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Navigation service with perspectives of digital technology developments in maritime sector

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NAVIGATION SERVICE WITH PERSPECTIVES OF DIGITAL TECHNOLOGY DEVELOPMENTS IN MARITIME SECTOR

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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 is 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.

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ABSTRACT

Title of Dissertation: **Navigation service with perspectives of digital technology developments in maritime sector**

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Under the perspectives of digital technology developments in maritime sector, the dissertation will show the navigation service system used before and currently used in China by means of literature review and general analysis. With rapid development of modern technology such as Internet of Things, big data, Artificial Intelligence, Maritime Autonomous Surface Ship and so on, the navigation service system comes to a new stage where there will be a long time for human-machine mixing period from the traditional to the intelligent. After the introduction and significance, the current navigation service system in China will be discussed in the next three aspects: historical evolution with seven stages, main structure of the Navigation Service Centers of the People's Republic of China and legal regime. In addition, the other states' navigation service system will be introduced as well, like UKHO, USCG and JCG. Then, there will be an example to show one kind of intelligent aids to navigation used in the Grand Canal involved in data acquisition equipment, management system, principle of realization and functions, and main technical innovation points. Finally, the concept of the integrated navigation service system will be introduced and clarified with suggestions to the significance and main construction contents.

KEYWORDS: Aids to navigation; digital technologies; navigation service; integrated navigation service system; Navigation Service Center

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LIST OF ABBREVIATIONS

5G	Fifth generation network
ACDP	Acoustic Doppler Current Profiler
AI	Artificial Intelligence
AIS	Automatic information system
AtoN	Aids to navigation
Bd-MCORS	Beidou Marine continuous operation reference station system
CCTV	Closed Circuit Television
CN	China
CPU	Central Processing Unit
CSSA	Common Shore System Architecture
DBD	Differential Beidou Satellite navigation system
DGNSS	Differential global navigation satellite system
DGPS	Differential Global Position System
DMA	Defense Mapping Agency
ENAV	E-Navigation Committee
ENC	Electronic navigational charts
EU	European Union
GPRS	General Packet Radio Service

GPS	Global Position System
GSM	Global System for Mobile Communications
IALA	the International Association of Marine Aids to Navigation and Lighthouse Authorities
IHO	International Hydrographic Organization
IMO	International Maritime Organization
IoT	Internet of Things
JCG	Japan Coast Guard
MASS	Maritime Autonomous Surface Ship
MCU	Micro-programmed Control Unit
MOC	Ministry of Communications
MOT	Ministry of Transport
MSA	Maritime Safety Administration
MSP	Maritime Service Portfolios
NAVDAT	Navigational data
NOAA	National Oceanic and Atmospheric Administration
NSC	Navigation Service Center
NSS	Navigation Service System
RBN-DBDs	Radio beacon differential Beidou satellite navigation system
RBN-DGNSS	Radio beacon differential global navigation satellite

system	
RTU	Remote terminal unit
SIP	Strategy Implementation Plan
SMS	Short Messaging Service
TCP	Transmission Control Protocol
TTL	Transistor-Transistor Logic
UAV	Unmanned Aerial Vehicle
UDP	User Datagram Protocol
UK	United Kingdom
UKHO	United Kingdom Hydrographic Office
US	United States
USB	Universal Serial Bus
USCG	United States Coast Guard
VDES	VHF Data Exchange System
VTS	Vessel Traffic System
WIFI	Wireless Fidelity

CHAPTER 1 INTRODUCTION

1.1 Background

In 2006, the International Maritime Organization (IMO) approved one proposal from its 7 member states to start the e-Navigation strategy, whose original objective is to develop a system to provide a higher safety and risk prevention for reducing the maritime accidents. Internationally, the Maritime Autonomous Surface Ship (MASS) has been included in the IMO work plan, and e-Navigation Committee (ENAV) of the International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA) has also set up a working group to study new technologies such as intelligent shipping. IALA is a nonprofit international technical association founded in 1957 and devoted to improve and harmonize the global marine Aids to Navigation (AtoN) to make ships safer and efficient. Since 2006, the ENAV has devoted to play a leading role in designing and formulating the e-Navigation Strategy Implementation Plan (SIP) under the IMO's e-Navigation framework. The ENAV also puts the e-Navigation concept into practice and a considerable number of relevant works, as well as the following technical sectors: data modelling and message systems, e-Navigation communications, shore technical infrastructure, e-Navigation test beds and maritime services portfolios. Under the leadership of IMO and the joint efforts of international organizations and institutions such as IALA, the concept of e-navigation has developed from abstract theory to integrated navigation service information system. Its strategic idea is to develop a highly intelligent and shared integrated data application system, which can be updated in real time, continuously improved, rapidly integrated and analyzed maritime information, and provide timely, rich and comprehensive information services for relevant personnel

engaged in maritime shipping, communication business and maritime security. The achievements of e-Navigation construction are constantly emerging and playing a huge role. In China, Artificial Intelligence (AI), supercomputing, Internet of Things (IoT), big data and other new technologies are on the stage， and the outline for building a Leading Transportation Nation has been issued. Meanwhile, the construction of intelligent shipping represented by "intelligent port" and "intelligent ship" is getting better and better, which puts forward higher requirements and standards for the navigation service business, which indicates that the navigation service has entered a new era, the traditional navigation service is in urgent need of transformation and upgrading, and the construction of intelligent navigation service with perspectives of digital technologies is imminent (Zheng, 2021, 72).

The shipping industry is one of the oldest industries in the world. As the most important mode of trade and transportation in the world, the five continents are closely linked, and people all over the world are heading for a promising road of common prosperity. Up to now, the international shipping industry undertakes more than 90% of the transportation tasks of Global trade. Driven by big data, information physical system, Internet of things and other technologies and concepts, profound changes are taking place. Navigation service is a kind of behavior of national institutions to provide maritime navigation service. It is the basic, technical and supportable work of maritime safety, water transport economic development and marine development. The construction and maintenance of AtoN, port and waterway nautical hydrography, and maritime safety communication are the three basic contents of navigation service, which together constitute the narrow concept of navigation service. In a broad sense, navigation service is the sum of human, ship, environment and management. It is not limited to navigation service itself, but also the object, tool, condition and method of navigation service. Intelligent transportation

originated from land transportation at first, and then it was applied to water transportation. Compared with aviation and land transportation service system, domestic and foreign navigation service theory and application have lagged behind. It is the consistent goal of the current international community to change the current situation of navigation service, use advanced scientific theory and technology, and further improve maritime safety and efficiency with automation and intelligence.

In recent years, with the rapid development of science and technology, especially electronic technology, radio communication and network technology, the continuous development and utilization of new technologies, new materials and new energy of aids to navigation, and the continuous improvement of the quality, efficiency and efficiency of AtoN maintenance, the ability and level of AtoN service are getting higher and higher, which provides effective service for the safety of ship navigation and also a more comprehensive, reliable, convenient and efficient service for marine activities (Song, 2018, 99). At the same time, the extensive application of new technology in the field of Aids to Navigation has made profound changes in the service function, self quality and management mode of traditional aids to navigation. Especially, the role of radio aids to navigation has become increasingly prominent, and its impact on traditional aids to navigation is obvious. It can be predicted that this influence will continue to intensify in the future, especially the construction and development of e-Navigation and the concept of intelligent shipping, which indicates that the development of aids to navigation has entered a new era of digitization, informatization and intelligence. With the increasing demand of navigation service and the rapid development of new technology, the development of multi-function, digital and intelligent AtoN will become an inevitable trend (Mao, 2021, 44).

Intelligent navigation service is by means of modern computer technology, communication technology, Internet of things, Internet and other technical means, to

gain a comprehensive perception of navigation information and environmental information closely related to ship navigation, and based on computer information technology, automatic control technology, big data processing and analysis technology, to achieve intelligent operation of navigation service, intelligent service and service of ship navigation safety in order to make the navigation safer and more convenient.

Nowadays, a new round of scientific and technological revolution and industrial change has emerged. The deep integration of modern scientific and technological information technology and navigation support has become an important driving point of navigation service work.

(1) Closely follow up and in-depth study of forward-looking technology. Internet plus, big data, 5G communications, Beidou navigation positioning, crowdsourcing deep survey, VDES, AI, new energy, new materials, new technologies and so on are constantly emerging and developing rapidly, creating new mode and new space for navigation service intellectualization, informatization and networking, and also providing the full realization ways and ways for intelligent navigation service construction.

(2) Promote independent scientific and technological innovation. The development of everything is inseparable from the drive of new technology, especially the intelligent navigation service. We should promote the deep integration of new technologies such as big data, Internet plus, AI and navigation service, compare the existing bottlenecks and shortcomings with the aim of intelligent navigation service development, strengthen the research on intelligent technology and drive the intellectualization of navigation with technology.

(3) Improving the system of scientific and technological innovation. The Outline for

Building a Leading Transportation Nation proposes to establish a technological innovation mechanism with enterprises as the main body and deep integration of University-Industry-Science, and build a new platform with national influence, such as laboratories and technological innovation centers(Lv, 2019, 4). According to the guidance of the outline, the construction of intelligent navigation service should also create a strong innovation atmosphere, carry out in-depth entrepreneurship and innovation, organize high-level scientific and technological forums, paper competitions and other activities, increase innovation assessment, build information sharing platform, implement the concept of innovation and development, strengthen the sharing of innovation achievements and innovation resources, and promote the construction progress of intelligent navigation service.

