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The review of implication and development of digital technologies in maritime sector

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THE REVIEW OF IMPLICATION AND DEVELOPMENT OF DIGITAL TECHNOLOGIES IN MARITIME SECTOR

By

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The People's Republic of China

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DECLARATION

I certify that all the material in this dissertation that is not my own work has been identified, and that no material has been included for which a degree has previously been conferred on me.

The contents of this dissertation reflect my own personal views, and are not necessarily endorsed by the University.

Signature: …………………………..

Date: …………………………..

Supervised by: …Associate Prof. Zhao Jian…..

Supervisor's affiliation: …Dalian Maritime University…

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ABSTRACT

Title of Dissertation: **The review of implication and development of digital technologies in maritime sector**

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Due to the impact of the COVID-19 in 2020, digital technology has gradually penetrated into various fields. Digitization is a general trend of the current era. The shipping industry may be one of the most traditional industries in the world, but you can still feel the breath of digital transformation. The development trend of high-tech digitalization in the maritime field is inevitable and has great development potentials and prospects. This thesis aims to review the concepts and principles of digital technology, such as big data, artificial intelligence, etc. It also summarizes the current development trend, development process and influence of digital technology in the shipping field, which may provide a reference for the future digital development of the maritime field. By reviewing the influence of the four industrial revolutions, especially the fourth industrial revolution on the shipping industry, the application and development trend of various digital technologies in the maritime field are summarized. Through reading a large number of literature, this paper provides digital development ideas for ports and other shipping related departments.

KEY WORDS: Development trends, Digital technologies, Maritime sector

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LIST OF ABBREVIATIONS

2D/3D/4D	2/3/4-Dimensional
AI	Artificial intelligence
AIS	Automatic Identification System
AR	Augmented Reality
COVID-19	Corona Virus Disease 2019
CPS	Cyber-Physical Systems
CBR	Constants Bit Rate
ECDIS	Electronic chart display and information system
EPC	Electronic Product Code
GPS	Global Positioning System
GIS	Geographic Information System
HF/MF	High frequency/ Medium frequency
M2M	Machine-to-machine
MPP	Massively Parallel Processing
PCAST	Presidential Council of Science and Technology
PLC	Programmable logic controller
ICT	Information and Communication Technology
ITU	International Telecommunication Union
IP	Internet Protocol
IWS	Inland Waterway Shipping Information Service
IT	Internet Technology
RFID	Radio Frequency Identification
RIA	Rich Internet Applications
RPM	Round per minute

SOMS	Ship Operation and Maintenance System
TCP	Transmission Control Protocol
TS	Transportation system
VHF	Very high frequency
VLCC	Very large crude carrier
VR	Virtual Reality
VPN	Virtual Private Network

CHAPTER 1 INTRODUCTION

1.1 Revolution of shipping age

The shipping age has undergone thousands of years of changes, and tremendous changes have been taken place in all aspects. Affected by the Industrial Revolution, the shipping industry has gradually changed from the traditional era of great navigation to smart navigation now or in the future. These include changes in ship types, changes in the Industrial Revolution, and changes in business models.

1.1.1 Revolution of ship type

The term "revolution" means sudden and fundamental change. Times are changing, and so is the shipping age. The shipping industry is undergoing three fundamental changes in power, capacity and service. The shipping age has developed from ancient canoes to modern transport ships. It has experienced the era of rafts, canoes, plank boats, oars, poles and sculls, sailing era, ancient sailing ships in the Mediterranean, northern and Western European sailing ships, flying shears sailing ship, Chinese sailing ship, steam engine ship age, early steam engine ship, "Great Eastern" steam engine ship, the improvement of steam engine ship, the advent of steam turbine ship and diesel engine ship, the emergence of oil tankers and bulk carriers, the rise of large ocean passenger ships, diesel engines ship age (Xu, 2019).

Ships have experienced large-scale ships, specialized ships, high-speed ships, ship automation, and internal combustion engines (Xu, 2019). It originated from the steam engine era of the Industrial Revolution in the 1860s. In the past 50 years, container ships have entered an era of large-scale. The shipping age is influenced by industry

1.0 to 4.0. From the 15th century to the 19th century exploration age, modern shipping has undergone unprecedented changes from the 19th century to the 21st century.

1.1.2 Industrial revolution

The first industrial revolution was driven by the rise of steam power, railways, and mechanized production. The second industrial revolution arose in 1890 with the rise of electricity and new manufacturing methods based on assembly lines and mass production. With the rise of semiconductors and the popularization of computers and the Internet, Industry 3.0 emerged in the 1960s. It promoted the containerization of ships. From 2005 to 2017, the volume of container shipping on various routes around the world is shown in Table 1. It can be seen that the proportion of container traffic is increasing.

Table 1- Global container shipping volume by routes in 2005-2017

Year	East-west/ Million TEU	North-south/ Million TEU	Total container shipping volume/ Million TEU	Regional container Proportion of seaborne volume/%
2005	49.3	18.5	105.1	35.49
2006	54.9	19.6	116.9	36.27
2007	60.0	20.2	129.3	38.05
2008	60.7	21.6	136.6	39.75
2009	55.7	20.3	124.2	38.81
2010	62.7	23.5	140.5	38.65
2011	66.1	27.2	150.0	37.80
2012	66.6	27.6	154.6	39.13

Year	East-west/ Million TEU	North-south/ Million TEU	Total container shipping volume/ Million TEU	Regional container Proportion of seaborne volume/%
2013	69.3	29.2	162.5	39.45
2014	72.8	30.4	171.2	39.72
2015	74.2	30.8	175	40.06
2016	77.1	31.6	181.6	40.14
2017	80.3	32.8	189.1	40.24

Source: Zhen, H. (2017). Thoughts on China's Shipping Development Strategy under the Influence of the Third Industrial Revolution. China Navigation, Vol.40, No.01, p.121.

The fourth industrial revolution with cyber-physical systems as the core is currently taking place. Industry 4.0 and its four industrial revolutions are shown in Figure 1. With the change of industrialization from 1.0 to 4.0, new technologies such as artificial intelligence have gradually been applied to the shipping field. Following the three industrial revolutions of steam engine application, large-scale production and electronic information technology, an industrial intelligence revolution featuring intelligent manufacturing and intelligent use based on big data and forecasting technology as the core is brewing (Dong, 2019).

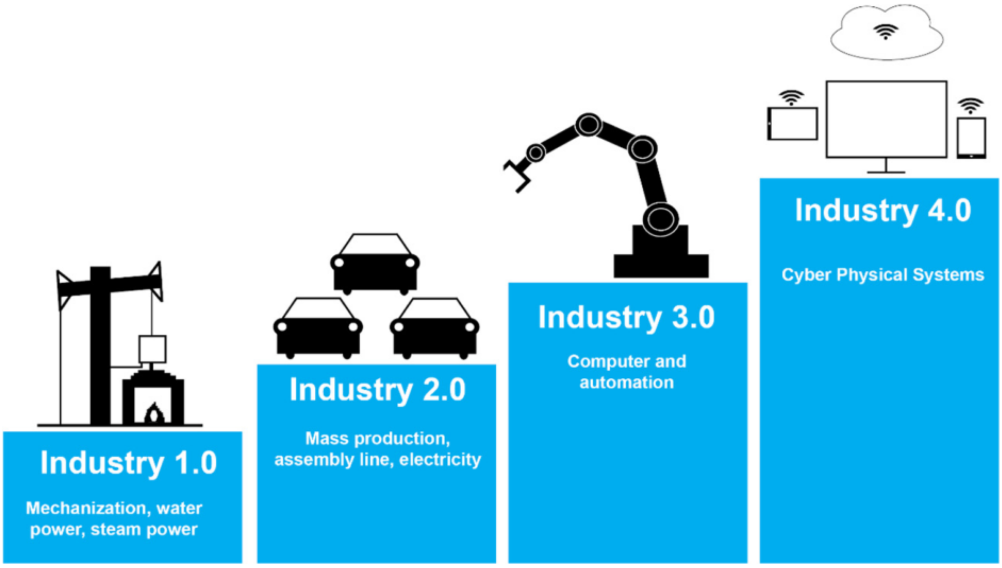

Figure 1-Industry 4.0 and its four industrial revolutions

Source: Stopford, M. (2008). Maritime Economics 3e. London: Taylor and Francis.

1.1.3 Revolution of business model

The new era of shipping reform started in 2018. The business model has shifted from purely or mainly based on maritime shipping services to providing full-process, high-efficiency, and fast-response end-to-end supply chain logistics services (Broker, 2018) . Shipping e-commerce, smart ships, the IoT, digital transactions, and blockchain technology have brought unlimited imagination to the traditional shipping industry. This change of business model provides application space for the development of digital technology in maritime field.

Giants in the industry are also constantly deploying digital applications, such as intelligent container tracking, blockchain-based electronic bills of lading and insurance control, smart ships, freight transaction platforms, and so on (Broker, 2018) . Modern navigation technology has developed in the direction of informatization, electronics, digitization, and intelligence. The International Maritime Organization has put forward the goal of implementing the electronic navigation strategy. All these changes show that the maritime sector is moving towards digital development.

1.2 Digital development history

1.2.1 Development Background

Digitization is the advanced stage of the development of information technology and the main driving force of the digital economy. As early as the 1940s, Shannon proved the sampling theorem, that is, under certain conditions, a discrete sequence can completely represent a continuous function (Dong & Liu, 2010). This proof initially introduced the concept of digitization to the human world.

In addition, many global organizations such as UNCTAD, ECE, World Customs Organization, WTO and Maritime Organization have been advocating to accelerate the digitalization process (Cicek et al., 2019). The operation model of various fields has gradually shifted from offline to online, and then combined with online and offline, and the digital model is becoming more and more perfect. It is inevitable that the shipping field will gradually become digitized and develop rapidly.

1.2.2 Development stage

Since the 1940s, the digital history of shipping has gone through the traditional stage, the interconnection stage, the intelligent stage and the autonomous operation stage (Group, 2019) . Data collection, written records, and speed and fuel consumption calculations are all done manually in the traditional stage. Although this stage is relatively straightforward, it is time-consuming, labor-intensive, and not highly accurate. In the interconnection stage, data collection relies on automation to realize ship-to-shore and shore-to-ship data communication, but data analysis and management still rely on manual completion.

In the intelligent stage, data collection and analysis rely on automation, and real-time analysis can also be carried out through cloud technology, and decision makers directly use the results to make judgments. At this stage, digitization is derived to strengthen digital analysis. In the autonomous operation stage, data collection, performance analysis and decision-making are completely automated, and decision-making is done by artificial intelligence (Zhong, 2018).

1.2.3 Development status and trends

So far, the digitalization of shipping has become more mature, and the operating model has become more automated. Facing the global digital transformation, the latest technologies have been developed and applied in succession, including cyber-physical systems, blockchain, IoT/IoS services, big data, artificial intelligence, machine learning, etc.

For example, in January 2018, Shanghai Yangshan Deepwater Port Phase IV, the world's largest and most automated container terminal, was opened and put into operation (Agency, 2019). On November 28, 2019, Shandong Port Group Qingdao Port fully automated terminal (Phase II) was put into operation (Agency, 2019). The use of "5G + automation technology" to achieve full coverage of the terminal, and successfully realized applications in scenarios such as quay crane and rail crane automatic control operations, grabbing and transporting containers, and high-definition video big data return under the 5G network (Agency, 2019).

All these indicate that the digitalization of shipping has a long history of development, and there is huge room for development in the future. In addition, another major achievement of shipping digitization is information sharing. This technology provides many opportunities for the shipping industry and can be said to have opened up a new era in the shipping industry.

1.3 The development trend of digital technology

1.3.1 Development areas

The Industry 4.0 have arrived, and the maritime field urgently needs the support of digital technology. According to the research results, the demand for real-time data acquisition from ships is increasing rapidly compared to using more manual methods. The demand for digital navigation solutions, ECDIS and route optimization is increasing year by year. For example, in terms of shipboard operations, maritime trade, shipbuilding technology and unmanned ships, port technology development, registration and maritime management (Athos et al., 2019). The digital technologies solutions in the shipping industry are shown in Table 2.

Table 2- Shipping Digital Solutions

Digitalization Areas	Digital Technologies-Solutions
Ship Operations-Autonomous Functions	IoT, analytics, Al, 5G Technical and nautical operations Various levels of Autonomy for Ship Operations: Navigation, Berthing, Collision Avoidance
Shipping Commercial and Business Management Operations	IoT, analytics, Al Asset optimization, fleet planning, service planning
Trade and Logistics Functions	IoT, analytics, blockchain

Digitalization Areas	Digital Technologies-Solutions
Digital Platforms	Cargo monitoring, Paperless Trade, Supply Chains Synchronization
Internet of Ships Platforms & Internet of Sea Services Platforms	Analytics, Al Smart Cargo Booking Open Data Hub for shipping companies, shipbuilders, equipment manufacturers, IT companies, weather information companies, and digital solution providers.

