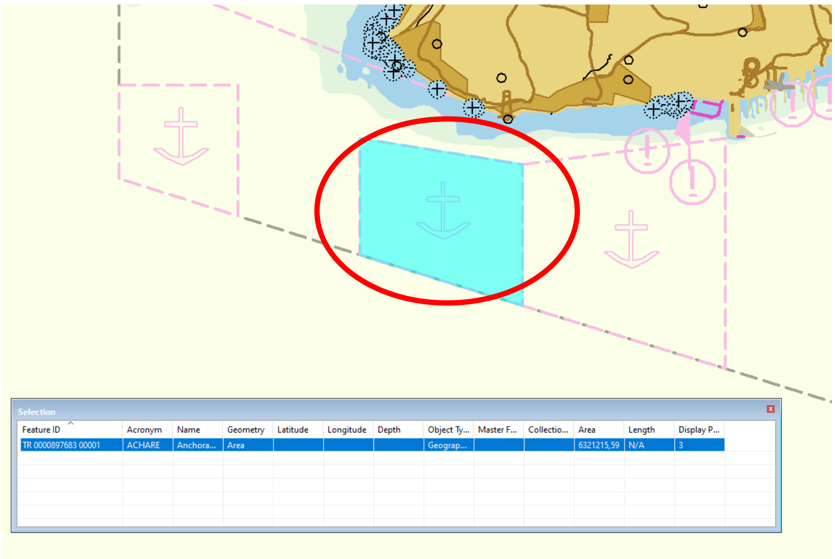


Figure 6. *A highlight object (ACHARE-Anchorage Area) is queried by the user on ECDIS.*

There are many essential features available within ECDIS. With a feature similar to the VDR recording feature called Logbook, it can store all the ship's movements during the cruise with time and direction information. With this feature, while the ship's movements are recorded, the efficiency can be observed with its contribution to the vessel monitoring process (IMC,2015). In addition, it is possible to use maps belonging to the same region, but at different scales, to display them on the screen following the needs and, in the area, where the cruise is made. Features called SCAMIN or SCAMAX primarily meet this need (Leder, 2007). These tools include checking the consistency, application of SCAMIN (density of features when zooming in and out), and usability of the ENC (Tyzack and Gkionis,2014). Another essential feature is the measurements of hydrographic circles and the quality of the data they use in the products they produce, thus determining the international clarity of their reliability levels. This term is called Category Zone of Confidence (CATZOC). The Zone of Confidence (ZOC) value is dependent on the positional and depth accuracy of the survey, and also confidence values are assigned to geographical areas to indicate whether data meets a minimum set of criteria for the exact position with the usage of WGS-84's LAT/LONG, depth accuracy surveys with ADCP and survey with side-scan sonar data seafloor coverage.

ZOC	Position Accuracy	Depth Accuracy		Seafloor Coverage	Typical Survey Characteristics	Symbol
A1	± 5m	=0.50 + 1%d		Full area search undertaken. Significant seafloor features detected and depths measured.	Controlled, systematic survey high position and depth accuracy achieved using DGPS or a minimum three high quality lines of position (LOP) and a multibeam, channel or mechanical sweep system.	
		Depth [m]	Accuracy [m]			
		10 30 100 1000	± 0.6 ± 0.8 ± 1.5 ±10.5			
A2	± 20m	=1.0 + 2%d		Full area search undertaken. Significant seafloor features detected and depths measured.	Controlled, systematic survey achieving position and depth accuracy less than ZOC A1 and using a modern survey Echosounder and a sonar or mechanical sweep system.	
		Depth [m]	Accuracy [m]			
		10 30 100 1000	±1.2 ± 1.6 ± 3.0 ± 21.0			
B	± 50m	=1.0 + 2%d		Full area search not achieved; uncharted features, hazardous to surface navigation are not expected but may exist.	Controlled, systematic survey achieving similar depth but lesser position accuracy less than ZOC A2 and using a modern survey echosounder, but no sonar or mechanical sweep system.	
		Depth [m]	Accuracy [m]			
		10 30 100 1000	±1.2 ± 1.6 ± 3.0 ± 21.0			
C	± 500m	=2.0 + 5%d		Full area search not achieved, depth anomalies may be expected.	Low accuracy survey or data collected on an opportunity basis such as soundings on passage.	
		Depth [m]	Accuracy [m]			
		10 30 100 1000	±2.5 ± 3.5 ± 7.0 ± 52.0			
D	Worse than ZOC 'C'	Worse Than ZOC 'C'		Full area search not achieved, large depth anomalies may be expected.	Poor quality data or data that cannot be quality assessed due to lack of information.	
U	Unassessed - The quality of the bathymetric data has yet to be assessed.					U
**In practice, it is usually assumed that the reliability error of bathymetric data measurements estimated for ZOC (D) and ZOC (U) zones assumes values at least 10% higher than the values estimated for the ZOC zone (C), which can also be recorded as: (2.0m ± 5% · d) · 1.1.*						

Figure 7. *IHO's categorization of CATZOC attribute (Rutkowski,2018).*

5. Conclusions

The indispensable element of the maritime transport sector, where developing technology products are frequently used, is also used at a high level on ships. For this purpose, the International Maritime Organization and its subcommittees are trying to set standards for safe navigation. In addition to IMO, the International Hydrographic Organization and its member hydrographic departments also support e-navigation with products with high accuracy for navigational safety and compatibility with new technology. In this way, deck department watchkeeping officers, especially the captain, who take part in the ship's dispatch and management during the cruise, support. Automation systems in the bridge on ships, the engine room, and infrastructures supporting electronic systems and components for cargo handling at ports also work with advanced technology products. Electronic navigation charts used on the bridge - ESH, Electronic Map Display Information systems - EHGBS and Automatic Information systems - AIS deck automation systems for the department, machine automation systems for the machine management and gantry, conveyor and port optimization systems used in ports are undoubtedly the best examples. There are many benefits of using high-tech products. It reduces the human-induced error rate and enables higher quality and more operations to be performed compared to the past. Developing technology in the maritime industry enables unmanned marine vessels, not only those on the ship. Even though it uses advanced technology, it needs human control and intervention when necessary.

Contribution Rate Statement

All research and writing steps belong to the corresponding author.

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