In recent years, China has made a lot of progress in the field of intelligent navigation service. The three major services of aids to navigation, nautical hydrography, and communication have made breakthroughs in the international frontier theory and technology tracking and technology transformation application. For example, the Chinese version of the Arctic navigation guide (northeast channel and northwest channel) and the Chinese version of the Antarctic electronic chart (14 pieces) were published for the first time; the professional marine survey ship was used for the first time to carry out the precise hydrographic survey of the Antarctic waters; the integrated navigation aid system for polar scientific research compatible with Beidou, GPS and AIS was applied for the first time; and the suitable anchorage near the islands in the Ross Sea was found. At present, the basic technologies of intelligent navigation service have been applied mainly as follows: first, positioning enhancement technology. For example, radio beacon differential global navigation satellite system (rbn-DGNSS), marine Beidou continuous operation reference station system (Bd-MCORS), and second, water digital communication technology. For

example, navigational data (NAVDAT), VHF Data Exchange System (VDES), WiFi and satellite communication coverage; third, navigation information integration and service technology. For example, the cloud platform of electronic chart service, the construction of low visibility e-Navigation demonstration area of Yangshan Port, the global maritime safety information system, etc. Radio beacon differential Beidou satellite navigation system (rbn-DBDs) is the world's first coastal differential satellite navigation system with completely independent intellectual property rights, providing navigation services with positioning accuracy of 1-2 meters for navigation users (DBDs + DGPS) station was officially put into operation on January 1, 2014, and “GB 17424” technical requirements for differential global navigation satellite system (DGNSS) was revised. The specific applications of Beidou CORS system include: high precision positioning is realized in the core area of 2213 square kilometers covered by the Yangtze River Estuary Beidou continuous operation reference station system, with the positioning accuracy of 3 cm in horizontal and 5 cm in vertical, real-time positioning of 15 cm in horizontal and 12 cm in peripheral areas covered by the system 132 square kilometers area to achieve sub meter level real-time positioning. In the aspect of water safety information digital broadcasting system (NAVDAT), NAVDAT is used to carry out the test of electronic chart release. The updated data size of electronic chart is 91KB, and the data transmission time is only 37 seconds. In terms of information system of global maritime safety information system, the main objectives are as follows: first, open the public platform, cooperate with application development, and carry out digital service business; second, establish a one-stop maritime information service platform to provide industry data thematic service business. Users can obtain the required data through highly integrated data pool, such as meteorological information data, marine resources data, marine ecological data, etc.

Taking buoy as an example, it is the sign facility with the most tails of AtoN on water. It was initially set up to guide the safe navigation of ships. Due to its special structure and throwing position, people began to use buoy as the carrier to develop marine environment monitoring buoy platform in the 1920s. Marine, meteorological and fishery departments call it marine data buoy, which is also called multi-functional buoy because of its multiple functions. The real-time and reliable hydrological and meteorological information of multi-functional buoy monitoring can be used for ship navigation, maritime supervision, maritime search and rescue, oil spill emergency response, scheme preparation, port construction, channel dredging, etc. it is particularly prominent in ensuring the safety of ships entering and leaving the port and reducing the time of ships in the port, which is of great significance to the construction of a comprehensive navigation service system. The sensor loaded on the navigation aid buoy is transformed into a multi-function buoy to sense the hydrological environment information in the sea area, which has been successfully applied. Marine environment perception is also the future development trend, which will provide strong support for the development of intelligent shipping in the future.

1.2 Significance and objectives

The new round of development shows that intelligence is the direction of future development, an important engine of modern economic and social development, and the only way for modern navigation service (Kong, 2019, 78).

(1) Carrying out the modernization of traditional management. Meet the needs of intelligent shipping information service, co-ordinate the navigation service information work, establish aviation insurance services and emergency management platform, carry out research and construction of star based AIS, e-Loran construction, and research on Internet+navigation service APP services.

(2) Optimizing infrastructure departments and construction. It is necessary to reasonably plan the function settings of basic stations such as aids to navigation, nautical hydrography, communication, etc., to meet the needs of the development of intelligent ships, and to promote the technical transformation of intelligent berthing and green energy-saving transformation of aids to navigation wharf facilities.

(3) Strengthening the modernization of equipment. Focus on promoting the construction of new multi-functional buoy tender, 60m survey ship and special equipment for deep sea hydrographic survey; explore new navigation service mode based on widely using UAV and unmanned ship; study the intelligent distribution system of navigation buoy tender and implement intelligent distribution, etc.

With the rapid development of digital technology, the trend of traditional navigation is gradually changing to big data and intelligence. Its main technical directions are ship operation automation, navigation and positioning electronization, ship collision avoidance intellectualization, chart electronization, navigation data digitization, high-speed communication and wide area. Navigation service must comply with the changes of the times, actively think about the countermeasures to deal with the development of intelligent shipping, with the help of subversive and epoch-making technology, form an intelligent navigation service system.

The most direct user of navigation service is ship, and the final service object is shipping. Therefore, the final objective of the construction of intelligent navigation service is to serve intelligent ship and intelligent shipping (Yu, 2019, 12). Intelligent shipping is a new type of modern shipping industry formed by the deep integration of traditional shipping elements and modern information, communication, sensing and artificial intelligence technologies. It mainly includes five basic elements: intelligent ship, intelligent port, intelligent navigation service, intelligent shipping service and intelligent shipping supervision. There is a congenital correlation between intelligent

navigation service and intelligent shipping. Intelligent navigation service provides external information materials for analysis, processing and decision-making of intelligent shipping, and intelligent navigation service can enhance the implementation effect of intelligent navigation service. In addition, the autonomous navigation technology of intelligent ship puts forward high requirements for the accuracy and density of electronic chart, and also requires the navigation service department to develop the database of intelligent routes and provide timely information of marine environment (Tang, 2019, 27). Therefore, in order to build intelligent navigation service, we must fully and deeply study and analyze the development direction and specific needs of intelligent ship, such as intelligent perception, intelligent decision-making and intelligent execution, and take this as the starting point to promote the construction of intelligent navigation service.

With the development of intelligent shipping, autonomous ships are being developed and there will be a long time for man-machine mixing stage. The traditional navigation service mode does not adapt to the new trend so a research on intelligent navigation service mode under the background of digital technology developments is necessary. The intelligent navigation service will adopt digital navigation assistance, which promotes the integrated land, air and sea navigation assistance services, in order to seek for one new mode to achieve the goals from the Outline for Building a Leading Transportation Nation.

1.3 Structure

The first chapter states the background, significance and objectives of this dissertation.

The second chapter illustrates the historical evolution of navigation service system in China, Navigation Service Centers of the People's Republic of China, legal regime of

the navigation service system in China and three other states' navigation service system respectively in UK, US, Japan.

The third chapter shows the perspective developments of digital maritime sector, taking an intelligent AtoN as an example to introduce the data acquisition equipment, management system, system function and realization principle, and main technical innovation points.

The fourth chapter introduces the mode of integrated navigation service system with its significance and main construction contents from six aspects.

The fifth chapter gives the conclusion of this dissertation.

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CHAPTER 2 ANALYTICAL REVIEW OF CURRENT NAVIGATION SERVICE SYSTEM

Maritime navigation service includes three major business, aids to navigation, nautical hydrography and communication, mainly responsible for the construction and maintenance of marine aids to navigation, hydrographic survey of port and waterway, maritime communication, navigation service emergency disposal and other technical support and service (Fan, 2017, 67). Maritime navigation service is an important part of maritime work and essential link of maritime safety chain. Additionally, it is one of the national transportation support system, is an important fundamental, strategic, leading resource to ensure efficient operation of waterway transportation, which plays an important role in maintaining water traffic safety, improving the quality of waterway transportation service and protecting the water environment.

At present, the maritime navigation service system has established a relatively sound management mode of unified management and hierarchical responsibility, and the internal management mechanism operates effectively. Since the transformation of navigation service system into public service unit, the navigation service system has continuously implemented the "Sanding scheme" plan, promoted the separation and classified management of government affairs and business, straightened out the responsibilities of various departments, strengthened the management and integration of the three major businesses, established and improved the quality management system, improved the regulations and standards and related business management systems, formulated and improved the internal work rules, promoted the standardization and informatization of internal management, and effectively

improved the level of internal management. In particular, in terms of approval of special aids to navigation, performance acceptance and supervision, and protection of aids to navigation, the Navigation Service Centers (NSC) and the Maritime Safety Administrations (MSA) have clarified their responsibilities and working procedures to ensure the orderly management of this sector.

2.1 Historical evolution of navigation service system

Figure 1-Historical evolution of navigation service system in China

China's navigation service system has undergone several changes and development, and its historical evolution is shown in figure 1. From the appearance of the first

modern lighthouse at the end of the 19th century to the formation of a relatively perfect navigation service system at the beginning of the 21st century, the navigation service system in China has undergone six great changes in the view of the management system (Wang, 2017, 36).

2.1.1 The first stage

The first stage is the establishment of customs from the end of the Qing Dynasty to the founding of the people's Republic of China. At this stage, most of the navigation mark facilities, such as lighthouses along the coast of the country, are managed by the customs as a whole. At that time, the Customs and Excise Department, which was open to all ports, was specially responsible for "the construction and management of coastal inland river lighthouses, lanterns, buoys, fog signals and other navigation signs, the removal of sunken vessels on the routes, the dredging of port waterways, the management of anchorages, and so on." After the Opium War in 1840, the Qing Customs set up a special navigation service department, which widely attracted foreign management methods and equipment, and began to manage and maintain the navigation marks in coastal and port waters. Since 1858, the maintenance and management expenses of navigation marks in China have come from the ship ton tax levied by the Customs. In 1868, three coastal areas of China were set up in the south, middle and north, who are responsible for the establishment and inspection of the coastal and port navigation marks under the jurisdiction of the section, and to inspect the buoys, piles and lanterns in the port. As a result, China formed the navigation service system of the General Department of Taxation, the Department of Maritime Taxation, the Department of Inspection and works and the Department of ship Management from top to bottom. In 1881, the southern and northern sections were abolished. Instead, the Division of Maritime Inspection and works and the Chief architect are in charge of the administrative and technical matters of the banknote

unit. After the establishment of the Shipping and Banknote Unit, it radiated from Shanghai port to the north and south, and built a large number of aids to navigation in the coastal areas. First, lighthouses were built in the Yangtze River Estuary, then in Zhoushan Islands, Taiwan Strait, Yellow Sea, Bohai Sea and South China Sea, and lightboats were also set up in Tongsha of the Yangtze River Estuary, Langshan waterway of the Yangtze River, Niuzhuang (Yingkou) of Liaoning Province and Dagu of Tianjin. After the revolution of 1911, the navigation service organization in China was still the customs, and the specific matters were managed by the Maritime Affairs Section. The Shipping and Banknote Unit was renamed the Maritime Administration Bureau, and it was renamed the Maritime Affairs Section in 1925. During the Anti Japanese War, the coastal AtoN were controlled by the Japanese army, but they were still maintained by the Maritime Affairs Section of the customs. After the victory of the Anti Japanese War, the customs adjusted the coastal AtoN to four sea areas of Shanghai, Qingdao, Xiamen and Guangzhou.