Source: Lambrou, M., Daisuke, W., & Junya, L. (2019). Shipping digitalization management conceptualization, typology and antecedents. Retrieved from Journal of Shipping and Trade: https://ishippingandtrade.springeropen. com/articles/10.1186/s41072-019-0052-7

In addition, the birth of telemedicine technology marks the development of shipping digital technology. According to statistics, 1,200 ships indicate that shipping may be ready to accept telemedicine in an unprecedented way (Group, 2019). At the same time, it is expected that video conferences will be widely used for training, monitoring and crew connections on all types of ships (Broker, 2018). At the same time, crew welfare issues and extensive social development have also driven the development of digital technology, giving digital technology a broad development prospect in shipping and maritime management (Broker, 2018).

1.3.2 Application status

Many technologies are now helping to shape digitalization that is conducive to ship safety and cost efficiency, the environment, and crew welfare. For example, digital navigation technology, maritime digital communication technology, digital ship handling and control technology, digital ship freight technology and digital maritime traffic management technology (Broker, 2018) . Technologies that have been integrated with shipping and maritime management include VHF and MF/HF, GPS technology, AIS technology, ECDIS, cyber-physical systems, blockchain, IoT/IoS services, big data, artificial intelligence, machine learning, etc. (Ellingsen & Knut , 2019) . These technologies will further increase support to help the continuous development of digital technology.

In addition, the technologies that will be integrated with shipping and maritime management include key technologies such as a new generation of network and communication technologies, wireless sensor networks, RFID technology and M2M technology (Ghobakhloo, 2020). These technologies can greatly improve operational efficiency and save manpower, which is conducive to the realization of digital navigation (Dong & Liu, 2010).

1.3.3 Development trend

Artificial intelligence will effectively reduce terminal human resources and crew quotas through automated terminals and smart ships, and big data will reduce the work pressure of shipping operators through decision-making support and precise services (Dong & Liu, 2010) . Blockchain-based multimodal transportation collaboration paperless, blockchain-based maritime asset liquefaction and shipping supply chain finance; blockchain-based shipping certificate paperless; blockchain-based mutual recognition of supervision and law enforcement in line with the trend of paperless shipping documents, it reduces the cost of coordination between different roles in the shipping business chain, and improves business standards, convenience and timeliness (Dong & Liu, 2010).

These digital technologies will be used more to research and develop automated ships/unmanned ships in the maritime field. In addition, the relevant shore-based authorities will more effectively use digital technology to monitor the maritime transport environment and more comprehensively maintain maritime traffic order. These will create more opportunities and challenges for shipping and maritime management in the future.

1.4 Research purpose, significance and methods

1.4.1 Research purposes

Digitization can ensure business continuity in critical supply lines, automating maritime trade and reducing traditional human interaction and paper-based transactions. Therefore, in the face of the changes brought about by Industry 4.0, the trend of digital development technology in the maritime field is inevitable. The purpose of this paper is to sort out the ethical challenges of science and technology brought by Industry 4.0, link them with shipping, and summarize the influence and development of digital technology in the maritime field. Starting from the perspective of introducing the background, development trend, application and significance of the maritime field, it comprehensively summarizes the changes in the shipping age, the digital development process and the development trend of digital technology in shipping and maritime management.

1.4.2 Research significance

Despite the broad prospects for digital development in the maritime field, there are still many problems. For example, the current problem is that although some port communities have seized the opportunity of the Fourth Industrial Revolution and developed into mature smart ports, many other port communities have hardly grasped the essence of digitalization. Therefore, the research significance of this article is to review the influence and development of digital technology in the maritime field to provide ports and other shipping related departments with digital development ideas, or provide a reference for the future digital development of the maritime field.

1.4.3 Research method

The research method of this article is to read a large number of literatures in the early stage and refer to the changes from 1.0 to 4.0 in industrialization for picturing an overview of the impact of the industrial revolution in the maritime sector , understanding the existing digital technology and the digital needs of maritime related fields, combining current technology and research results, and conducting background introduction and discussion on functions and development prospects of cyber-physical systems, blockchain technology, IoT/IoS, big data, artificial intelligence and machine learning. By consulting the data on the practical application of digital technology on ships and combining with the current digital technology that has been applied, the developments and applications of digital technology in maritime trade, shipbuilding technology/unmanned ships, port technology development, registration and maritime management are analyzed.

CHAPTER 2 DIGITAL TECHNOLOGY CONCEPTS AND PRINCIPLES

2.1 Cyber-physical system

2.1.1 Background

The rapid development of computing technology, communication technology and control technology has caused great changes in human social life. With the in-depth integration and development of informatization and industrialization, traditional single-point technology can no longer meet the needs of informatization and networking of new generation production equipment. In this context, cyber-physical systems (CPS) emerged. Germany's "Industry 4.0 Implementation Recommendations" regard CPS as the core technology of Industry 4.0. CPS is a multi-dimensional and complex system that integrates computing, network and physical environments (Guo & Jia, 2017) . Through the organic integration and in-depth collaboration of Computation, Communication and Control technologies, it realizes real-time perception, dynamic control and information services for large-scale engineering systems (Guo & Jia, 2017). As shown in Figure 2.

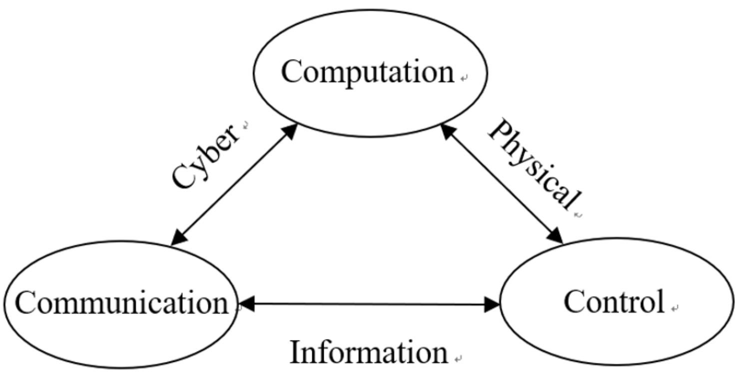

Figure 2-CPS system

Source: Guo, N., & jia, C. (2017). Survey on Research and Application of Cyber-Physical Systems at Home and Abroad. Information Technology and Standardization, No.06.

CPS is a system closely related to information systems and physical systems, which introduces more physical system factors on the basis of traditional security issues. The CPS realizes the interaction with the physical process through the human-computer interaction interface and uses the networked space to control a physical entity remotely, reliable, real-time, safe, and collaborative (Li, et al., 2019). As shown in Figure 3, the basic composition of CPS includes sensor, control execution unit and calculation processing unit. However, CPS introduces network technology and communication technology into the control of traditional physical systems, which brings challenges to the robustness and reliability of the existing control methods in application.

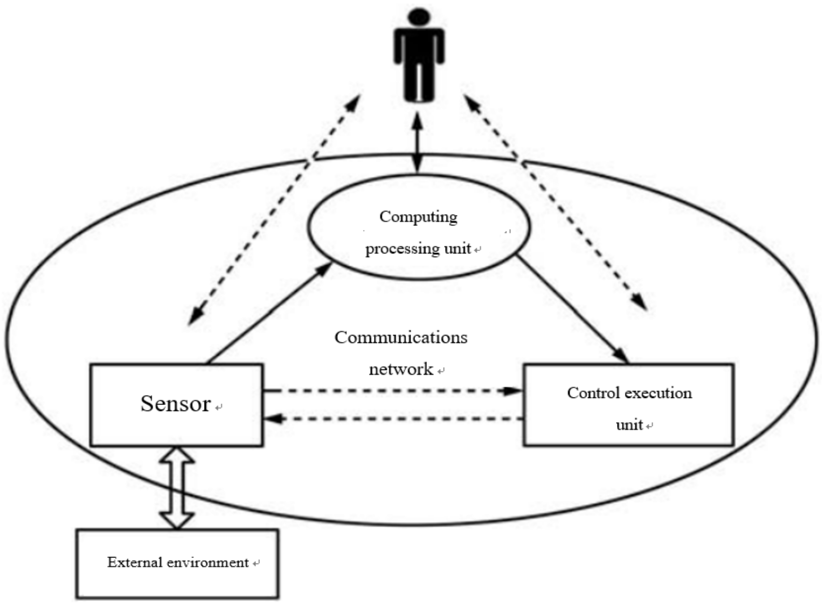

Figure 3-The basic composition of CPS

Source: Cyber-Physical/Systems (2021). Retrieved from CHINA SCIENCE COMMUNICATIONS: https://baike.baidu.com/item/3728320

In July 2007, the US Presidential Council of Science and Technology Advisory Committee (PCAST) listed eight key information technologies in a report titled "Information Technology Research and Development in a Globally Competitive World Under Challenges", of which CPS ranked first (Guo & Jia, 2017). The EU has also done a lot of work on CPS. As a traditional manufacturing powerhouse, Germany has always been concerned about the development of CPS. In Japan, South Korea and other countries, CPS has attracted attention since about 2008. China had already carried out similar research before the CPS was clearly proposed. The research directions and research results of various countries that mainly study CPS are shown in Table 3.

Table 3-Research directions and research results of CPS in various countries

Countries and organizations	Research direction	Research results
United States	Theory and standard research: reference architecture, application cases, time synchronization, CPS security, data exchange	Establishment of CPS Public Working Group (CPS PWG) Released CPS framework 1.0 (May 2016) CPS test verification platform (Testbed)
United States	Standard research: carry out the research and development of CPS related standards	Established IEEE TC-CPS Regular academic conferences CPS Weeks
European Union	Strategic analysis and theoretical research: smart devices, embedded systems,	Set up CPS research team Launched the ARTEMIS project

Countries and organizations	Research direction	Research results
	perceptual control, complex systems (SoS)	Release of "CyphERS CPS European Roadmap and Strategy"
Germany	National strategy and theoretical research: CPS characteristics, CPS applications, smart devices, cyber-physical manufacturing system CPPS	German Industry 4.0 is determined to take CPS as the core Released "Living in the Online World" Established the world's first CPPS laboratory in production
China	Standards, technology, and application research: focus on research on reference structures, core technologies, standard requirements, and application cases	Cyber-Physical System Development Forum CPS common key technology test and verification platform construction and application promotion projects

Source: Guo, N., & ja, C. (2017). Survey on Research and Application of Cyber-Physical Systems at Home and Abroad. Information Technology and Standardization, No.06, p.47.

2.2.2 Functions

Cyber-physical systems include system engineering such as ubiquitous environment perception, embedded computing, network communication and network control in the future, enabling the physical system to have functions of computing, communication, precise control, remote collaboration, and autonomy (Li, et al., 2019) . It focuses on the close integration and coordination of computing resources and physical resources, and is mainly used in some intelligent systems such as intelligent navigation. CPS realizes the integrated design of computing, communication and physical systems, which can make the system more reliable, efficient, and real-time collaboration, and has important and extensive application prospects (Du & Pang, 2015).

CPS is a controllable, reliable and scalable networked physical equipment system that deeply integrates computing, communication and control capabilities on the basis of environmental perception (Du & Pang, 2015). It achieves deep integration and real-time interaction through the mutual influence of computing and physical processes through the feedback loop. Add or extend new functions to detect or control a physical entity in a safe, reliable, efficient and real-time manner (Li, et al., 2019). CPS can also interact with each other using standard Internet-based protocols, analyze data to predict failures, configure itself, and adapt to changes (Li, et al., 2019). The functional composition of CPS is shown in Figure 4.

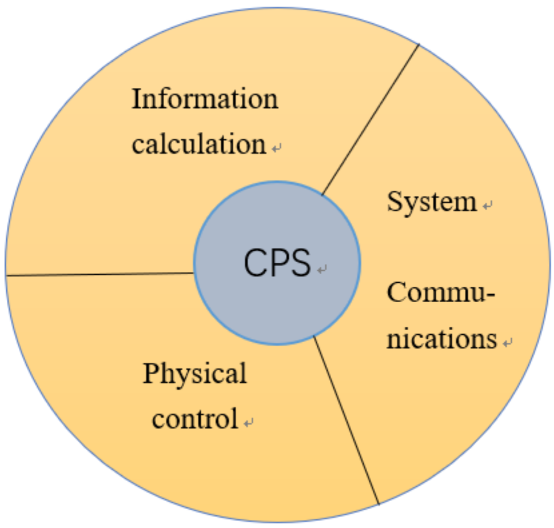

Figure 4-CPS functional composition

Source: Author

The information platform system based on CPS can greatly improve office efficiency and management decision-making level. The application in the maritime field is to establish a port and shipping geographic information platform to improve the operational efficiency and service level of port and shipping management, and to encourage people to acquire, query and output port and bank information more digitally and intelligently (Du & Pang, 2015). The ship equipment can obtain its own intelligence, the deck equipment can be connected, the cargo may also be monitored and controlled, and the port equipment can be integrated into the ship's control (Li, et al., 2019).

2.2.3 Application prospects in the maritime field

CPS is the current frontier research direction in the field of automation and has attracted widespread attention in the maritime field. As a supporting technology system for the development of industrial intelligence, CPS is developing in the direction of systematization and complexity. In 2013, the Marine Intelligent Technology Center jointly established by China Shipbuilding Industry Corporation and the US NSF-IMS Center based on the system-level CPS architecture of the system, developed a smart ship operation and maintenance system (SOMS) and SOMS system architecture for ship and shipping intelligence (China Electronics Standardization Institute, 2019).

The application deployment diagram is shown in Figure 5. It faces the fleet, shipowner and ship industry chain, and has designed CPS application solutions for ships (individuals), fleets (groups) and industrial chains (communities) respectively (China Electronics Standardization Institute, 2019, p. 62) . SOMS, as the two core systems of domestic smart ships, has been widely used on bulk carriers, container ships and VLCC ships, and will gradually be updated and expanded (China

Electronics Standardization Institute, 2019, p. 69). Especially in the intelligent ship, shore-based management and shore-sea integration, there are very broad application prospects. However, the application of CPS in the maritime field still lags behind the application level of other industries. Therefore, it is imperative to accelerate its application in the maritime field in the future.

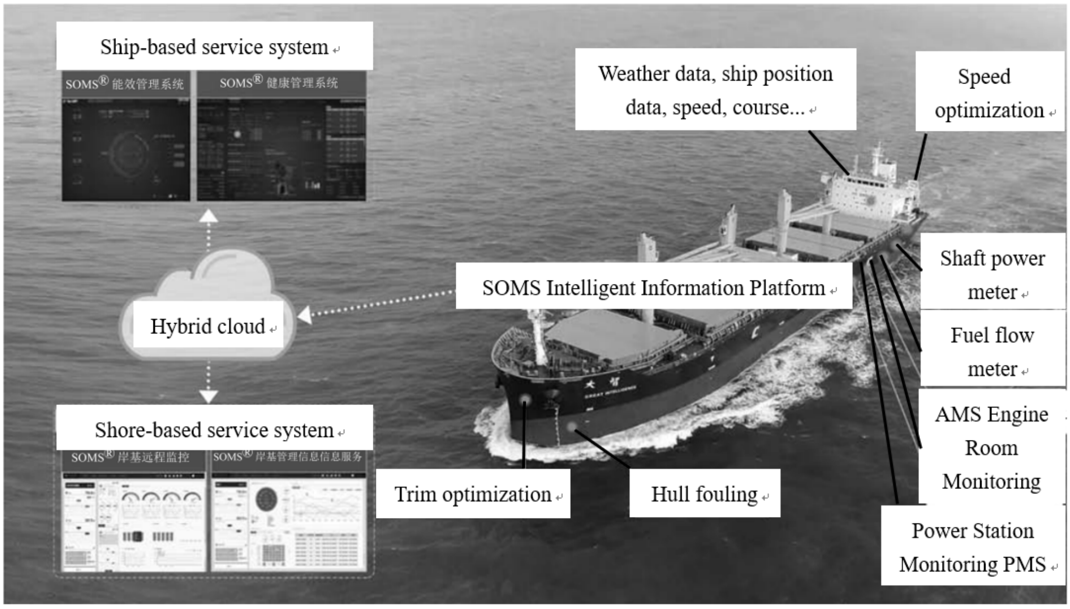

Figure 5-SOMS system architecture application deployment diagram

Source: Collection of typical application cases of Cyber-Physical Systems (CPS). (2019). Beijing: Publishing house of electronics industry.

CPS will be more inclined to the development of automation and intelligence in the maritime field. He will gradually be applied in various aspects of the maritime field, such as ship positioning and navigation, ship automatic driving, unmanned ships, automatic ship control technology, and build intelligent service platforms, autonomous control terminals, intelligent management terminals and hybrid cloud platforms (Du & Pang, 2015). CPS-based maritime field takes industrial intelligence as the core breakthrough point, and will show application prospects in the following aspects. First, break through the predicament of the shipbuilding industry and improve the efficiency of ship operations. Second, we will create worry-free ships and worry-free operations together with data as the driving force. Third, build the SOMS system to lead the new development of the shipbuilding industry. Fourth, realize the intelligentization of ships; realize the intellectualization of shore-based management; realize the integration of shore and sea (China Electronics Standardization Institute, 2019, p. 69) . Fifth, to promote new formats of the shipbuilding industry. Among them, the architecture of the SOMS system covers CPS status awareness, real-time analysis, scientific decision-making and precise execution.

CPS has five core technical elements, which can provide prospective ideas for different applications of CPS in the maritime field. As shown in Figure 6, including perception and automatic control technology, industrial software technology, industrial transmission network technology, hybrid cloud platform technology, intelligent management and service platform (Li, et al., 2019) . Perception and automatic control technology are applied to comprehensive perception, autonomous cognition and application-oriented autonomous decision support (Li, et al., 2019) . Industrial software technology is applied to data reception, storage, conversion and cleaning, etc. Industrial transmission network technology is applied to ubiquitous connection and interconnection between devices. Hybrid cloud platform technology is applied to system autonomy. The intelligent management and service platform is used for resource integration, activity optimization, and decision support related to work collaboration between organizations and between the business processes of various departments of the organization (Athos, Wagner, Francesco, & Giovanni, 2019).

Figure 6-Cyber-Physical Systems

Source: Kvamstad-Lervold, B. (2017). 9 PATHS INTO THE MARITIME FUTURE. Retrieved from SINTEF.

In summary, CPS will have a huge application prospect in the maritime field under the birth of Industry 4.0. For example, in the application of navigational instruments, CPS will strengthen the optimization of electronic charts and develop new functions, including graphic display, information query, database management, information analysis and other functions (Du & Pang, 2015) . In the application of maritime affairs, CPS will promote the establishment of shipping databases in various countries, and provide decision-making basis for maritime planning through a variety of analysis and evaluation models (Bucak, Mehmet, & Hakan, 2019) . It will also promote the efficient mode of multimodal transportation, use information sharing, resource sharing, combined with advanced systems such as GIS, GPS, and promote the development of digitization, informatization, and intelligence in the maritime field (Athos, Wagner, Francesco, & Giovanni, 2019) . At the same time, CPS will develop a series of application systems, such as information release, dynamic tracking and other systems, to realize the digitization of information and the network of information services (Du & Pang, 2015) . In future practical applications, the database will be updated, the system will be improved, and the scope of application will be expanded.

2.2 Blockchain

2.2.1 Basic knowledge introduction

Blockchain is a new application mode of computer technology such as distributed data storage, point-to-point transmission, consensus mechanism, and encryption algorithm (Li L., 2020). From a technological perspective, blockchain involves many scientific and technological issues such as mathematics, cryptography, the Internet, and computer programming (Zou, 2020) . From an application point of view, in simple terms, a blockchain is a chained data structure that sequentially combines data blocks in chronological order. It is non-tamper able and non-forgery guaranteed by cryptography. Distributed ledger. It has the characteristics of decentralization, non-tampering, full trace retention, traceability, collective maintenance, openness and transparency, etc. (Xing, 2020). It is divided into three types: public blockchain, joint (industry) blockchain and private blockchain.

Generally speaking, a blockchain system consists of a data layer, a network layer, a consensus layer, an incentive layer, a contract layer, and an application layer (Zou, 2020) . The blockchain infrastructure model is shown in Figure 7. Among them, the data layer encapsulates the underlying data blocks and related data encryption and time stamping and other basic data and basic algorithms; the network layer includes distributed networking mechanisms, data propagation mechanisms, and data verification mechanisms; the consensus layer mainly encapsulates network nodes. The incentive layer integrates economic factors into the blockchain technology system, mainly including the issuance mechanism and distribution mechanism of economic incentives; the contract layer mainly encapsulates various scripts, algorithms and smart contracts, which is a blockchain the basis of programmable features; the application layer encapsulates various application scenarios and cases of blockchain (Jingdi, Wu, Zhao, & Liu, 2017).

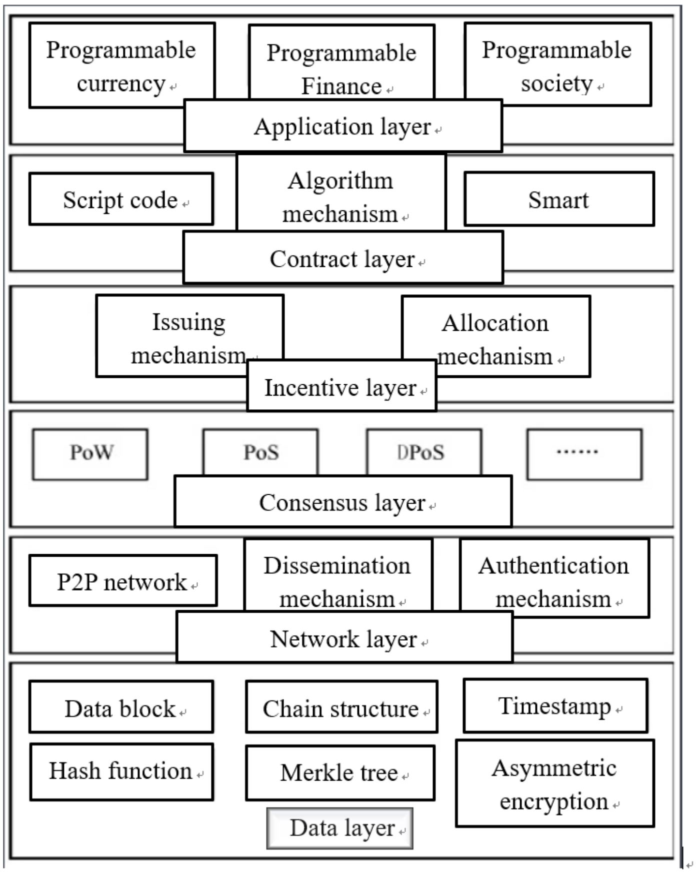

Figure 7-Blockchain infrastructure model

Source: Author

The core technologies of the blockchain include distributed ledgers, asymmetric encryption, consensus mechanisms and smart contracts (Zou, 2020). This determines its characteristics mentioned above. The main application areas of blockchain include the financial field, the IoT and logistics, the public service field, the digital copyright field, the insurance field, and the public welfare field (Song, 2020) . However, although it is widely used in various fields, it also faces many challenges, such as being restricted by current concepts, systems, and laws, technical challenges, and competitive technical challenges (Li L., 2020). Currently, with the advent of Industry 4.0, blockchain has also been applied to the maritime field. Especially the development prospects and influence in maritime management should not be underestimated.

2.2.2 Application

Blockchain technology has been applied in maritime management, but it has not been widely used in the maritime field. Blockchain is mainly used to digitize and simplify paperwork, tracking and tracing, customs clearance and management (Jingdi, Wu, Zhao, & Liu, 2017). Specifically, it includes the paperless shipping certificate based on the blockchain, the blockchain based on the AIS system and the Beidou system, the ship traffic organization based on the blockchain, and the integrity management of the shipping company and crew based on the blockchain (Jingdi, Wu, Zhao, & Liu, 2017) . Blockchain can also be effectively applied to maritime management, including crew management, ship management, navigation management, dangerous goods management, pollution prevention management, and maritime emergency assistance (Ellingsen & Knut, 2019). It can promote data sharing, optimize business processes, reduce operating costs, improve collaboration efficiency, and build credible systems (Li L., 2020).

Using the blockchain data sharing model, maritime government service data can also be jointly maintained and utilized across departments and regions. The application of "smart port" is mainly reflected in the application of blockchain technology, the promotion of electronic documents, online business processing, full chain supervision of dangerous goods, and full logistics visualization (Sun, 2019) . In addition, "blockchain+" is applied in maritime supervision and service work such as crew management, ship management, navigation management, dangerous goods management, pollution prevention management, and maritime emergency assistance (Sun, 2019).

2.2.3 Influence and change

The application of blockchain technology in shipping and maritime management can solve the problem of insufficient internal maintenance and sharing of maritime department supervision and service information, which leads to complex business processes and low supervision efficiency, and insufficient cross-regional and cross-department supervision information maintenance and sharing leads to insufficient trust (Song, 2020). In addition to difficult and painful issues such as the difficulty of obtaining and the repeated running of the relative person and the repeated submission of materials, we can provide the people with smarter, more convenient and better-quality public services. Facilitate the standardization and standardization of maritime information resources, assist the construction of maritime information disclosure platforms and government service platforms, and improve the level of information disclosure and online processing (Song, 2020).