2.1.2 The second stage

In the second stage, the related navigation service management functions were transferred from the customs to the Ministry of Communications. Since July 26 in 1950, the Finance and Economics Committee of the Government Affairs Council had issued the "Instruction on the Unified Administration of Navigation and Port Affairs" and decided to transfer the aids to navigation managed by the customs to the Ministry of communications, among which the AtoN in ports are transferred to the Port Authorities for administration purpose. The Finance and Economic Committee of the Government Affairs Council decided that the Port Authorities of each important port shall be responsible for the construction, maintenance and management of AtoN in the port area. In order to manage them, the General Administration of Maritime Affairs of the Ministry of Communications has set up the

Maritime Affairs Office, and four regional maritime affairs offices in Qingdao, Shanghai, Xiamen and Guangzhou. So far, China's coastal navigation service system and inland navigation service system had been formed.

2.1.3 The third stage

In the third stage, the function of the Ministry of communications is transferred to the military department. In 1953, due to the complicated situation of coastal military struggle, in order to adapt to the situation of military struggle and develop maritime transportation, the Government Affairs Council decided to "transfer the AtoN under the management of the Ministry of Communications to the naval command". Since July 5 in 1953, the General Administration of Maritime Affairs of the Ministry of Communications and the maritime affairs offices had been abolished, and the aids to navigation in coastal areas and ports had been taken over by the Navy. As a result, the naval Hydrographic Bureau was expanded into the Hydrographic Department. In 1958, the Hydrographic Department was renamed the Department of Navigation Assurance. After 1960, the navy fleet in the North Sea, East China Sea and South China Sea was established, with functional departments in charge of navigation aids in the headquarters, and navigation guarantee areas and navigation guarantee sections. After 1960, the navy fleet in the North Sea, East China Sea and South China Sea was established, with functional departments in charge of navigation aids, and navigation guarantee areas and navigation guarantee sections.

2.1.4 The fourth stage

In the fourth stage, most of the management functions of AtoN are transferred back to the Ministry of Communications. After the implementation of reform and opening up in 1978, in order to meet the continuous needs of the development of shipping industry on April 24, 1980, the State Council and the Central Military Commission

approved the reform of the management system of public aids to navigation on maritime trunk lines managed by the Navy. The Ministry of Communications and the naval command signed the "agreement on the handover of public aids to navigation in sea areas". The handover work was divided into sea areas, stages and batches and all of them are under the management of the Ministry of Communications, except for the Changhe-2 navigation system. Since 1981, Tianjin, Shanghai and Guangzhou Waterway Bureaus had respectively taken over the AtoN of some ports directly under the Ministry of Communications in order to realize the unified management of commercial ports, coastal short-range routes and maritime trunk lines.

Later, in order to strengthen the management of AtoN in sea areas, the Ministry of Communications divided the coastal AtoN into three sea areas in 1981: the north, the East China Sea and the South China Sea, which were respectively managed by Tianjin, Shanghai and Guangzhou navigation bureaus. The three navigation bureaus established a hierarchical management system and management mode of navigation aids, including navigation mark survey office, AtoN area and AtoN station, and basically formed a relatively perfect navigation service system. The navigation mark survey office was set up in the Waterway Bureau, which was specifically responsible for the nautical hydrography.

2.1.5 The fifth stage

In the fifth stage, there was a pattern of dual leadership. In 1986, the Ministry of Communications set up 14 Maritime Safety Supervision Bureaus by merging the three navigation mark survey offices and the regional navigation mark stations from the three waterway bureaus with the port supervision agencies of the coastal port administration. Since 1988, the Ministry of Communications had assigned part of the AtoN areas (offices and stations) to the local Maritime Safety Supervision Bureaus.

The operation of AIDS to navigation is managed in accordance with the principle of integration of three sea areas, namely the North Sea, the East China Sea and the South China Sea. However, the operation of aids to navigation is still managed by Tianjin, Shanghai and Guangzhou Maritime Safety Supervision Bureau, forming a pattern of dual leadership in some areas (offices and stations).

2.1.6 The sixth stage

As for the sixth stage, the management system of navigation service system was jointly managed by the Ministry of Communications, Navy and Department of Fisheries. At the end of the 20th century, China's maritime safety supervision and management system implemented the major reform of "one water one supervision, one port one supervision". The Ministry of Communications established the Maritime Safety Administration of the People's Republic of China (the China MSA), and 20 branches of Maritime Safety Administration in the coastal areas, the Yangtze River and Heilongjiang River. Along with the reform of the management system of AtoN in sea areas, 17 areas (offices and stations) of aids to navigation in China were renamed as 16 aids to navigation offices, which were respectively managed by Tianjin, Shanghai, Guangdong and Hainan MSA. The Ministry of Communications is responsible for the public AtoN at sea, the AtoN of commercial ports, and inland navigation aids. The navy is responsible for the AtoN of the military ports and the military commercial ports. The fishing ports, fishing grounds and other special AtoN for fisheries shall be in the charge of fishery departments.

2.1.7 The seventh stage

After the efforts of the first six stages, the seventh stage of China's AtoN has formed a distinctive system. Due to the important role of AtoN in supporting water transportation, fishery, marine development and national defense construction,

according to the role of AtoN, China's AtoN are divided into military AtoN, fishery AtoN and maritime AtoN. The AtoN of military ports and military commercial ports mainly for military use are managed by the Navy. The AtoN of fishing grounds and fishing ports shall be managed by the Ministry of agriculture. The commercial ports along the coastal trunk lines, the military and commercial ports mainly for commercial use, and the AtoN in inland waters are managed by the Ministry of transport, and three Navigation Service Centers of the Ministry of transport are responsible for the management of the AtoN along the coastal trunk lines and maritime AtoN.

2.2 Navigation Service Centers in China

The symbol of the seventh stage of the historical evolution of the maritime service system in China is the establishment of the Maritime Service Center of the Ministry of Transport. According to the general requirements of the national marine development strategy and the reform of the administrative management system, three Navigation Service Centers of the Ministry of Transport in the South China Sea, the East China Sea and the North Sea have been established across regions by integrating the existing AtoN, nautical hydrography, and communications of the maritime system directly under the maritime system. The Maritime support Center mainly undertakes the responsibilities of technical support and service support such as the construction and maintenance of maritime navigation marks, the nautical hydrography of port waterways, and maritime communications within the jurisdiction. In September 2012, the South China Sea, the East China Sea and the North Sea Navigation Service Centers were approved and set up at the same time, and were officially listed on November 26, December 7 and December 20, respectively. The Maritime Service Center is an institution directly under the Ministry of Transport, with the scope of management of the Maritime Safety

Administration of the People's Republic of China, and entrusts the Guangdong Maritime Safety Administration, the Shanghai Maritime Safety Administration and the Tianjin Maritime Safety Administration respectively. The three Navigation Service Centers and navigation mark offices shall undertake the construction and maintenance of AtoN within the corresponding jurisdiction. As a result, the administrative management power of coastal navigation mark management institutions and the right to enforce the law of navigation marks are stripped from the original institutions, and the public welfare attributes of the current navigation service institutions are more clear. In accordance with the principles of simplification, unity and efficiency, each navigation service center shall, after straightening out the relationship and changing their functions, carry out hierarchical management and make the duties of maritime service more clear. The duties of each navigation service center shall be reflected on the following aspects:

(1)to undertake the construction, operation, detection, maintenance, evaluation, adjustment and dynamic release of public navigation marks, ship automatic identification systems, radio and satellite navigation systems in the jurisdiction, and to undertake the research and protection of historical lighthouses and navigation mark cultural relics in the jurisdiction.

(2)to carry out the nautical hydrography of coastal port waterways under the jurisdiction, and to undertake the monitoring, collection, analysis, collation and publication of navigable water depth and hydrological information.

(3)to be responsible for the construction, maintenance and management of the survey database of sea lanes in China; to be responsible for the compilation, printing, publication, distribution and updating of paper charts, electronic charts and related nautical books and materials along the coast of China.

(4)to undertake the work of maritime distress and safety communication and the dissemination of maritime safety information such as navigational warnings and meteorological forecasts; and to be responsible for the emergency disposal of navigation service such as navigation marks, nautical hydrography, communications, and related work on traffic combat preparedness.

(5)to undertake the research and development of science and technology, technical training and consulting services for the development strategy of maritime security; and to participate in relevant international exchanges and cooperation.

At present, the comprehensive navigation service system in China takes navigation marks, nautical hydrography and maritime communication as the three main plates, which is an important part of the water traffic safety guarantee system of our country, undertaking the technical support of ship navigation and the service guarantee function of shipping economy, and plays an irreplaceable important role in the sustainable stability of the water traffic safety situation in China. We should further innovate management ideas, optimize coastal AtoN, nautical hydrography, and communication resources, separate navigation service work such as maritime navigation mark construction and maintenance, port waterway hydrography, and water safety communication with maritime administrative law enforcement and management, set up maritime service centers, and persist in taking scientific and technological innovation and technological progress as an important support for speeding up the development of maritime security. It not only captures the important strategic opportunity for the development of water transportation and maritime undertakings in China, but also provides omni-directional, high-quality and professional public welfare services for shipping safety and the development of marine resources, and is also an inevitable choice for promoting the construction of modern comprehensive navigation service system and the development of navigation

support. At present, the management system of maritime navigation service in China is shown in figure 2.