The influence of blockchain technology on future shipping and maritime management is mainly reflected in the following aspects. First, promote data sharing and open and transparent maritime services. Second, optimize the business process, and the maritime law enforcement is intensive and convenient. Third, reduce operating costs and save time and effort in maritime management. Fourth, to improve the efficiency of coordination, and co-governance and management of maritime affairs. Fifth, build a credible system with strong maritime security authority. At the same time, the use of blockchain applications will benefit shipping companies, port operators, freight forwarders, shipping agents and other maritime supply chain operators (Song, 2020).

Blockchain is the infrastructure for the development of shipping and maritime management in the future, and it has broad application prospects. But its replacement of the existing shipping order rules and information system is not overnight. In the long run, blockchain provides a data island solution for future shipping and maritime management, and improves the sharing and flow of supply chain data (Song, 2020). And may successfully change the supply chain. Its special privacy security protection mechanism also eliminates information sharing barriers for future shipping and maritime management (Li L., 2020) . Czachorowskil and others predicted the environmental effects of blockchain technology, especially in the maritime field (Bucak, Mehmet, & Hakan, 2019). In addition, the blockchain will promote industry changes, resulting in structural and policy influences. More intelligent equipment will be invested to stimulate the application of more intelligent technologies and the development of new energy. Drive the intelligent development of shipping and maritime management.

2.2.4 Countermeasures

As an emerging technology in the maritime field, blockchain will face many challenges in shipping and maritime management. For example, the current lack of global-consistent technology standards for blockchain technology is a common obstacle to the implementation of this technology. In the specific application practice of blockchain in maritime management, the business department should have a relatively large workload in process research and element combing (Lambrou, Daisuke, & Junya, 2019). When designing a blockchain-based business model, digital information exchange to simplifying paperwork, tracking and tracing goods, clearing customs, and managing maritime operators are key issues that need to be resolved.

Therefore, in view of the opportunities and challenges brought by industry 4.0, the blockchain still has a lot of room for improvement in the future. For example, standardization and platform development, business model and supervision, establishment of government support and review system, etc. (Yin, Xie, Wu, & Fang, 2020) . It is expected that the blockchain business model and governance and supervision issues will become the key to future blockchain development and also the focus of future research (Yin, Xie, Wu, & Fang, 2020).

In view of the data security, supervision and other issues involved in blockchain technology, the following countermeasures are proposed. First, there must be specific data access standards, electronic evidence management and use rules, etc. to match it. Second, before the construction of the maritime management data chain, it is necessary to fully investigate the development and preparations of the relevant port and shipping units and relevant institutions to implement the blockchain. Third, with regard to important aspects of data right confirmation, privacy security, and transaction and governance, various supporting tasks such as data traceability, data encryption, authority control, identity authentication, and electronic evidence verification and confirmation should be done. Fourth, clarify the rights and obligations of all parties in the production, use, circulation, and storage of maritime-related data, so as to achieve a balance between data openness, privacy protection, and data security (Yin, Xie, Wu, & Fang, 2020).

2.3 IoT / IoS

2.3.1 Background

In recent years, with the rapid development of Industry 4.0 and a new generation of information technology, the Internet of Things (IoT) has become one of the strategic commanding heights of a new round of economic and technological development in the world in 2005. On November 27, at the Information Society Summit held in Tunisia, the International Telecommunication Union (ITU) released the "ITU Internet Report 2005: IoT", which officially put forward the concept of the IoT (Li K., 2019). The Internet began in 1969 in the United States' ARPANET. Since the birth of the Internet, the number of netizens has soared, and the application areas have increased year by year. The global Internet has rapidly expanded since it entered commercial use in the 1990s and has become an important information infrastructure for promoting economic development and social progress in the world today.

The Internet is a network formed by the meeting of multiple computer networks. The IoT is a new application technology developed at high speed relying on the Internet. It is regarded as the third wave of informatization after computers and the Internet. It has Internet characteristics, identification and communication characteristics, and intelligent characteristics (Dong & Liu, 2010) . Established information exchange between people, people and things, things and things. With the in-depth application of the IoT/IoS, information can be transmitted to all areas on the network in time and information can be interacted at multiple points in real time (Du & Pang, 2015, p. 24). The relationship between the two concepts is interdependent. The relationship between the two is shown in Figure 8.

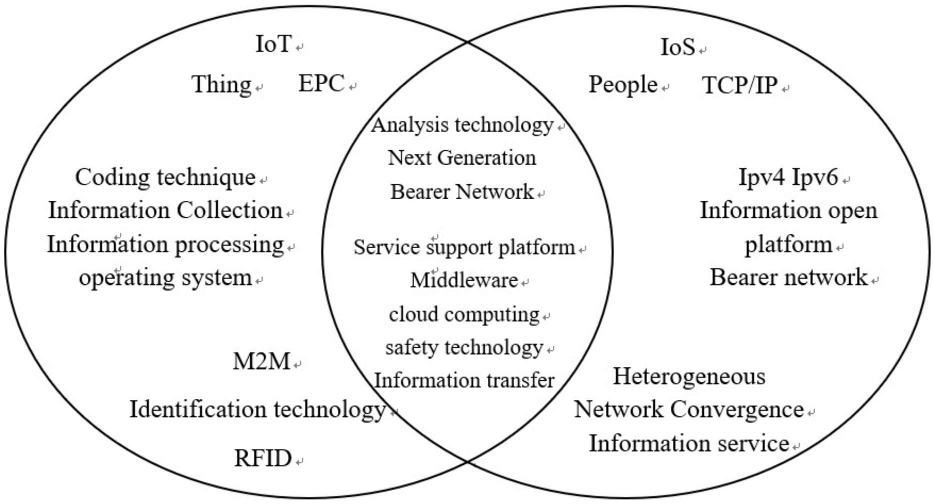

Figure 8-The relationship between IoT and IoS

Source: Author

IoT/IoS services have been applied in many areas of people's daily lives, such as smart home, smart transportation, smart healthcare, smart grid, smart logistics, smart agriculture, smart power, smart security, smart cities, smart cars, smart buildings, and smart Water exhaustion, business intelligence, smart industry and safe cities (Du & Pang, 2015, p. 445) . It will provide users with ubiquitous terminal equipment and facilities in the intranet, private network, and/or Internet environment. Therefore, the development of IoT/IoS services is of great significance for promoting economic development and social progress, and has an important role in accelerating scientific research and development and application.

2.3.2 Functions

The application of the IoT can realize the intelligent identification, positioning, tracking, monitoring and management of items. And provide safe, controllable and even personalized real-time online monitoring, positioning traceability, alarm linkage, dispatch command, plan management, remote control, security prevention, remote maintenance, online upgrades, statistical reports, decision support, leadership desktop and other management and services Function to realize the integration of "management, control and operation" of "high efficiency, energy saving, safety and environmental protection" of "everything" (Du & Pang, 2015, p. 440).

The perception technology, network and communication technology, data processing technology, information security technology and standardization technology possessed by the IoT are all serving applications (Du & Pang, 2015, p. 445) . From the application point of view, it can transmit business information and realize automatic and intelligent information collection, transmission and processing between objects. Realize the intelligent interaction between people and things and the information interaction between things. It has a perception layer that can collect information, the network layer can transmit information, and the application layer can process information (Du & Pang, 2015, p. 433) . In general, the IoT has three major functions. Comprehensive perception, reliable delivery, and intelligent processing.

The main functions of Internet applications include communication, social networking, online trade, cloud-based services, resource sharing, media, and service objectification. Through artificial intelligence, middleware, cloud computing and other technologies, various information is collected and processed to provide application solutions for different industries (Du & Pang, 2015, p. 440). Based on the "point-to-point" information exchange on the Internet, ship networking can realize the "communication" between ships and ships, ships and people, ships and shores, and ships and ports. Realize refined shipping management, comprehensive industry services, and humanized travel experience.

2.3.3 Application prospects in the maritime field

The Internet of Ships is a new application of the IoT in the maritime field. Inmarsat's research shows that the expenditure on the Internet of maritime affairs exceeds that of other industries, and the shipping industry's capital investment in the IoT far exceeds that of other industries. As the development trend of hybrid web/desktop applications continues, we will be able to expect to see RIA (Rich Internet Applications) continue to improve in use and functionality (Du & Pang, 2015, p. 450) .

The application of IoT/IoS services in the maritime field involves intelligent transportation systems, maritime warehousing management, shipping supervision, IWS (Inland Waterway Shipping Information Service Network System), digital port and shipping construction, maritime satellite call center platform construction, and maritime affairs based on credit management Public service platform construction and other aspects. Among them, the Intelligent Transportation System (ITS) uses modern information technology as the core, and uses advanced communications, computers, automatic control, and sensor technologies to pass AIS, VTS, LRIT, readers, sensors, navigation aids, remote sensing, GPS, broadband networks, Multimedia and virtual simulation technologies to achieve real-time traffic control and command management (Du & Pang, 2015, p. 440). In the future, it is possible to realize remote computer rooms, remote pilotage, remote bridges, etc. based on Internet technology.

In addition, the application of maritime networking technology will rely on technological innovation to integrate dynamic and static management information related to maritime management, such as crews, ships and their cargo, navigation environment, and navigation assistance services, which are closely related to maritime management in maritime supervision, maritime security and comprehensive management (Dong & Liu, 2010). A comprehensive perception of ship navigation safety management and navigation aid service elements between ships and between ships and shores, to realize the interconnection and intelligent processing of various maritime supervision objects and navigation support resources, and build a maritime information sharing platform (Athos, Wagner, Francesco, & Giovanni, 2019). The IoT/IoS services will focus on new interconnected technologies to help IT operations in a better, more efficient, more environmentally friendly and more sustainable way.

The application of Internet technology and the Internet of Things technology represented by radio frequency identification (RFID) technology in the maritime field has long-term significance (Bucak, Mehmet, & Hakan, 2019). First, the degree of informatization of maritime transportation facilities and equipment will be accelerated, and existing facilities and equipment will be updated, optimized, and upgraded to promote the informatization process of maritime transportation. Second, accelerate the realization of information resource sharing and business collaboration among maritime systems. Third, it has become a necessary technical support for advancing the development of the integrated transportation system. Fourth, improve maritime transport safety supervision and emergency response capabilities. Fifth, it is conducive to promoting the construction of shipping informatization perception, the construction of shipping information basic and private networks, the construction of basic databases, and the development of shipping informatization applications.

In summary, the IoT/IoS services have broad application prospects in the maritime field of ship dynamic information collection, unmanned ships, unmanned driving, digital port and shipping construction, VTS water supervision, and maritime emergency command search and rescue. It will be based on the current maritime private network, Internet, wireless communication network, etc., more convenient and faster to realize the real-time transmission of traffic element perception information. The IoT/IoS services are continuing to promote the digital and intelligent development of the maritime field.

2.4 Big Data

2.4.1 Background

In recent years, big data, together with Industry 4.0, cloud computing, and self-media, have formed an informatization frenzy. Big data was born in the rapid development of the Internet. The term big data first appeared in the book "The Third Wave" published by Alvin Toffler in 1980 (Wu, 2020). McKinsey & Company released a report on big data in June 2011, which really popularized the concept of big data (Huang, 2020). The impact of big data, key technologies and application areas are analyzed in detail. The prehistoric era of big data has experienced the ancient era, the era of writing and the era of Arabic numerals (Chang, 2020). With the advent of the cloud era, big data is now being used more and more.

Big data refers to a collection of data whose content cannot be captured, managed, and processed with conventional software tools within a certain period of time (Chang, 2020) . "Data" not only refers to the information and data generated by various activities on the Internet, but also includes the location, temperature, and light intensity measured and transmitted by various sensors installed in the world, including industrial equipment, instrument meters, and various sensors all over the earth. Weather data, air quality changes and other data (Chang, 2020) . It is a new form of production factors.

Big data technology refers to the ability to obtain valuable information from various types of data quickly It has four basic characteristics, including huge data volume, diverse data types, fast processing speed and low value density (Chang, 2020) . Technologies applicable to big data, including massively parallel processing (MPP) databases, data mining, distributed file systems, distributed databases, cloud computing platforms, the Internet, and scalable storage systems (Dong & Liu, 2010). In the future, the development of artificial intelligence, deep learning, VR, AR and container technology will bring big data into a new stage (Dong & Liu, 2010).

2.4.2 Functions

Big data has functions of visual analysis, data mining algorithms, predictive analysis, semantic engine, data quality and data management (Jingdi, Wu, Zhao, & Liu, 2017). The characteristic of a large amount of data leads to a complete description of the whole of big data. The characteristics of data diversity cause big data to fill in the missing core information in all aspects. Big data can also better predict the future, and analysis results can be quickly put into use. The cloud data platform based on big data speeds up data sharing and data interconnection, effectively improving work efficiency and reducing workload (Huang, 2020). Ensure the accuracy and reliability of data and reduce human filling or calculation errors.