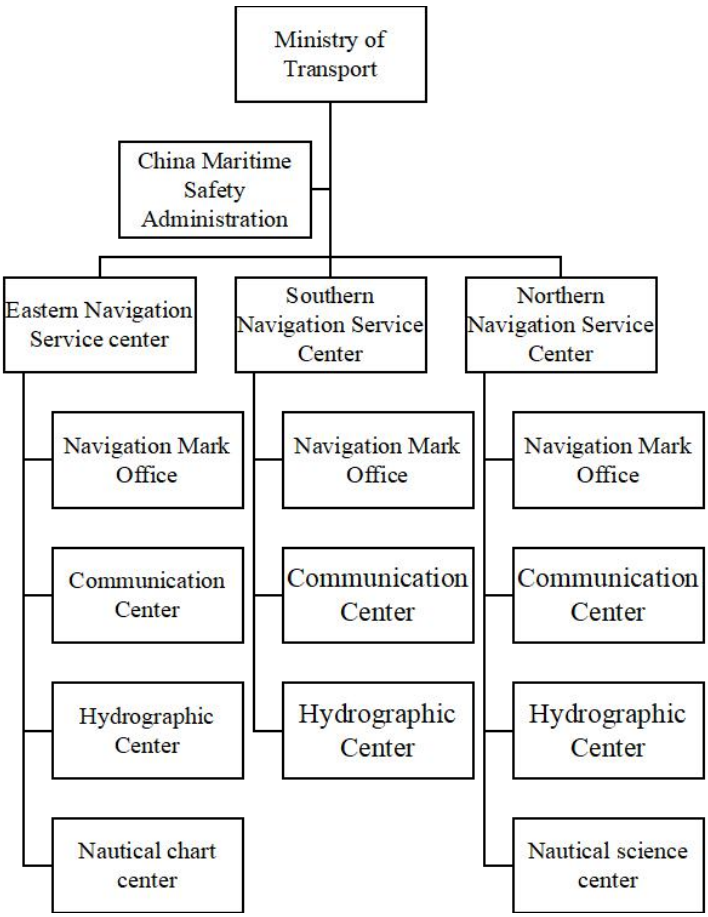


Figure 2-Current navigation service system in China

2.3 Legal regime of navigation service system in China

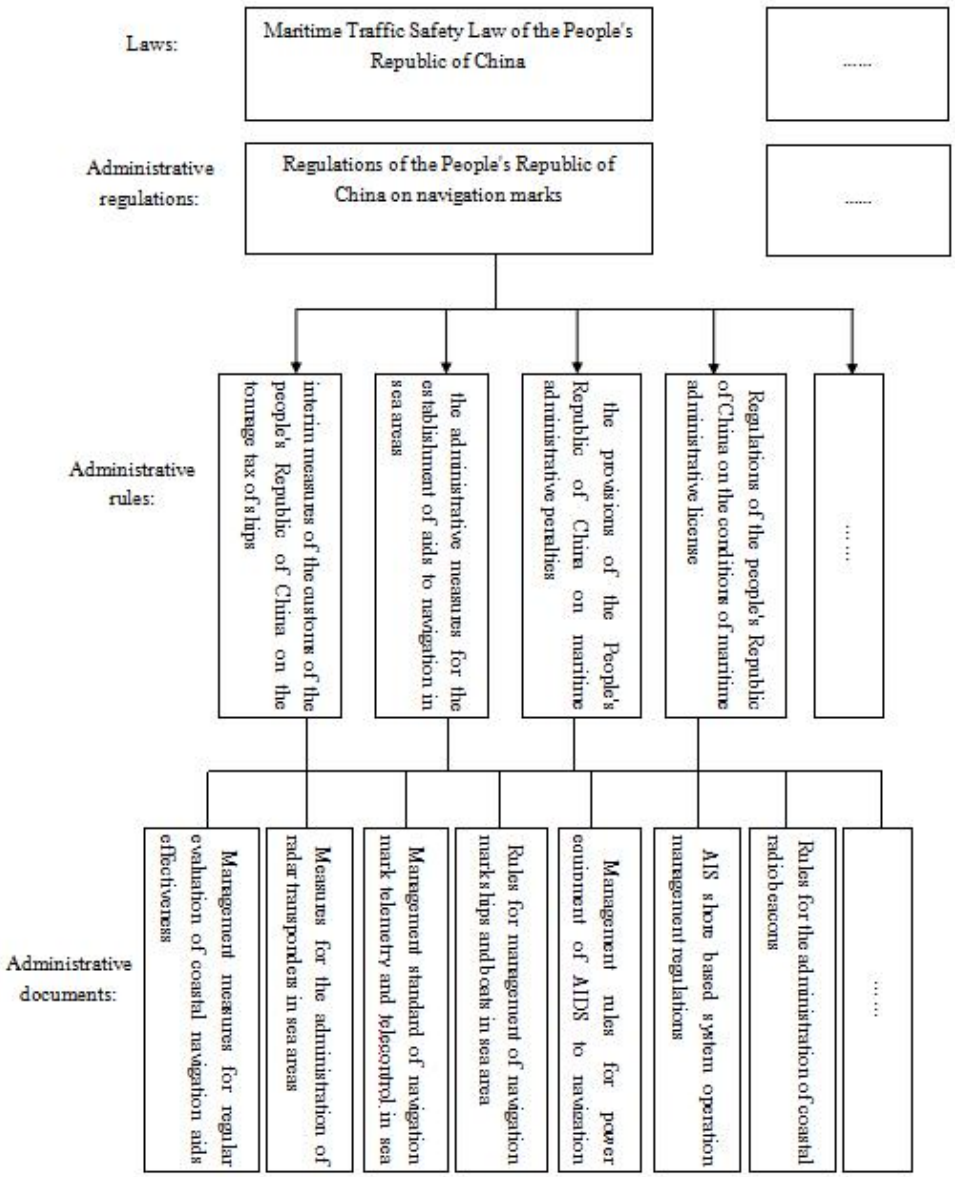


Figure 3-Framework of the laws and regulations for AtoN management in China

Navigation marks are not only an important aids to navigation to ensure the safety and economy of ships and facilitate navigation, but also an important part of the water traffic safety service system. They can provide important information for traffic safety and environmental protection, and play an important role in the political prestige, economic development and national defense construction of the country.

Therefore, many countries in the world attach great importance to the management and protection of navigation marks, and many countries have formulated their own navigation mark laws and regulations and established a navigation mark legal regime(Wang, 2017, 42). At present, China has also established a three-level legal regime for navigation mark. The specific framework diagram is shown in figure 3.

As shown in figure 3, the laws and regulations of AtoN management in China can be divided into four levels according to their legal effects, namely, laws, administrative regulations, administrative rules and administrative documents. The administrative regulations, rules and administrative documents of AtoN are formulated on the basis of the “Regulations of the People's Republic of China on Navigation Marks”. In addition to the “Law of the People's Republic of China on Maritime Traffic Safety” and the “Waterway law of the people's Republic of China”, there are also the “Port Law of the People's Republic of China” and the “Marine Environment Protection Law of the people's Republic of China”. In addition to these administrative regulations, rules and administrative documents, there are also provisions on navigation marks in other laws and regulations, such as articles 28, 29 and 39 of Chapter VII in the “Regulations of the People's Republic of China on the Administration of Traffic Safety on Inland Waters”. The name, document number and effective date of the laws and regulations currently involved in the aids to navigation in China are shown in Table 1.

Serial number	Name	Document number	Effective Date
1	Maritime Traffic Safety Law of the People's Republic of China	President's Order [1983] No. 7	January 1, 1984
2	Marine Environmental Protection Law of	President's Order	April 1,

	the People's Republic of China	[1999] No. 26	2000
3	Law of the People's Republic of China on Waterways	President's Order [2014] No. 17	March 1, 2015
4	Regulations of the People's Republic of China on the Safety Management of Inland Waterway Traffic	State Council No. 355 of 2002	August 1, 2002
5	People's Republic of China Navigation Regulations	The State Council in 1995 No. 187	December 3, 1995
6	People's Republic of China Waterway Management Regulations Implementation Rules	Ministry of Transport No. 9 of 2009	June 23, 2009
7	Regulations of the People's Republic of China on the Management of Waterways	State Council No. 545 of 2008	December 27, 2008
8	Measures for the Management of Dynamic Notification of Navigational Beacons in Marine Areas	Traffic Safety Supervision [1995] No. 1180	December 13, 1995
9	Measures for the Management of Inland Waterway Beacons	Ministry of Communications Order No. 2 of 1996	August 1, 1996
10	Measures for the Administration of Navigational Beacon Setting in Marine Areas	Decree No. 12 of 1996 of the Ministry of Communications	March 1, 1997
11	Rules for the Management of	Supervision of the	December

	Navigational Beacon Operations in Maritime Areas	word [1996] No. 290	3, 1996
12	Sea area beacon boat management rules	Security supervision word [1996] No. 291	December 3, 1996
13	Rules for the management of sea-area beacon machinery and power equipment	An Supervision word [1996] No.292	December 3, 1996
14	Coastal beacon management measures	Ministry of Communications Order No. 7 of 2003	September 1, 2003
15	Measures for the management of fisheries beacons	Ministry of Agriculture Decree No. 13 of 2008	June 1, 2008
16	Measures for the management of radar transponders in the sea area (for trial implementation)	(88) Jiaoshui Supervision No. 345	May 23, 1988
17	Traffic industry waterway beacon special engineering design qualification classification standards	Work port word [1993] No. 242	September, 1993
18	Measures for the Protection and Management of Historical Lighthouses in China Sea Area (Temporary)	Sea navigation survey [2004] No. 484	October 11, 2004
19	AIS shore-based system operation management regulations (for trial implementation)	The sea navigation survey [2006] No. 360	February 8, 2010

20	Management rules for setting emergency wreck markers in China Sea Area (for trial implementation)	The sea navigation survey [2007] No. 363	September 1, 2007
21	Coastal beacon effectiveness regular assessment management measures (for trial implementation)	Sea navigation survey [2009] No. 457	September 7, 2009
22	Measures for the management of emergency response of beacons in the sea area	Sea navigation survey [2010] No. 12	January 8, 2010

Table 1-The laws and regulations for aids to navigation in China

2.3.1 The relevant laws

The first level is the legal level, which mainly includes four laws: Maritime Traffic Safety Law of the People's Republic of China, Port Law of the People's Republic of China, Marine Environmental Protection law of the People's Republic of China and Waterway Law of the People's Republic of China. These four laws are not specific laws on aids to navigation, but contain regulations related to the management of aids to navigation. The Maritime Traffic Safety Law of the People's Republic of China was adopted at the second meeting of the Standing Committee of the Sixth National People's Congress on September 2, 1983 and promulgated by order No. 7 of the president of the People's Republic of China on September 2, 1983. It came into force on January 1, 1984. The Port Law of the People's Republic of China was promulgated in the No. 5 presidential order signed on June 28, 2003 and came into force on January 1, 2004. The Marine Environmental Protection Law of the People's Republic of China was adopted at the 24th Meeting of the Standing Committee of the

Fifth National People's Congress on August 23, 1982, revised and adopted at the 13th meeting of the Standing Committee of the Ninth National People's Congress on December 25, 1999, promulgated by order No. 26 of the president of the people's Republic of China on December 25, 1999, and shall come into force as of April 1, 2000. The Waterway Law of the People's Republic of China was adopted at the 12th meeting of the Standing Committee of the 12th National People's Congress of the People's Republic of China on December 28, 2014 and promulgated in order No. 17 of the president signed on December 28, 2014, which came into force on March 1, 2015.

Article 23, Article 24 and Article 25 of Chapter V in the Maritime Traffic Safety Law of the People's Republic of China are the legal provisions related to the administration of aids to navigation. Article 23 stipulates that it is forbidden to damage AtoN and navigation facilities and any damage to AtoN or navigational facilities shall be reported immediately to the competent authority and shall be liable for compensation. Article 24 stipulates that vessels and installations shall promptly report to the competent authority if they find the following situations: first, the variation or abnormality of AtoN or navigation facilities; Second, there are obstacles and drifting objects that hinder navigation safety; Third, other abnormal conditions that hinder navigation safety. Article 25 stipulates that no obstacles affecting the efficiency of navigation aids shall be built or set up around them. The AtoN and lights in the vicinity of navigation channels that hinder navigation safety shall be properly screened.

Articles 2 and 4 of the general provisions in Chapter I of the Waterway Law of the People's Republic of China, Article 22 of Chapter IV waterway maintenance, Article 28, Article 31 and Article 34 of Chapter V waterway protection, and Article 41 and Article 42 of Chapter VI legal liability are provisions related to aids to navigation.

Article 2 stipulates that waterways include navigation structures, aids to navigation and other waterway facilities. Article 4 stipulates that the State Council and the relevant local people's governments at or above the county level shall, in accordance with the level of economic and social development and the needs of waterway construction and maintenance, reasonably arrange the funds for waterway construction and maintenance in the financial budget. Article 22 stipulates that the installation, maintenance, protection and management of aids to navigation shall be carried out in accordance with the provisions of relevant laws, administrative regulations and national or industrial standards. Article 28 for the construction of a waterway related project, the construction unit shall, at the feasibility study stage of the project, make an evaluation on the impact of the construction project on the navigation conditions of the waterway, and submit it to the competent department of transportation or the waterway administration organ with the right of examination and approval for examination and approval. Article 31 stipulates that if the construction of a waterway related project affects the normal function of the waterway, the department in charge of waterway administration and the maritime administrative agency shall temporarily adjust the position and direction of the AtoN or the waterway according to needs. Article 34 states that, in the construction of bridges and other structures in navigable waters, the construction unit shall set up aids to navigation and other facilities in accordance with the relevant provisions and technical requirements of the state, and bear the corresponding expenses. The department in charge of waterway management and the maritime administrative agency shall be responsible for the management and maintenance of AtoN in the bridge area. Article 41 stipulates that if a construction unit fails to set up AtoN and other facilities in accordance with the provisions when building bridges and other structures in navigable waters, the department in charge of waterway administration or the maritime administrative agency shall order it to make corrections and impose a

fine of not more than 50000 yuan. Article 42 : in violation of the provisions of this law, commits one of the following acts shall be ordered by the department in charge of waterway administration to make corrections, and shall be fined not more than 50000 yuan to the unit and not more than 2000 yuan to the individual; If losses are caused, they shall be liable for compensation according to law.

2.3.2 The administrative regulations

The second level is the administrative regulations represented by the regulations of the People's Republic of China on navigation marks (hereinafter referred to as the regulations on navigation marks). The promulgation of the regulations on navigation marks not only makes the management and protection of aids to navigation into a legal track, but also lays the foundation for the legal system of aids to navigation. On December 3, 1995, the "Regulations on navigation marks" was issued and implemented in the form of the order of the State Council of the People's Republic of China. It is the first administrative regulation on aids to navigation promulgated in China and establishes the basis of the legal system of aids to navigation in sea areas. There are 25 articles in the regulations on aids to navigation, which are divided into five parts: Articles 1 to 5 are the general provisions, which define the purpose of the regulations, the scope of aids to navigation applicable in the regulations, the competent units of aids to navigation in China, and the principles of aids to navigation management, so as to ensure that the responsibilities of aids to navigation management organizations are clear and the basic obligations of the public to aids to navigation management are clear. Articles 6 to 13 are management clauses, which regulate the setting, removal, movement and maintenance of AIDS to navigation. Articles 14 to 18 are protection clauses, which stipulate that it is forbidden to damage aids to navigation and affect the normal working efficiency of aids to navigation. Articles 19 to 24 are penalty clauses, which punish the violation of the relevant

provisions of the regulations on aids to navigation. Article 25 is a supplementary clause. The Regulations of the People's Republic of China on the Investigation and Handling of Maritime Traffic Accidents are listed at the same level as the regulations on navigation marks.

2.3.3 The administrative rules

The third level of the legal regime is the relevant administrative rules established on the basis of the Regulations on navigation marks and the Regulations of the People's Republic of China on the investigation and handling of maritime traffic accidents, including the administrative measures for dynamic notification of aids to navigation in sea areas, the administrative measures for the establishment of aids to navigation in sea areas, the administrative measures for coastal aids to navigation, the provisions of the People's Republic of China on maritime administrative penalties, and the administrative measures for maritime traffic accidents Regulations of the people's Republic of China on the conditions of maritime administrative license, detailed rules for the implementation of the regulations of the people's Republic of China on the administration of shipping lanes, notice on bringing the tonnage tax of ships into the budget management, interim measures of the customs of the people's Republic of China on the tonnage tax of ships, etc.

Although the measures for the administration of dynamic notification of navigation aids in sea areas was issued as an administrative document by the former China Safety Supervision Bureau on December 13, 1995, it belongs to the second level of the overall framework in terms of legal effect. Meanwhile, it mainly stipulates the functions and powers of the administrative organs for dynamic notification of aids to navigation in sea areas, the dynamic classification of AtoN and the dynamic notification procedures of AtoN. The Ministry of Communications (also known as

Ministry of Transport after 2008) issued the "measures for the administration of the establishment of aids to navigation in sea areas" on December 25, 1996, which specifies in detail the functions and powers of the administrative organs of aids to navigation at all levels, the application and approval procedures for the setting of AtoN, and the relevant legal responsibilities. The measures for the administration of coastal aids to navigation, which was completed by the Ministry of communications in 2003, is an important administrative regulation at the same level. It mainly stipulates the responsibilities, management procedures and management standards of aids to navigation administration departments at all levels.

Articles 21 and 22 of the regulations on navigation marks clearly stipulate that those who cause losses to aids to navigation shall be compensated according to law. In order to regulate maritime administrative punishment, protect the legitimate rights and interests of the parties, safeguard and supervise maritime administration, maintain maritime traffic order and prevent ships from polluting coastal waters, in accordance with the maritime traffic safety law, marine environmental protection law, administrative punishment law and other relevant laws and administrative regulations, the provisions of the People's Republic of China on maritime administrative penalties have been formulated and shall come into force on April 1, 2006. This regulation mainly specifies the scope, procedure and standard of damage compensation.

In accordance with the administrative license law of the people's Republic of China, the relevant laws and administrative regulations on maritime administration and the relevant international maritime conventions concluded or acceded to by the people's Republic of China, the provisions on the conditions of maritime administrative license of the people's Republic of China are formulated and shall come into force on April 1, 2006. The provisions mainly make detailed provisions on the conditions of maritime administrative license to apply for, examine and decide maritime

administrative license.

According to Article 32 of the regulations of the People's Republic of China on the administration of waterways and the provisions of relevant national laws and regulations, the Detailed Rules for the Implementation of the Regulations of the People's Republic of China on the administration of waterways were formulated and promulgated by the Ministry of communications on August 29, 1991. The detailed rules give a clear explanation of the national channel, local channel and channel facilities, and make detailed provisions on the channel management agencies and their responsibilities, channel planning and construction, channel protection, channel maintenance funds and penalties.

Since January 1, 2001, according to the notice of the General Administration of Customs of the Ministry of Finance and the Ministry of Communications on the budget management of ship tonnage tax payers, ship tonnage tax, as the central budget collector, will be turned over to the central treasury instead of being managed as extra budgetary funds, so as to standardize the management of ship tonnage tax payers. The tonnage tax is the use fee that foreign ships should pay when they use the public aids to navigation on the main lines of the sea established in China when they enter and leave the territorial waters of the people's Republic of China. The Interim Measures of the Customs of the People's Republic of China on Tonnage Tax on Ships has made detailed provisions on the scope, method, tax rate and use of tonnage tax.