In practical applications, big data has been widely used in many fields. The use of big data technology can target the placement of intelligent recommendations, optimize the performance of machines and equipment, improve law enforcement and fight crime, risk prediction, improve the quality of medical and research and development, and optimize the latest traffic conditions (Jingdi, Wu, Zhao, & Liu, 2017) . Among them, the powerful data processing and analysis capabilities have prompted its gradual application in the maritime field, bringing hope to the informatization of the shipping industry.

2.4.3 Application prospects in the maritime field

The shipping industry is a typical traditional industry with massive amounts of data. For example, shipping market data, port terminal data, shipping talent data, ship transaction price data, shipping service data, etc. (Zhang & Han, 2016). The current wave of electronic informatization is coming, especially in recent years, the digitalization trend in the maritime field is obvious, and the application of big data is imperative (Zhang & Han, 2016).

Big data has broad application prospects in terms of safety supervision, business application, emergency management, public service and maritime security in the maritime field. For example, ship dynamic monitoring system, maritime cloud data, maritime management cross-departmental data sharing, AIS data, AIS virtual navigation mark application, GPS positioning system, maritime big data cloud service platform, one-stop real-time information services for ships, containers, and cargo platforms, port operation management, autonomous ships, and unmanned detectors can all be implemented using big data (Ren, 2021).

At the same time, visualized big data can provide shipping companies with predictive analysis, and provide a basis for route development planning by analyzing trade export volume (Ren, 2021) . Big data can also be applied to port heat, weather warning and customer analysis in the maritime field (Huang, 2020). Promote the development of the shipping e-commerce market. With the development of electronic information in the shipping market, big data will promote the construction of an integrated e-commerce network platform in the maritime field (Wang, 2021).

The latest shipping big data application concept has a multi-dimensional and multi-type big data route visualization system, a shipping enterprise customer relationship management system, and a full-information traceability and auxiliary decision-making system for the port production operation chain (Chang, 2020). These are expected to be applied in the future. Therefore, big data and data services have very good application prospects in the maritime field.

2.5 AI

2.5.1 Background

Since 1950, when Alan Turing proposed the Turing test to test the ability of a machine such as a human-machine dialogue, artificial intelligence (AI) has become the dream of computer scientists (Zhong, 2018). AI is the key enabler of so-called intelligent machines and intelligent systems. The key drivers of AI are the ever-increasing computer processing power, connectivity, and technologies such as voice and image recognition (Zhong, 2018). It provides the ability to analyze and make decisions far beyond human speed. AI must be a very broad field, including a lot of machine learning. For example, many aspects of deep neural networks, cognitive computing and natural language processing are classified as shown in Figure 9.

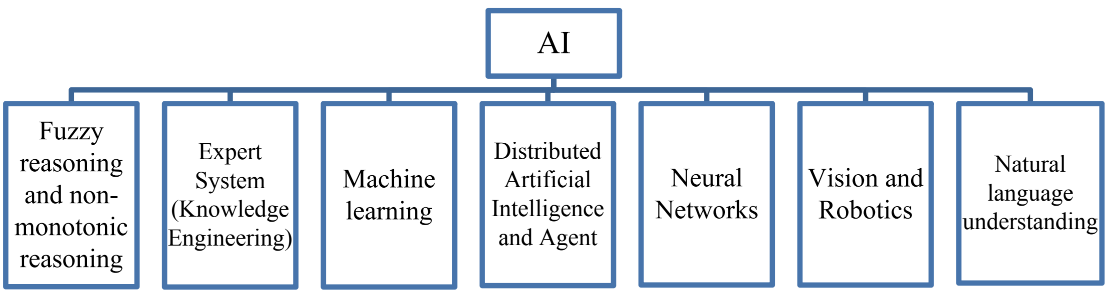

Figure 9-Classification of AI

Source: Shi, P., & Li, Y. (2007). Application of artificial intelligence in the field of ship collision avoidance. Journal of Guangzhou Maritime College, No.02, p. 1.

Humanity is entering Industry 4.0, of which Al is its driving force. Humanity's dream and pursuit of artificial intelligence can be traced back more than 3,000 years ago, but AI is still in its infancy. The development process of artificial intelligence is shown in Figure 10. However, driven by the investment of almost all major industry suppliers, Al is currently experiencing tremendous growth and will continue this trend.

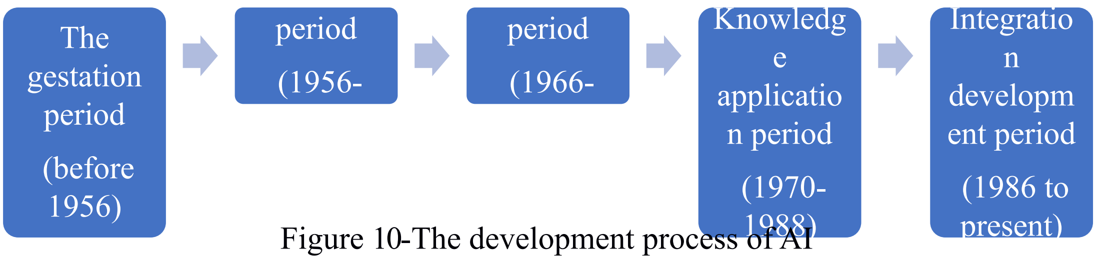

Figure 10-The development process of AI

Source: Author

2.5.2 Functions

AI has been used in some national defense research work and proved to be an effective tool for identifying and classifying maritime objects. It also has problem solving and game, logical reasoning and theorem proof, computational intelligence, distributed artificial intelligence and Agent, automatic programming, expert system, machine learning, natural language understanding, robotics, pattern recognition, machine vision, neural network, functions and applications such as intelligent control, intelligent dispatch and command, intelligent retrieval, system and language tools (Zhong, 2018).

There are three major commercial directions for artificial intelligence: one is information aggregation; the second is to evaluate users' emotional reactions; and the third is to build relationships with users (Cai, Liu, Cai, & Chen, 2016). Many fields extended through artificial intelligence will bring many job opportunities in the future. Artificial intelligence can also analyze large amounts of data in a short period of time. In the maritime field, the biggest function of artificial intelligence is to build unmanned ships and autonomous driving (OSO system) (Cai, Liu, Cai, & Chen, 2016).

2.5.3 Application prospects in the maritime field

Compared with other digital technologies, AI is more advanced and has a broader development prospect. It will greatly improve the efficiency of the port and other shipping departments. It will lead the shipping industry into the road of technological innovation. AI provides huge opportunities for all sectors of society, especially the maritime sector, who will benefit from being able to conduct business faster, cheaper and more efficiently. When using ships, oil rigs or any other platforms, AI may support manned and unmanned options. In the research of unmanned ships and autonomous driving technology, the AI application will be placed on the ships to further promote unmanned shipping (Rødseth & Håvard, 2017).

The application prospect of artificial intelligence in water traffic safety supervision is also broad. It can be applied to intelligent identification of water traffic violations, intelligent cruise and intelligent auxiliary decision-making. The application prospect in water search and rescue lies in the expert system of search and rescue in extreme weather conditions, ships in distress, personnel positioning, search and rescue and emergency response (Shi & Li, 2007) . The application of artificial intelligence technology in the field of collision avoidance has also achieved certain theoretical breakthroughs and practical values (Shi & Li, 2007). The application of technologies from fuzzy inference, neural network, expert system to CBR in the field of collision avoidance, the future collision avoidance system tends to be more systematic and intelligent (Shi & Li, 2007).

2.6 Machine learning

2.6.1 Background

Machine learning is a branch of artificial intelligence. With the continuous increase in the demand for data analysis in various industries in the era of big data, the efficient acquisition of knowledge through machine learning has gradually become the main driving force for the development of today's machine learning technology (Akyuz, Kadir, & Metin, 2019) . Machine learning is the core of AI and the fundamental way to make computers intelligent. From the perspective of the development process of AI, machine learning is another important research field of AI application after expert systems, and it is also one of the core research topics of AI and neural computing (Cai, Liu, Cai, & Chen, 2016).

The development process of machine learning can be roughly divided into four stages. The first stage was from the mid-1950s to the mid-1960s, which was a period of enthusiasm. The second stage, from the mid-1960s to the mid-1970s, was called the cool-down period of machine learning. The third stage, from the mid-1970s to the mid-1980s, is called the revival period. The fourth stage is the latest stage of machine learning in the mid-1980s. The latest phase of machine learning began in 1986. Knowledge discovery was first proposed in August 1989 (Cai, Liu, Cai, & Chen, 2016).

2.6.2 Functions

With the continuous increase in the demand for data analysis in various industries in the era of big data, the efficient acquisition of knowledge through machine learning has gradually become the main driving force for the development of today's machine learning technology. Machine learning becomes a support and service technology. It is not only used in knowledge-based systems, but also widely used in many fields such as natural language understanding, non-monotonic reasoning, machine vision, and pattern recognition (Akyuz, Kadir, & Metin, 2019).

Machine learning has functions such as data analysis and mining, and pattern recognition. It conducts in-depth analysis of complex and diverse data. Uses information more efficiently. Intelligent computing technologies such as machine learning and data mining play an extremely important role in the application of intelligent analysis and processing of big data (Akyuz, Kadir, & Metin, 2019). It can improve sustainability, improve transportation and reduce operating costs. It can also greatly improve operational efficiency and save manpower. In the maritime field, the application of machine learning also provides the greatest benefits for sustainable transportation.

2.6.3 Application prospects in the maritime field

Machine learning is not only used in knowledge-based systems, but also widely used in many fields such as natural language understanding, non-monotonic reasoning, machine vision, and pattern recognition (Akyuz, Kadir, & Metin, 2019) . With the gradual rise of shipping digitalization, machine learning has also been gradually applied to the maritime field. But compared with other industries, the scope of application of machine learning technology in maritime transportation is narrower.

Machine learning technology can be used in maritime network planning, voyage planning, cargo operation optimization, maintenance procedures, sustainable transportation, freight control, reinforcement learning, energy efficiency management, maritime safety improvement and other fields (Akyuz, Kadir, & Metin, 2019) . Among them, voyage planning includes operating fuel efficiency, minimizing crew load work, improving voyage estimation, calculating the best RPM curve, ship speed control, route planning, etc. (Akyuz, Kadir, & Metin, 2019) . The maintenance process includes helping to optimize the maintenance and repair work of the hull and engine.

In addition, the maritime field involves more data, which can help various tasks in the maritime field to proceed in an orderly manner. For example, ship intelligent collision avoidance decision-making, ship scheduling optimization, maritime safety information automatic classification and decision support, AIS track analysis and abnormal trajectory detection, autonomous unmanned boat collision avoidance, ship traffic safety warning, ship adaptive trajectory prediction, maritime case intelligence analysis, fault diagnosis of marine diesel engine, identification of marine traffic signs, etc. (Cai, Liu, Cai, & Chen, 2016).

CHAPTER 3 THE DEVELOPMENT AND APPLICATION OF DIGITAL TECHNOLOGY IN THE MARITIME FIELD

With the advent of the information age, digital technology is gradually being applied to the maritime field. The key digital technology applications used in the maritime industry are shown in Figure 11. In this traditional industry, the integration of digital technology seems like a fish in water, which has a lot of application space and development prospects.

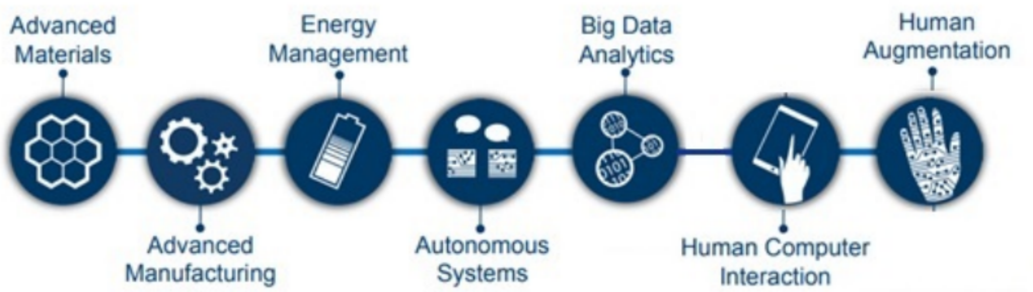

Figure 11-Technical Application in Maritime Field

Source: Yfantis, E. (2019). 4.0 challenges for the maritime sector The Cyprus Marine and Maritime Institute approach. Economy 4.0: Connected Future. Athens: Author.

In an interview in 2017, Dr. Martin Stopford suggested that digitization would be the best solution to achieve the best operation of the maritime sector (Lambrou, Daisuke, & Junya, 2019). The application area of digital technology in the maritime field can be roughly divided into the following six aspects.