2.3.4 The administrative documents

The fourth level of the overall framework is the relevant normative documents formulated according to the above three regulations and relevant administrative rules, including four kinds of documents: organization functions, funds and projects, business management and facilities and equipment. From the macro point of view,

China's aids to navigation management has formed its own legal system. From the specific micro level, the current system is only basically formed. Some of the relevant provisions of the laws and regulations show deficiencies in the specific implementation process. It still needs to be developed and improved according to the practice and practical needs of aids to navigation management. In order to realize the transformation and development of aids to navigation, we must take the perfect legal system as the guarantee, and timely revise the inappropriate provisions in the relevant laws and regulations, so as to promote the rapid development of China's navigation service system.

2.4 Other states' navigation service system

2.4.1 The navigation service system of United Kingdom

The United Kingdom Hydrographic Office is mainly responsible for the navigation service in the UK. Founded in London in 1795, it has a history of more than 200 years. The organizational structure of UKHO includes source data processing and storage department, chart drawing department, nautical list production department, marine safety information center, archives management department, printing department, training department, administrative department, etc. At present, UKHO has more than 1000 employees, a few of them are active naval officers, and the vast majority are civilian staff employed by the British Department of defense (Wang, 2015, 57). These personnel are respectively engaged in data management, paper and digital chart production, nautical publications editing, nautical publications printing and publication and other auxiliary work. Many of the professionals are retired seamen and captains with rich experience in navigation and Navy veterans who have been engaged in navigation and nautical hydrography for many years. UKHO is responsible for supporting the Royal Navy and other British military forces in

hydrographic survey; providing hydrographic services in UK National waters; providing global products and high-quality services for merchant ships and other civil sea voyagers. UKHO is the official representative of the UK in the International Hydrographic Organization (IHO) and other relevant international organizations. It plays an important role in the national decision-making process of maritime affairs. At present, UKHO has produced and maintained more than 3300 global charts and more than 220 nautical publications, both in electronic and paper formats. UKHO has its distribution offices in the world's important port cities, which carry out one-stop product sales and services. At present, there are more than 100 distribution offices. UKHO is under the direct leadership of the British Defense Minister. Responsible for providing global hydrographic support for British military operations. It works closely with the maritime and coastal guard, which is part of the UK Department of transport, and assists the marine and coastal guard in the protection of hydrographic survey to help them perform their statutory duties. UKHO attaches great importance to product quality and has taken a series of effective measures to ensure data quality-everything is centered on the quality of navigation publications.

2.4.2 The navigation service system of United States

The maritime service of the United States is in the charge of National Oceanic and Atmospheric Administration, National Ocean Service Center, Maritime Administration and United States Coast Guard (Wang, 2015, 58). The National Oceanic and Atmospheric Administration of the United States, under the U.S. Department of Commerce, is the main Department of the U.S. government in the management of marine resources. It is responsible not only for ocean affairs, but also for atmospheric affairs. NOAA's ocean and atmosphere office is in charge of scientific research in the U.S. ocean field.

The U.S. Ocean Service Center is affiliated to the National Oceanic and Atmospheric Administration of the United States. The main responsibilities are to collect, process and provide sea level and tidal current data, bathymetric data, chart mapping data (coastline, location of underwater sunken ships and obstacles, navigation aids), geodetic control data, coastal image and coastline data, coastal monitoring and evaluation data. The U.S. maritime administration, subordinate to the U.S. Department of transportation, is mainly responsible for maintaining and promoting the development of U.S. maritime transportation, and has the ability to serve the Navy during the war. The U.S. Coast Guard is a military multi-functional maritime service force, mainly responsible for port security services, navigation assistance, search and rescue, drug enforcement and other work. It is under the leadership of the Ministry of transportation and under the command of the navy in wartime. It is responsible for escorting the maritime transport fleet, carrying out anti submarine tasks, and providing crew for naval ships.

According to the previous data in 2015, more than 4700 nautical charts and 860 charts of other types have been published in the United States. The publication cycle of American chart is 6 months to 12 years, with an average of 2.5 years. The U.S. chart is compiled by the National Oceanic and Atmospheric Administration of the United States. In addition, the U.S. Department of Defense Mapping Agency (DMA) and the U.S. Coast Guard also have their own products. The U.S. Marine Service Center is responsible for nautical hydrography of the U.S. coastal waters and the Great Lakes region. In addition to the survey fleet of the U.S. Maritime Service Center, the U.S. Coast Guard, the Army Department of engineering, the Naval Oceanographic Survey, and the port administration also provide data for the compilation of nautical charts, marine basic maps, and geographic information systems. Seafarers and coastal volunteers also have the obligation and action to

report Maritime changes. The U.S. version is similar to the U.K. version, which is published by two departments.

2.4.3 The navigation service system of Japan

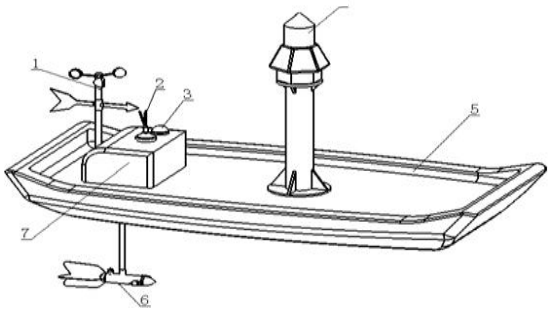
Due to the narrow sea route, complex terrain, weather, sea condition and tidal current, as well as the influence of transportation, fishery and entertainment activities, the navigation environment of ships around Japan is very complicated. In such a complex sea area, the rate of maritime traffic accidents in Japan is relatively small, and its maritime security system plays an important role in the advanced and comprehensive nature of the system. Japan's Ministry of Land, Infrastructure and Transport is the highest level government functional department related to the sea. The Japan Coast Guard (JCG), a subsidiary organ of the Ministry of Land, Infrastructure and Transport, is an administrative organ set up in Japan to maintain maritime safety and public order (Wang, 2015, 58). Its main functions are maritime rescue, traffic safety, disaster prevention and environmental protection, public order maintenance, marine rights and interests protection, etc. In terms of personnel, all JCG maritime security officers are required to go through the entrance selection, training selection and post selection of maritime security school or maritime security university. The specialties set up by these two schools cover almost all disciplines related to the sea. Maritime security test and research center is the authoritative maritime equipment R&D, application and testing organization of JCG. It provides JCG with the research, development and inspection of maritime equipment, as well as the analysis and inspection of marine communication electronic information. JCG is the main function and law enforcement department of the whole navigation service system in Japan. It is responsible for the establishment and management of Japan's navigation service system, as well as the formulation and implementation of relevant laws, regulations and systems. Japan's maritime traffic center has seven locations,

which provide information required by maritime traffic, including meteorological information and ship dynamics, as well as traffic management services for safe navigation of large ships on the route based on Japan's domestic laws and regulations, so as to ensure the safety of ships and smooth maritime traffic in areas with heavy traffic and difficult navigation.

CHAPTER 3 PERSPECTIVE DEVELOPMENTS OF DIGITAL MARITIME SECTOR

3.1 Example of intelligent aids to navigation

Taking the intelligent current measurement buoys used in the Grand Canal as an example to introduce the intelligent aids to navigation in China.



1.Anemometer
2.GPRS Antenna
3.GPS Antenna
4.Beacon light
5.Buoy
6.Detector of the Doppler log
7.Instruments warehouse

Figure 4-Structure diagram

(1)Reason why choose the cross current buoys as the carrier

According to the inland aids to navigation (national standard) and relevant regulations, the cross current mark should be set in the place where there is cross current in the channel, indicating that there is cross current in the water area, and the place where there is cross current is the place where the average accident is most likely to occur in the channel in the flood season (Yang, 2016, 89). Therefore, the selection of cross current buoy as the carrier, and the relevant equipment on it (see

Figure 4), all-weather collection and application of channel elements such as water flow, can effectively protect the navigation safety of passing ships.

(2)Fundamental requirements to convert cross current buoy into intelligent current measurement buoy

The multi-function intelligent current measurement mark for measuring current is transformed on the basis of the cross current mark. The standard cross current buoy is kept unchanged in the production process, and the applied transformation is made according to the actual needs (Cheng, 2020, 32). In this example, the 7m standard cross current buoy is selected. In the reconstruction design, the existing mature technology is used to meet the basic requirements of the stability, sinking resistance, collision resistance, corrosion resistance and operability of the buoy.

(3)Setting and positioning of multifunctional intelligent current measurement buoy

The setting and positioning of multi-functional intelligent current measurement buoy is an important link to ensure the safe acquisition of setting data. High precision survey should be carried out at the mark setting place before throwing to achieve the accuracy of centimeter level of regional riverbed topographic map. On this basis, data model should be established and the river bottom should be marked for manual processing to ensure that the riverbed of the measuring point is relatively flat. After the carrier throwing and positioning, the direction should be relatively fixed, the turning radius should be within the set value range, and the restricted inland waterway should not be more than 10m. From the practical application, it is found that the direction of crossflow sign will not change when there is cross current, and the safety is very high.

3.2 Research on the data acquisition equipment

(1) Composition of the data acquisition equipment

The data acquisition equipment is mainly composed of ultrasonic Doppler flow velocity and direction log, high-precision GPS locator, dual system specific data terminal, anemoclinograph and related power supply equipment (Niu, 2020, 51). Among them, the detector of the ultrasonic Doppler current velocity and direction log integrates ultrasonic sensor, temperature sensor, current direction sensor and water depth sensor, and is suspended under the water of the carrier, and the detector is connected with the main processor through a cable; anemometer, beacon light, battery, data integrator, high precision GPS locator, dual system specific data terminal and antenna are installed on the carrier (Yang, 2006, 32). Each measuring equipment is connected with the data integrator to form a complete working system of multi-functional intelligent current measurement buoys (see Figure 5).