3.1 Practical operation on board

3.1.1 Background

The shipping industry has always been traditional. There are many places where a lot of manpower is needed in terms of practical operations on board. Nowadays, with the deepening of shipping digitization and the wide application of digital technology. The machinery and equipment on board and the overall actual operation are moving towards digitalization and intelligence.

Advanced digital technologies such as big data, IoT, artificial intelligence, and machine learning have gradually replaced the original on-board practical technology. Such innovation can greatly improve the accuracy and efficiency of practical operations. The application of digital technology on ships is the development trend and the only way in the maritime field.

3.1.2 Development and application

Many operations on the ship that require manpower to complete manually can be replaced by digital technology. Existing smart devices will also be updated with the deepening of the application of digital technology in the maritime field. For example, VHF devices, machinery and equipment, sensors, etc. Establish a ship AIS supervision system based on a big data platform, and realize the supervision and identification of ship AIS equipment through the analysis of AIS data (Mei, 2007). Realize the real-time data transmission of marine equipment, electrical installations and other shipboard equipment and instruments.

The application of digital sensors helps to realize scene perception, including regular acquisition of long-term and short-term weather forecast data on the route, real-time perception of environmental weather data during navigation, real-time perception of own ship information, real-time acquisition of real-time video picture information in all directions of the ship's level, and timely Obtain the data and information update of the electronic chart involved in the planned route, obtain the port tide change information and other relevant environmental information, etc. (Kvamstad-Lervold, 2017) . Use shipboard data for AIS data analysis, ship performance analysis, and operating equipment analysis.

3.2 Maritime trade

3.2.1 Background

With the emergence of Covid-19 and the advent of Industry 4.0, world trade has begun to change under the influence of digital trends. For example, the rise of e-commerce platforms has promoted the prosperity of trade. The maritime field is no exception. Many digital technologies have had a significant impact on maritime trade. New big data analysis and IoT applications are developing rapidly. They are applied together with digital technologies such as blockchain in the field of maritime trade, making maritime trade globalized and promoting the transformation and upgrading of maritime trade (Stopford, Maritime Economics 3e, 2008) . The development of global trade in 5000 years is shown in Figure 12. Judging from this trend, maritime trade has broad prospects for development.

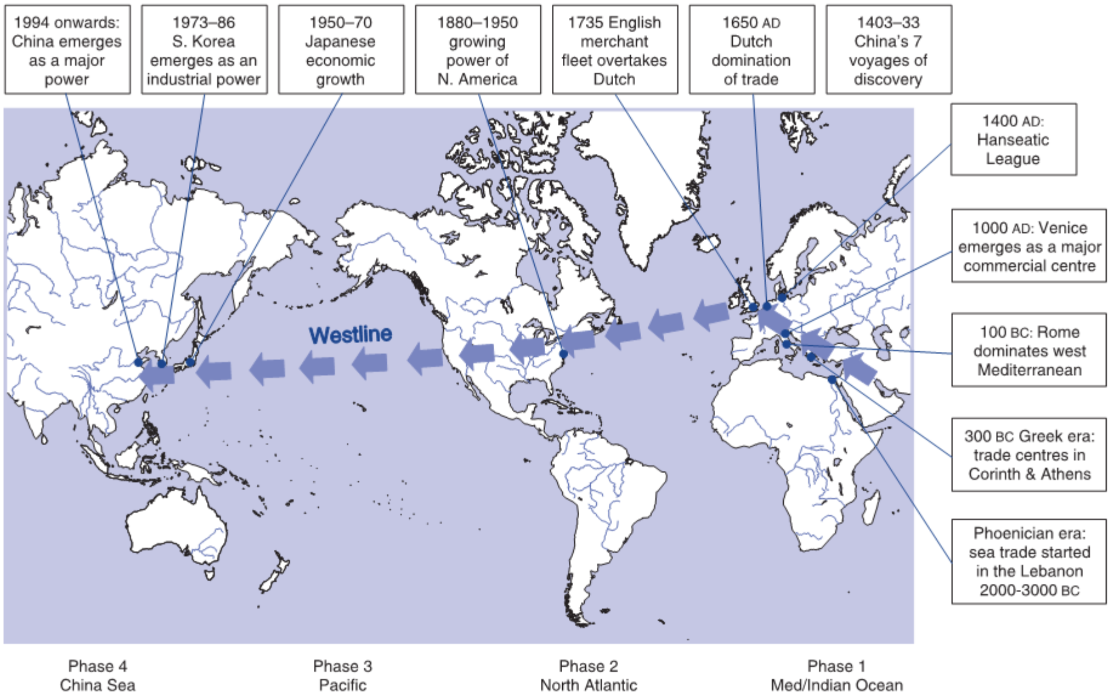

Figure 12-The West line: 5,000 years of maritime trading centers

Source: Stopford (2008)

3.2.2 Development and application

With the development of electronic information in the shipping market, the establishment of an integrated e-commerce network platform in the maritime field by big data can effectively promote the rapid development of maritime trade (Stopford, Maritime Economics 3e, 2008) . Unite ship terminal manufacturers and shipping information platforms (Dong & Liu, 2010). Promote the design and implementation of a single-window manifest data sharing system for maritime international trade. Establish shipping database, trading platform and electronic port platform (Liu, 2016) . Cooperate with high-precision technologies such as the IoT/IoS, cloud services, and cloud computing to realize the storage and management of massive data (Chang, 2020). Build a public information platform, improve the functions of data collection and integration, and fully serve the maritime trade field, including port logistics and customs clearance services.

The application of the IoT/IoS and blockchain technology has strengthened the information construction of port ports, the emergence of "virtual ports", the rapid development of shipping e-commerce, and the emergence of integrated supply chain management such as collective ship transactions, cruise bookings, and ship material supply (Huang, 2020). Shipping e-commerce platform. And use big data to evaluate and analyze maritime trade data such as freight index, ship prices and market intelligence, ships and shipyards (Wu, 2020). This will promote a higher level of information fusion among supervisory departments such as ports and trade.

Digitization will help importers and exporters to monitor the status, location and movement of goods in real time, thereby helping them make more informed decisions in areas such as sales, marketing, and logistics (Zhang & Han, 2016) . Shippers, freight forwarders, brokers, agents and other cargo trackers will be able to track all cargo-related transactions online through digital technology. The digitization of bills of lading has also been put on the agenda. According to the needs of each electronic bill of lading, a legal basis that provides appropriate support for blockchain technology is required (Zou, 2020). In recent years, various port cities are also working hard to build regional shipping centers. The application of big data in maritime trade is far beyond our imagination, and will initiate a new round of changes with the participation of shipping e-commerce (Chang, 2020).

3.3 Shipbuilding Technology/Unmanned Ship

3.3.1 Background

Within the scope of Maritime 4.0, a commercial ship transformation was proposed.

Intelligent manufacturing is the only way for the development of the shipbuilding industry. With the in-depth adjustment of the global ship market, the shipbuilding industry must accelerate structural adjustment and digital transformation and upgrading. More and more companies are beginning to realize the importance of informatization construction and intelligent manufacturing upgrades (Du & Pang, 2015). They must accelerate the integration of intelligent technology and shipbuilding technology, and accelerate the improvement of ship construction efficiency and reduce resource consumption through the widespread application of intelligent processing equipment (Dong & Liu, 2010). To achieve the goal of reducing costs and enhancing competitiveness.

Human factors in maritime accidents, the negative impact of long voyages on seafarers' social life, and the reduction of ship carbon emissions all support the idea of transforming existing ships into autonomous ships. With the rapid development and application of intelligent technology, the autonomy of ships will become the inevitable trend of future shipping development. The development of unmanned ships is gradual and phased. With the improvement of the level of autonomy of ships, it will gradually replace the people on board, and finally realize the unmanned autonomous navigation of ships (Lloyd's Register Group Ltd, 2017). In this context, AI and machine learning are widely used in the research and development of unmanned ships, and continuous development and innovation in the advancement of digital technology.

3.3.2 Development and application

In the field of shipbuilding, digital technology integrates information technology, advanced manufacturing technology, automation technology and AI technology to establish intelligent production lines through intelligent innovation, and finally builds intelligent workshops and intelligent workshops (Zhao & Liu, 2021). The emergence of ships that can realize remote driving and unmanned driving. As an important part of intelligent shipping, unmanned ships are developing rapidly in the information age. With the rapid development of technologies such as big data and AI, the technical bottleneck restricting the development of unmanned ships has gradually been resolved.

Each system on the unmanned ship will use a separate control algorithm. But the control algorithm applied to autonomous ships is sometimes not enough, especially in port operations, where human factors are still very effective in critical situations (Lloyd's Register Group Ltd, 2017). The unmanned ship can feed back the real scene of the water area from the first perspective, form a mobile high-density coverage in the target water area, and play an important role in multiple fields such as cruise supervision, investigation and evidence collection, life rescue, and pollution prevention of dangerous pipes . The application of unmanned ships can divide ship operation scenarios, identify risk events, carry out risk analysis, propose control measures for risk events, and form the goal of autonomous cargo transport ships.

3.4 Port technology development

3.4.1 Background

In recent years, the construction of smart ports has attracted more and more attention. It is a digital representation of port jurisdiction, management objects and management activities. It is a hub for various modes of transportation in port cities and an operating platform for modern logistics (Huang, 2020). Automated and fully automated ports using unmanned handling equipment should become commonplace to increase the speed of port operations (Fan, 2007) . The application of digital technology to innovate traditional ports is an inevitable trend for future port development. In this context, digital technologies such as big data, IoT, blockchain, and AI have been successively applied to the construction of digital ports.

As shown in the figure 13, the port technology includes the shore power system of the docking ship, the ship's side high voltage shore power system, the ship docking speed measurement system, the rail crane/tyro crane automatic control system, the energy monitoring system, the automated quay crane system, and the bulk cargo yard Intelligent sprinkler system, three-dimensional simulation linkage, unattended weighbridge system, etc.

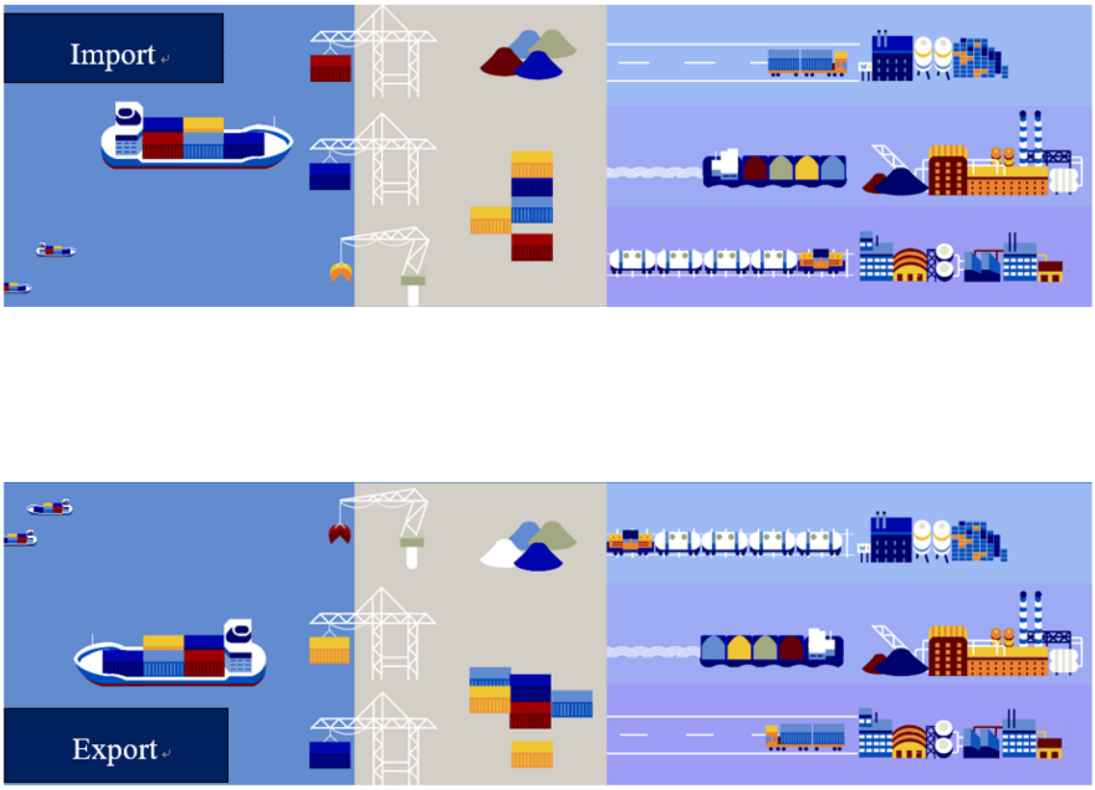

Figure 13- Intelligent port solutions

Source: INTELLIGENT PORT SOLUTIONS. (2018). Retrieved from NAVSTON TECHNOLOGY: http://www. navston.com

Digital technology can help ports achieve effective control of remote resources, build a powerful perception system and monitoring system, and fully control remote information resources such as waterways and anchorages (Fan, 2007). Realize a high degree of sharing of information resources. Under the effective integration of port information resources, fully integrate the information resources of government departments, port units, and port and shipping companies to build an integrated development that integrates port management, security communications and real-time monitoring Pattern (Qi, Su, & Yan, 2020).