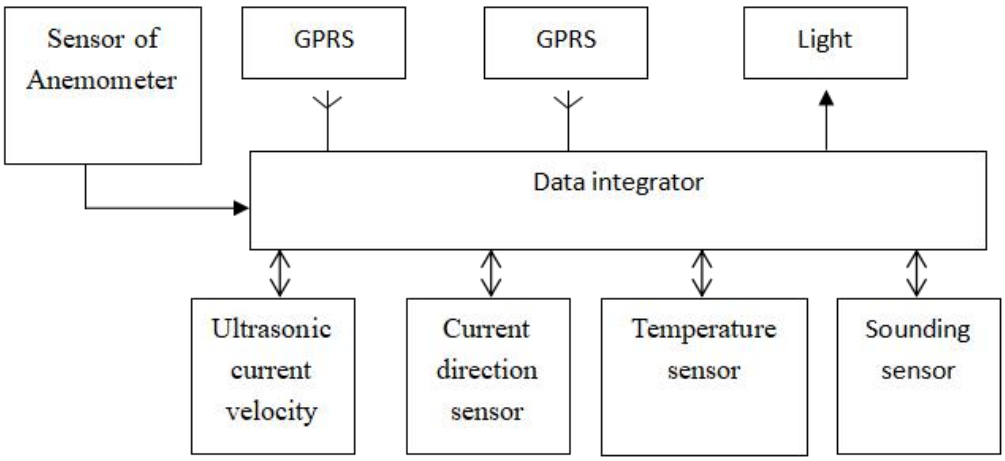


Figure 5-Electrical principle block diagram

(2)Characteristics of ultrasonic Doppler current log

LSH10-1 ultrasonic Doppler current log is a new type of ultrasonic current measurement equipment independently developed in China. The equipment is made by the principle of Doppler effect, and the technology is very mature. The research of this project is mainly based on the technical transformation of the equipment, which organically combines other channel element acquisition equipment and management system to realize intelligent data exchange, thus forming a specific equipment for this project. Among them, underwater acquisition has the following application characteristics:

a. Current measurement range: 0.02-7.0m/s, measurement accuracy: 1.0% ± 1cm/s, high precision, wide range, can measure weak current, strong current as well;

b. It can measure instantaneous velocity and average velocity with rapid responding speed

c. There is no K and C value of the calibration curve;

d. Ultra high resolution: 1 mm (in the case of low current rate, it can measure the current rate data of millimeter level, and is the only equipment that can measure the current rate of millimeter level in China). It has high sensitivity, high resolution and is not limited by the start-up current rate;

e. Light weight (4.3kg), low power consumption (current measurement < 600mA, power consumption < 7W; the standby current is about 15mA and the power consumption is less than 0.18WA;

f. Not afraid of sediment and floating debris, easy to operate, not easy to damage.

3.3 Research on the management system

This system is a comprehensive application system which integrates global positioning system (GPS), acoustic Doppler Current Profiler (ADCP) for velocity

measurement, acoustic sounding for water depth measurement, mobile communication technology (GSM or GPRS), electronic navigational charts (ENC) and computer network technology. It is mainly composed of multi-function buoy telemetry terminal, "Dynamic monitoring platform for AtoN" (which can be regarded as the server of the system), client, database, communication network and other parts. "Dynamic monitoring platform for AtoN" is responsible for collecting information from multi-function buoy telemetry terminal through wireless mode, pre-processing, and then saving the data to "database server"; all clients obtain information or send instructions through the "Dynamic monitoring platform for AtoN". The details are as follows:

(1)Terminal

The terminal consists of six parts: central control module, measurement and control module, wireless communication module, storage module, expansion interface and power system. Functions of each module and subsystem:

A.Central control module: mainly responsible for data processing and controlling other modules or subsystems;

B.Measurement and control module: monitoring GPS position information, beacon light quality (flashing cycle), beacon working status (voltage and current), battery charging and discharging status, solar panel status and other analog and digital signals. It can also expand the function of monitoring water temperature, water depth, current rate and other information;

C.Wireless communication module: responsible for wireless communication with channel dynamic monitoring platform to realize remote wake-up, remote monitoring, remote control, remote data transmission, etc;

D.Storage module: responsible for saving and reading the configuration data and

historical data of each module or subsystem;

E.Expansion interface: provide RS-232 / 485 or USB and other peripheral communication expansion;

F.Power supply system: composed of power module, solar cell module and storage battery, it provides stable and reliable power supply for the whole terminal.

(2)Dynamic monitoring platform for AtoN

If the terminal is the basis of the system, then the dynamic monitoring platform for AtoN (that is, the server) is the core of the system. The platform can collect, process and distribute information to the distributed terminals in real time, and process the terminal settings and information requests of various users in a centralized way. Each service performs its own duties and cooperates with each other to ensure the real-time, stability and reliability of the system. At the same time, it provides technical support for the system function decomposition and step-by-step construction. The dynamic monitoring platform for AtoN receives the information collected by the terminal, saves the effective information to the database according to the protocol and sends it to the client for display; forward the commands and settings requested by the client to the terminal.

(3)Client

The client is directly oriented to users in the whole system. The system provides different services to different user groups through these clients, so as to realize the optimal management and information sharing of the whole system. The client can display the information reported by the terminal in various ways, and the information is forwarded through the dynamic monitoring platform for AtoN; at the same time, the client can also send commands to the terminal.

(4)Database

It stores the configuration information of all terminals, the user information of the client, the port information of the server, the navigational chart information, as well as the real-time data, alarm data, historical data, analysis summary data, operation log data collected by the terminal. These data are an important part of the system construction and the basic information for making full use of the navigation channel at present and in the future.

(5)Communication network

The communication network realizes the data transmission between the terminal and the dynamic monitoring platform for AtoN, between the platform and the client, between the platform and the database, and between the client and the database.

3.4 System function and realization principle

(1)Data exchange

According to the given collection cycle or timing, the working state parameters of the beacon light, its own position information, water temperature, current rate and water depth are collected (Niu, 2020, 52). After alarm recognition and other processing, the data is sent to the dynamic monitoring platform according to the given transmission cycle through GSM/GPRS or SMS communication network; or receive the command sent by the monitoring platform through GPRS network or SMS command sent by GSM network, verify and identify the command, then respond to the legal control command, and finally return the corresponding data.

In order to realize the function of data exchange, the following three aspects shall be stipulated:

A.Data exchange bearer protocol: that is, the underlying network protocol carrying

data exchange is specified. The terminal uses the transport layer protocol between the commercial wireless communication network and the dynamic monitoring platform for AtoN, which is one or more of TCP/UDP and SMS.

B.Communication working mechanism: that is to specify the communication mechanism between the telemetry & remote control terminal, and the dynamic monitoring platform for AtoN. The communication mechanism of the system is mainly based on TCP/UDP protocol, and supplemented by short message interaction.

The terminal collects GPS position, battery, flash cycle, etc. through analog and data signal
Reaching the terminal upload time, or the terminal detects abnormalities
The terminal connects to the dynamic connecting platform and is not logged in or carries out logging operation
The information is processed by the processing module and sent to the dynamic monitoring platform for data packaging
The channel dynamic platform receives the data (after the terminal communication service platform)
The dynamic monitoring platform processes data, stores and checks with the database server into the database
The terminal sends heartbeat packets to the dynamic monitoring platform to maintain the terminal on line
When the terminal is idle for a specified period of time, it actively logs out and closes the connection to the dynamic monitoring platform

Table 2-Upstream work flow for terminal based on TCP/UDP communication mode

b-1. Communication mechanism based on TCP/UDP protocol

After the terminal starts, it can access the Internet through GPRS. The terminal wireless communication module runs automatically, and sends TCP connection request or UDP connection to the fixed IP address of the dynamic monitoring platform for AtoN through socket. At the same time, the platform uses socket to monitor the connection request of the terminal, and the terminal can exchange data with the dynamic monitoring platform for AtoN. The terminal adopts TCP/UDP protocol communication mode to submit data to the dynamic monitoring platform for AtoN, and the upstream chart is shown in table 2.

Monitoring platform control
The monitoring platform wakes up the non-logged-in terminal and logs into the dynamic platform through dialing or SMS
The terminal is in the login state and the monitoring platform sends data to the terminal
The terminal responds to the data from the monitoring platform
The terminal sends heartbeat packets to the dynamic platform to maintain the terminal on line
The terminal closes the connection and notifies the terminal to shut down the server when the control of the dynamic control platform is completed

Table 3-Downstream work flow for terminal based on TCP/UDP protocol communication mode

The downstream work flow of remote terminal unit (RTU) based on TCP / UDP protocol communication mode is similar to that of upstream, that is, the dynamic

monitoring platform for AtoN implements system setting, system restart, system test and system remote control and telemetry through the above work flow. The downstream work flow of dynamic monitoring platform for AtoN transmitting data to RTU based on TCP / UDP protocol communication mode (see Table 3).

b-2. Communication mechanism of short message interaction

In data interaction, the communication mode based on TCP/UDP protocol is preferred, but in the case of abnormal communication connection, the system automatically uses short message service (SMS) mode for interaction. Short message service interaction mode does not follow the mechanism of login and logout, heartbeat maintaining online, and this communication mode does not affect the online status of the terminal in the system. The upstream workflow of the terminal submitting data to the dynamic monitoring platform in the form of SMS (see Table 4).

After processing the information by the processing module, the terminal packages the data according to the data exchange standard
The terminal uploads the data to the dynamic platform
The dynamic platform responds to the terminal

Table 4-Upstream work flow by SMS

The downstream working mechanism by monitoring platform transmitting data to the terminal through SMS interaction (see Table 5).