3.4.2 Development and application

Smart ports represent the best level of port productivity, so some processes are used in the operation process, such as the IoT, information and communication technology (ICT), big data and environmental protection technology (Qi, Su, & Yan, 2020). The application of digital technology is mainly to use big data to establish data collection and database, visualized management, dynamic supervision of port production processes and intelligent decision-making early warning (Dong & Liu, 2010) . Through various sensing devices such as RFID and AIS terminals and video surveillance, it can effectively collect all-round information of the port. Use the Internet, mobile communication network and VHF communication network to transmit the data information collected by the sensing terminal to the server (Du & Pang, 2015).

The application of AI in the port can realize automated loading and unloading and intelligent tallying through automation (Huang, 2006). When the goods arrive at the yard, autonomous ground port vehicles and remote port cranes for transportation are used, including intelligent dispatch between yards, and security within the port area (Huang,2020). The port infrastructure has been continuously optimized and improved.

There will be big data centers with ports as the unit. There is also the customs clearance environment at the port. The overall efficiency is not only the terminal itself, but also the port's customs clearance environment. To achieve rapid inspection, and the entire inspection process is visible.

The technology of the IoT is widely used in the fields of logistics trans (Huang, 2020). To better apply the IoT to the land transportation links outside the port, make full use of wireless communication tools and necessary sensor equipment to better realize the port IoT system (Qi, Su, & Yan, 2020). The port big data analysis system must also be able to be in port physical. The application of IoT technology in the process of continuous management effectively penetrates the port big data analysis system into the overall process of port logistics management (Qi, Su, & Yan, 2020).

The smart port operation department has been committed to improving the port's total throughput capacity by effectively using the shared data in the dock area (Huang, 2020). Information sharing and transmission are carried out on the basis of IoT/IoS (Du & Pang, 2015) . Use system theory and optimization technology for process design and transformation. The information system is applied to the management of the supply chain. The integrated port data platform, digital port supporting technology system, digital port information management system and digital port security system based on digital technology will also become important technologies supporting the development of port technology (Huang, 2020).

3.5 Registration

3.5.1 Background

Affected by the Industrial Revolution, registration in many areas has become online. The registration procedures in the maritime sector are lengthy and diverse, and digital registration has become the current and future development trend. Paperless handling of crew certificates is now popular. This move of digital technology has greatly facilitated the crew and improved the efficiency of business processing. The IoT/IoS, and big data can solve this problem for maritime business handling, greatly improving work efficiency, simplifying the registration process and time, and reducing the workload of personnel.

3.5.2 Development and application

With the deepening of the construction of a free trade port, a more open shipping policy will be implemented and an international ship registration system that is in line with international standards will be established. The IoT/IoS will set up an online service platform for ship registration, crew certificate processing and other businesses, and innovatively establish convenient and efficient ship registration procedures in the maritime field (Group, 2019).

On the basis of the IoT/IoS technology, ship networking technology has been promoted and applied. Establish a data sharing platform for registration and realize online processing. Promote electronic certificates and provide shipping certificate mailing services. With the development of the Internet, maritime registration will become more and more convenient.

3.6 Maritime management

3.6.1 Background

Maritime management is the coordinated activity of command and control of maritime agencies at all levels. It usually includes the formulation of policies and objectives, the planning and control of maritime management, and the continuous improvement of maritime management (Ellingsen & Knut, 2019) . With the development and popularization of information technology, people's information literacy has been significantly improved, which has changed society's work and lifestyle.

The informatization work of maritime institutions has achieved remarkable results. More and more digital technologies, such as big data, IoT/IoS, AI, etc., and more and more information technologies, such as VTS, CCTV, GIS, OA System, etc., are applied to the field of maritime management (Du & Pang, 2015). The role of "digital maritime" in maritime management is becoming more and more obvious.

3.5.2 Development and application

The creative use of information technology in maritime organizations can enable maritime organizations to reduce costs, improve the speed and accuracy of information decision-making processing, and maintain the level of maritime management and advanced productivity (Ellingsen & Knut, 2019). For example, the establishment of a “digital platform” for the reorganization of maritime management business processes and the establishment of a global ship management system (PAL ERP 2G) (Du & Pang, 2015). The application of digital technology can be more in line with objective reality and break the boundaries between departments, units, and regions.

Big data technology through the application of data preprocessing and data mining technology, this method can realize the automatic analysis and reasoning of maritime data information to realize the function of safety assessment (Wu, 2019). This provides forward-looking guidance for the scientific deployment of maritime supervision resources, improves the intelligence level of the VTS system, and relieves the work pressure of supervisors (Ellingsen & Knut, 2019). It can be seen that this method can be used in existing VTS systems.

The IoT/IoS also plays an important role in maritime management. More and more services are carried out onshore. Including route planning/optimization (electronic navigation), administrative procedures, monitoring and maintenance plans, performance monitoring and technology (Ellingsen & Knut, 2019). This requires the maritime department to install a virtual private network (VPN) based on the IoT/IoS, which constitutes a maritime ship traffic management information network based on all ships AIS, with the AIS monitoring center as the core, and the maritime AIS network as the link (Ellingsen & Knut , 2019). It has become an important part of the maritime information network, providing important conditions for realizing the modernization of maritime management. With the continuous improvement and development of digital technology, the application of AIS in maritime management will also continue to expand (Qiang, 2020). As a new science and technology, AIS has promoted the informatization and intelligent construction of maritime management (Qiang, 2020) . It is compatible with other information technologies. The combination has promoted the construction of "digital maritime" .

CHAPTER 4 THE IMPACT OF THE INDUSTRIAL REVOLUTION IN THE MARITIME SECTOR

The Industrial Revolution is a stage in which capitalist production has completed the transition from workshop handicraft to machine industry. The production and technological revolution of replacing manpower with machines and replacing manual production in individual workshops with large-scale factory production. This process brought some obstacles and threats, but also provided opportunities and strength for the department. Since the Industrial Revolution, technological progress has led to a sharp increase in industrial productivity. It has promoted the development and transformation of many areas of society, especially in the maritime field where there is a lot of room for development.

From Industry 1.0-4.0, industrial technology progress has shown a gradual growth pattern. The evolution of the four industrial revolutions is shown in Figure 14. Under the influence of the Industrial Revolution, the maritime field is constantly undergoing innovations, from the traditional shipping industry to digital and intelligent shipping in two steps (Valco & XING, 2019). In particular, the impact of Industry 4.0 on the maritime sector may change the entire industry. The following describes the impact of the four Industrial Revolutions on the maritime field, and will focus on the impact of Industry 4.0.

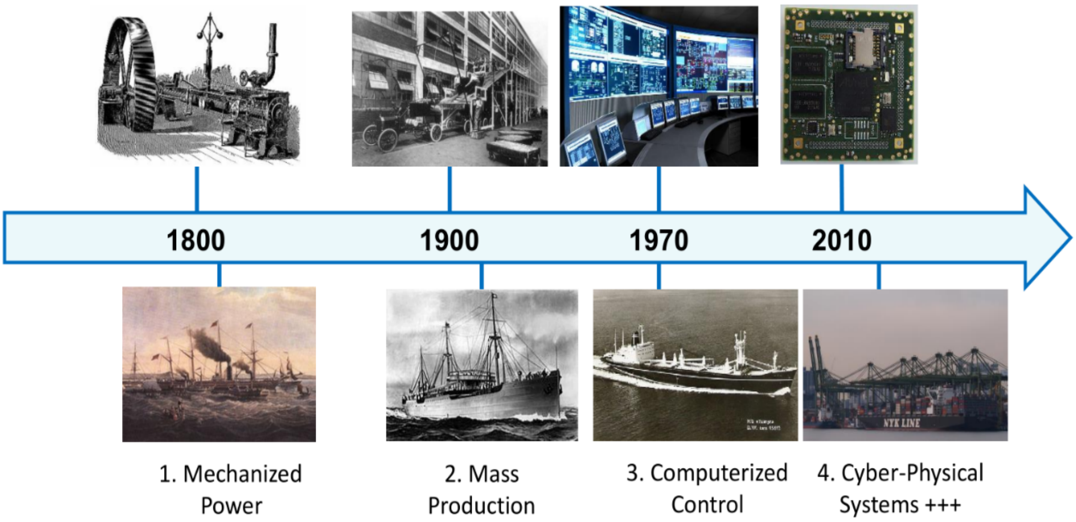

Figure 14-The course of the four Industrial Revolutions

Source: Kvamstad-Lervold, B. (2017). 9 PATHS INTO THE MARITIME FUTURE. Retrieved from SINTEF.

4.1 The impact of Industry 1.0

Occurred in the 1860s-mid-19th century. Industry 1.0 first occurred in Britain, and this Industrial Revolution was in the handicraft stage. Realize the mechanization of specialized manual operations. At the end of the 18th century, steam power was used in mechanized production to promote technological development, which was called Industry 1.0.

In 1807, American Fulton invented the steamship. After entering the 19th century, the steam engine became a universal and convenient power machine for ships, which contributed to the prosperity of the shipping industry. It can be said that the transformation of human water transportation technology began with the use of steam engines. Therefore, the impact of Industry 1.0 on the maritime field is mainly reflected in the improvement and popularization of steam engines.

4.2 The impact of Industry 2.0

It happened in the second half of the 19th century-the beginning of the 20th century. The sign of Industry 2.0 was that meat factories in Chicago and Cincinnati began to use electricity and assembly lines to achieve mass production in the 1870s. In Industry 2.0, the most representative technology was the invention of the internal combustion engine and the application of electrical technology. Therefore, the impact of Industry 2.0 on the maritime field is mainly reflected in the invention, promotion and application of internal combustion engines.

4.3 The impact of Industry 3.0

Approximately after the Second World War. In 1969, Modicon designed the first programmable logic controller (PLC) in the United States, large-scale industrial production was put into production, and humanity realized automation through the use of electronics and information technology, thus entering Industry 3.0 industrial revolution period in the second half of the 20th century.

Humanity has entered the era of science and technology, and the maritime field has gradually appeared in the development of informatization. The economic transition from globalization to continentalization (regionalization) has caused changes in the shipping space pattern (Zhen, 2017) . Changes in energy structure have caused changes in transportation methods. The traditional large-scale shipping methods have changed to flexible and customized transportation methods (Zhen, 2017) . The transformation of the entire logistics organization mode of supply chain services, and the transformation from exclusive logistics resources to shared logistics resources, etc. (Broker, 2018).

4.4 The impact of Industry 4.0

Now, we are in the fourth wave of technological progress. The rise of new digital industrial technology has led to another transformation of industry, which is often referred to as Industry 4.0. Industry 4.0, which is actually "built on the basis of the Industry 3.0". The digital revolution has occurred since the middle of the 20th century. It represents a series of highly disruptive technologies, such as AI, robotics, blockchain and 3D printing, but there are differences in the maritime field (Bucak et al., 2019). The difference in technology in the maritime field is shown in Figure 15.

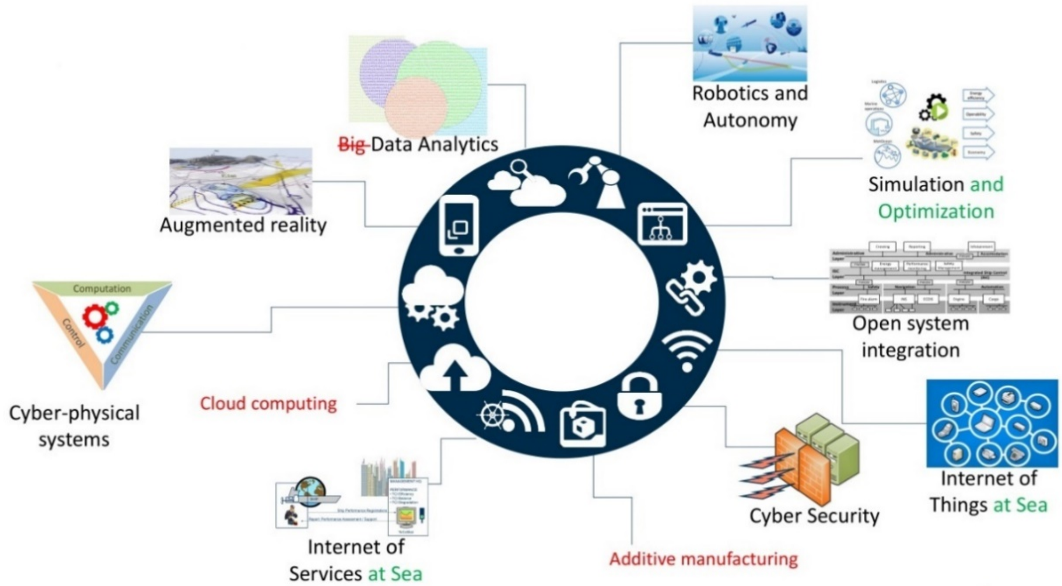

Figure 15-Industry 4.0 technology in the maritime field

Source: Kvamstad-Lervold, B. (2017). 9 PATHS INTO THE MARITIME FUTURE. Retrieved from SINTEF.

Maritime 4.0 provides new opportunities for new market entry, horizontal and vertical integration, new safety and security solutions, etc (Athos, Wagner, Francesco, & Giovanni, 2019) . The maritime field requires large human resources and huge data processing workloads. The unmanned ship technology and data analysis technology, maritime IoT, maritime IoS, cyber-physical systems, open system integration, etc. spawned by Industry 4.0 in the maritime field will help the maritime field to reduce manual labor and replace it with autonomous machines and AI. It has had a profound impact on the digital development of the maritime field.

4.4.1 Unmanned ships and autonomous ships

"Industry 4.0" makes the maritime field face transformation and upgrading, and promotes the integration of the maritime field into the wave of intelligence and digitalization. Most companies gradually apply robots and intelligent equipment. Highly developed artificial intelligence is most commonly used in what we call "autonomous machines". As shown in Figure 16, unmanned ship and autonomous ship technology are one of the manifestations of AI. In Industry 4.0, automated ship technology is still regarded as essential. Minimizing human errors, reducing ship carbon emissions, and minimizing accidents are directly related to automation technology.

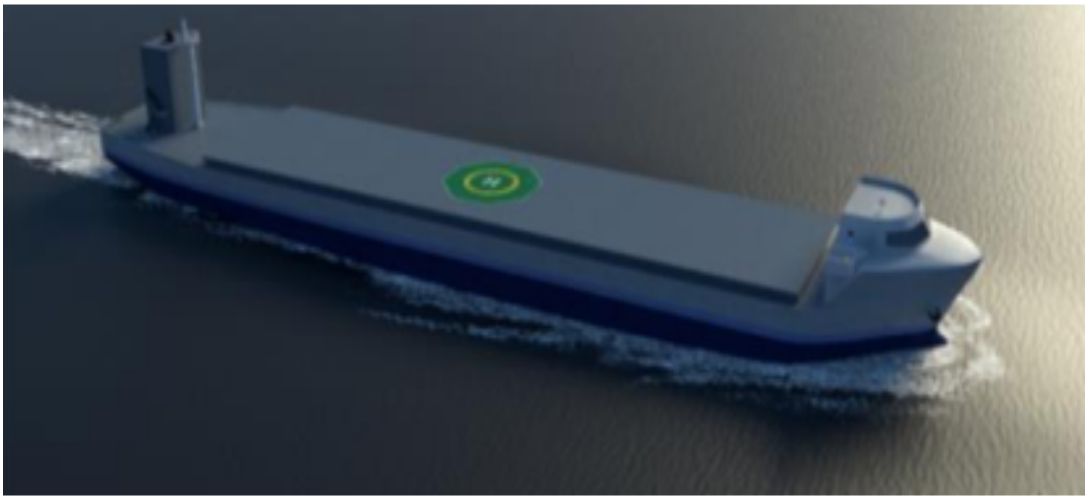

Figure 16-Autonomous vessels

Source: RØdseth, Ø., & Håvard, N. (2017, 10 10). Definition for autonomous merchant ships. SINTEF Ocean AS. Retrieved from http://astat. autonomous-ship. org/

In the past Industrial Revolution, robots have replaced human workers, and the maritime field is at the stage of technological exploration for unmanned ships and autonomous ships. At present, robots and intelligent equipment such as unmanned detection vessels, unmanned underwater detectors, small automatic barges, and unmanned underwater vehicles for inspection and maintenance have been put into use or tend to be put into use, and have achieved forward-looking results (Zhao & Liu, 2021). In the future, Industry 4.0 will make them more intelligent. The concept of unmanned ships is different from autonomous ships. Combining the level of staffing and operational autonomy, we can define different types of ship autonomy, as shown in Table 4. Industry 4.0 also promotes the manufacture of autonomous ships.

Table 4-Ship autonomy types

	Manned bridge	**Unmanned bridge - crew on board**	**Unmanned bridge - no crew on board**
Decision support	Direct control No autonomy	Remote control	Remote control
Automatic	Automatic bridge	Automatic ship	Automatic ship
Constrained autonomous	-	Constrained autonomous	Constrained autonomous
Fully autonomous	-	-	Fully autonomous

Source: Radseth, Ø. J. & Håvard, N. (2017). Definition for autonomous merchant ships. SINTEF

Ocean AS. Retrieved October 10, 2017 from http://astat.autonomous-ship.org/

The ship uses digital technology for remote control without anyone operating reliably on the bridge. Together with autonomous ships, new business areas and subsidiary departments will be formed (Rødseth & Håvard, 2017) . According to the plan, unmanned ships and autonomous ships will operate at low speeds (slow speeds). This means reducing carbon emissions from ships. Therefore, Industry 4.0 has also indirectly enhanced environmental protection in the maritime field.

Digital technology under Industry 4.0 provides automated processes and decision support for unmanned ships and autonomous ships. Enable the autonomous ship's operating system to make decisions and decide actions on its own. Unmanned ships provide shipowners with cost advantages, can be used as a safer means of transportation, and have great development prospects. Autonomous and autonomous shipping technology has been developed for many years and will continue to develop for many years to come.

4.4.2 Other impacts

In the maritime industry, the different components of Industry 4.0 describe this new technology. Many different topics, such as autonomous ships, shipping digitization, smart ports, big data analysis, blockchain technology, etc., have been tested and studied in this field (Zhao & Liu, 2021). Among them, the high throughput potential of ports is the most important opportunity provided by Maritime 4.0. Industry 4.0 makes data sharing more and more important, especially when big data can be processed. The potential uses of Industry 4.0 go far beyond the optimization of production technology. The comprehensive analysis and use of data are the key capability of Industry 4.0.

As we all know, various tasks in the maritime field require the support of a large amount of data, whether it is data during voyages at sea or data on shore-based incident management. The processing and analysis of these data is a huge task. The future digital maritime affairs will generate huge amounts of data, all of which need to be stored, processed and analyzed (Ghobakhloo, 2020) . The digital and information technology brought by Industry 4.0 can greatly reduce human data processing and analysis, and can use intelligent technologies such as machine computing to analyze data accurately and provide decision-makers with a basis for decision-making (Bucak, Mehmet, & Hakan, 2019) . Business processes related to transportation have been transferred to the visualization platform. Due to the nature of digitalization, the need for manpower is decreasing, thereby minimizing the risk of human error (Zhen, 2017).

Shipping technology and application development are in progress. Energy efficiency optimization, ship automation and autonomy, network security and data protection, big data analysis, and 3D/4D printing are development trends (Kvamstad-Lervold, 2017). Digital equipment such as ECDIS and navigation simulators, which have been widely used, can automatically display sea charts and simulate sea navigation scenes. Allows the crew to judge the navigation situation more clearly, which greatly reduces the navigational hazards. The navigation simulator also allows students to wait for the navigator to practice ship navigation skills through simulated operations. These are all digital technologies and digital devices that are spawned under the background of Industry 4.0. It can be seen that Industry 4.0 has a huge impact on the maritime field.

4.4.3 Negative impacts

In addition to the positive impact of Industry 4.0, it also has a negative impact on certain elements of the maritime field. For example, investment in the technology needed for Industry 4.0 is potentially risky. In addition, in today's digital world, the number of qualified staff may be insufficient. Especially when it comes to managing robots, the staff with expertise is very limited. In terms of cyber security, within the scope of Industry 4.0, due to the reliance of autonomous ships and fully automated or semi-automated ports on software, if cyber-attacks are achieved, the maritime sector may face great dangers (Zhen, 2017).

In addition, subject-based big data analysis data sharing may cause some problems. It will encourage companies with higher financial resources to access and use information, and put small businesses in a more difficult situation (Meadow, Ridgwell, & Kelly, 2018) . The lack of legal infrastructure is also the top priority among the negative effects of Industry 4.0. The risk of unemployment is also prominent (Xin, 2015). It and the risk of shortening the distance between the market and the production center are seen as major threats.

CHAPTER 5 COUNTERMEASURES

The advent of the digital age has not only brought unprecedented opportunities to the maritime field, but also brought risks and challenges. In order to seize the opportunities brought by Industry 4.0, and be able to deal with various problems after the application of digital technology in the maritime field. Countries should take decisive measures to minimize risks. Only in this way can we welcome the advent of digitalization in the maritime field in the best possible state. The countermeasures are elaborated from the following aspects.

5.1 Social acceptance

In order to support the maritime industry to move towards a digital future, the following countermeasures are proposed.

1. Create an infographic on what long-distance and autonomous shipping mean in the marine world.
2. Create an information map for the general public that emphasizes essential facts about the shipping sector as well as current operational statistics (Meadow, Ridgwell, & Kelly, 2018).
3. Make it clear to the industry (particularly seafarers) that robots will not take their employment.
4. Fifth, act to encourage society to embrace new technology from sea and shore workers.

5.2 Skills and education gaps

In order to close the skills and education gap between seafarers after digital transformation, the following countermeasures are proposed.

1. Match the digital ship's functions to the needed qualifications.
2. The industry will continue to require workers, but roles, responsibilities, and training will change. Create a training course structure that is compatible with the future responsibilities and functions of sea-based and shore-based operators (Meadow, Ridgwell, & Kelly, 2018).
3. Collaboration with training providers is encouraged, as is sharing future skill requirements.
4. Provide on-the-job training to seafarers as soon as possible.
5. Countries must develop human capital with new skills to assist seafarers in becoming relevant personnel and maintaining current knowledge to support them in the future (Meadow, Ridgwell, & Kelly, 2018).
6. The goal is to get the expertise of the senior personnel on board.
7. Employees on shore must also have a strategic plan.

5.3 Industry Cooperation

In order to deal with digital issues more efficiently, industry cooperation is essential. Not only can we better avoid risks in cooperation, but also promote the rapid development of digitalization. The following countermeasures and suggestions are specifically put forward.

1. Continue to enhance the roadmap or framework for workforce succession planning, training, and education.
2. Coordinated discussions among stakeholders are required to ensure that the consistency of information and opinions is considered (Meadow, Ridgwell, & Kelly, 2018).

3. Create a skills matrix to establish the crew's abilities/functions in currency jobs, transition arrangements, and plans for the next 25 to 30 years (Meadow, Ridgwell, & Kelly, 2018).
4. Collaborate with regulators to assist them comprehend industry developments and to build a regulatory framework that allows the sector to employ new technology for development (Meadow, Ridgwell, & Kelly, 2018).
5. Collaborate with business, regulatory agencies, and technology suppliers to test the system for exceptions.

CHAPTER 6 CONCLUSION

Based on the impact of the industrial revolution, the digital age is approaching. In the context of this era, digital technologies such as cyber-physical systems, blockchain, IoT/IoS, big data, AI and machine learning can be developed and applied on a large scale. And it is expected that the digital technology will be reasonably applied to the corresponding maritime field at a reasonable time. In essence, these digital technologies are inseparable from each other, complement each other, and jointly promote digital development. This will usher in earth-shaking changes in the maritime field, making the maritime field face unprecedented opportunities and challenges.

Digitization in the maritime field is a trend. It is an area that people have been researching and exploring. This article reviews the evolution of the shipping era under the influence of the Industrial Revolution and the development of digitalization. The concept of digital shipping is introduced. The concept and principle of digital technology are introduced, and the applications and development prospects of various digital technologies in the maritime field are enumerated through examples. The application, influence and development prospects of various digital technologies in the maritime field are reviewed. In view of the industrial revolution, especially the impact of Industry 4.0 on the maritime field, it summarized and predicted the future development trend. Finally, it puts forward countermeasures and suggestions for the development of digitalization in the maritime field.

Facing the digital trend in the maritime field, we must have the courage to try, innovate, and improve. The maritime sector should seize the opportunity of Industry

4.0 and be brave enough to learn from the digital transformation experience of other industries in the digital age, such as digital aerospace. Fully and reasonably apply cyber-physical systems, blockchain, IoT/IoS, big data, AI and machine learning technologies, and sum up experience after each experiment. Digitization is a changing concept. Therefore, while applying digital technology, it is necessary to take precautions before they occur and formulate reasonable countermeasures. In summary, digitization and digital technology have great influence and application prospects in the maritime field. It will help the maritime field to flourish and open up new horizons. Digitalization in the maritime field has a bright future and the future can be expected.

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