The dynamic monitoring platform control
Dynamic monitoring platform
Terminal responds to the data of the dynamic monitoring

platform

Table 5-Downstream work flow by SMS

Communication data format: including the communication message structure, message field semantics, data format and other issues.

(2)Acquisition function of beacon light operation parameters

The terminal collects the operation parameters of aids to navigation, including: lamp quality, battery charge and discharge capacity, charging voltage, charging current, battery voltage, battery current, bulb voltage, bulb current, working state, sunlight value and other data. The data acquisition and transmission density is controllable, and the maximum transmission and acquisition density is once per second.

The data of charging voltage, charging current, battery voltage, battery current, bulb voltage, bulb current and sunlight value are completed by the system A/D conversion module; the lamp quality detection is realized by hysteresis comparison circuit composed of single chip microcomputer, and the lamp quality data is calculated by CPU in the form of interrupt; battery charge and discharge detection is completed by the integral circuit composed of bq26220, and sent to the CPU for processing through HDQ bus.

(3)Acquisition function of position parameters

The acquisition function of position parameters is mainly realized by the communication between GPS module and main MCU through the serial port of TTL level. Through this serial port, the terminal can forward the correction data from the GPS reference station to the GPS module, and the GPS module also outputs the difference data through this serial port.

The terminal and the GPS reference station receive the GPS satellite signal, and the

GPS reference station sends the received GPS satellite signal to the terminal through GPRS. The terminal obtains the longitude, latitude, speed and time information of the terminal after calculation, and sends it back to the dynamic monitoring platform for AtoN after packaging according to the specified protocol by using the GPRS data service or network. The dynamic monitoring platform decomposes the received data packets, transforms the longitude and latitude coordinates of the tracking points into the plane coordinate system coordinates used in the electronic charts, and then displays them in real time, dynamically and intuitively on the electronic charts, the channel dynamic monitoring platform feeds back the dispatching management command to the designated AtoN, and finally packages the data sent back by the terminal and GPS reference station, and stores it in a unified data format.

(4)Acquisition of dynamic information

The function of dynamic information acquisition is mainly realized by the special equipment such as current log, depth sounder and so on through RS485 serial port and terminal communication. Through this serial port, the terminal can receive the real-time data measured by current log, depth sounder and other equipment, including acquisition time, water temperature, current rate and water depth. The terminal then uses the GPRS data service or network, packages according to the specified protocol and sends it back to the dynamic monitoring platform. The dynamic monitoring platform decomposes and intelligently processes the received data packets. For example, the current velocity and water depth of a certain point or multiple points are transformed into a certain section current and a certain point water level according to an empirical formula or a measured data model, which are displayed in real time, dynamically and intuitively on the client, and stored in the database according to a unified data format for future query.

(5)Automatic alarm

The automatic alarm function is realized by setting the alarm threshold of the terminal. Alarm threshold is an important data of navigation aids operation, which is set by the client and then transmitted to the terminal for storage. If the current value exceeds the threshold, the terminal will report to the dynamic monitoring platform, and the channel monitoring platform will automatically notify the relevant maintenance personnel through mobile phone SMS. These thresholds include: upper limit of battery voltage, lower limit of battery voltage, lower limit of bulb current, lamp quality, longitude and latitude, displacement radius, etc.

(6)Remote control and data storage function

After the terminal starts, it can access the Internet through GPRS. The terminal wireless communication module sends TCP/UDP connection request to the fixed IP address of the dynamic monitoring platform, and the platform uses socket to monitor the connection request of the terminal. The dynamic monitoring platform can remote control the terminal.

Remote control: set the light quality, voltage and current threshold, reference position and displacement radius, transmission cycle and acquisition cycle.

Telemetry: the dynamic monitoring platform queries the current operation status of the terminal, or the terminal regularly reports the current operation status.

The terminal stores all the above parameters locally. When the network communication is abnormal, the terminal saves the current operation parameters and reissues them after the network communication is normal without missing data.

3.5 Main technical innovation points

(1) The standard cross current buoy is used as the carrier, and the equipment including special ultrasonic Doppler velocity log, ultrasonic sounding instrument,

anemoclinograph, GPS satellite positioner, data information intelligent processor and other equipment are equipped as one of the specific management system of aids to navigation. It has complete functions, strong compatibility and wide applicability.

(2) The data transmission is realized by mobile GPRS and GSM communication technology, which is convenient to use, guaranteed by mature technology and low price.

(3) The dynamic information management system developed by ourselves is used to analyze and process the relevant data intelligently to realize intelligent data screening, classification and release. It is targeted and can realize information sharing.

(4) CJS57 chart is used to show the survey point, the precise position of the ship and the actual condition of the channel.

(5) Using general smart phones to realize intelligent perception of information.

(6) Develop a "navigation and positioning system based collision degree detection system", determine the buoy drift, swing, collision degree and other abnormal situations, and use the system intelligent analysis and processing to realize intelligent repair, to ensure the data collection is safe and accurate.

(7) It can be installed on all kinds of buoys, buoy tenders and other water platforms.

(8) It has the advantages of timely data acquisition, high precision, low labor intensity and safety.

CHAPTER 4 THE MODE OF INTEGRATED NAVIGATION SERVICE SYSTEM

4.1 Significance of integrated navigation service system

The integrated navigation service system is on the basis of consolidating and developing the existing navigation service , to integrate and apply all kinds of resources, give full play to the overall advantages of maritime management, build the international advanced level of China's integrated navigation service system, and provide more comprehensive, timely, reliable and integrated comprehensive safety information for ships (Su, 2019, 5). The purpose is to let the seafarers at any time and any place can enjoy high quality navigation service. This integrated navigation service system includes coastal navigation system for aids to navigation, navigation information monitoring and releasing system, and maritime emergency response system.

At present, the information technology represented by the Internet has been developed and changed with each passing day, leading the new changes of social production. Bringing benefits to the world and mankind via the Internet becomes people's common wish. In August 2016, the Maritime Safety Administration of the People's Republic of China issued the "The 13th Five-year Plan for Maritime Navigation Service", which proposed that in the next five years, "relying on the Internet plus" and "e-navigation" concept, we should basically build a comprehensive maritime service system covering a comprehensive, efficient management, high quality service and timely protection. In order to better implement the 13th five-year plan from the Ministry of Transport, three Navigation Service Centers further refines

the comprehensive navigation service system into six major contents, namely: scientific and reasonable layout, complete functional support, advanced and applicable equipment, standardized operation, timely emergency response, reliable and efficient service. So, how to promote the construction of comprehensive navigation service system? The author believes that the system is a systematic concept, which involves not only the management system and mechanism and equipment foundation, but also the comprehensive support service and other aspects. It can be said that the core is comprehensive support and the objective is high-quality service. However, only from the analysis of its connotation and form, the key to lead that is to effectively establish a comprehensive navigation service system through scientific and technological innovation, especially strengthening information work, on the basis of coordinating the three major businesses of navigation service, so as to better enhance the comprehensive service ability and provide comprehensive and timely navigation information services for ships and other users.

The basic ideas for building an integrated maritime service system can be summarized as follows: to implement the national development strategy in depth, to take "Institutionalized, standardized and procedural construction" as the leading, to serve the needs of the object as the guidance, to the goal of the comprehensive service system construction, to improve the service quality, to increase the total service amount, to "intelligent, global" as the development direction, to comprehensively coordinate three major businesses of aids to navigation, nautical hydrography and maritime communication, to make full use of modern information technology such as "Internet plus" and "big data", to carry out top-level design according to the general standards, establish a unified shore-based navigation service system, and realize the whole-process information management and intelligent management of navigation service, providing users with a comprehensive, timely,

efficient and intelligent integrated navigation service.

Therefore, from the technical aspect, it should be clear how to establish a unified shore-based system, how to carry out efficient data and information transmission, how to compile a unified information standard, how to realize broadband ship-shore data communication, how to provide users with unified integrated navigation services, and how to plan and manage the integrated navigation service system intelligently and efficiently. It will be a long and complicated process to solve these technical requirements. At present, the e-navigation strategy and related technical system promoted by the International Maritime Organization can solve these problems. We can carry out the top-level design of integrated navigation service system and carry out the corresponding system construction based on the concept of e-navigation.

4.2 Main construction contents of integrated navigation service system

In 2006, IMO proposed the E-navigation development strategy, aiming to build a unified e-navigation environment based on modern information technology, to enhance the navigation capacity and other related services from berths to berths, to improve the safety and security level of the sea and protect the marine environment. The overall structure of e-navigation includes the shore-based system based on the Common Shore System Architecture(CSSA), the ship-shore broad-band communication system based on VDES as the main communication mode. The structure is supported by this structure and provides unified maritime services for all kinds of users through the Maritime Service Portfolios (MSP) (Liang, 2017, 68).

Since 2010, Norway, Denmark and other EU countries have successively built several e-navigation pilot test platforms such as Monalisa, efficiensea and accseas in accordance with the above-mentioned e-navigation concept, initially realizing some

functions such as real-time port environment information service, maritime safety information service, route exchange service, crew certificate verification, emergency search and rescue support service, etc. In 2015, the "AIS information service platform" of the Ministry of maritime affairs of the people's Republic of China was put into operation. By using big data processing technology, it can effectively access and process AIS system data, ship database, hydrology, meteorology, maritime management and other data, providing three-dimensional and comprehensive navigation information services for platform users, as well as ship dynamic app application services for mobile end users, It has effectively improved the level of maritime supervision and comprehensive service (Yue, 2017,12). Since 2010, Norway, Denmark and other EU countries have successively built several e-navigation test platforms such as MONALISA, EfficienSea and ACCSEAS in accordance with the above-mentioned e-navigation concept, which initially realizes some functions such as real-time port environment information service, maritime safety information service, route exchange service, crew certificate verification, emergency search and rescue support service, etc. In 2015, the "AIS information service platform" of the Maritime Safety Administration of the People's Republic of China was put into operation. By using big data processing technology, it can effectively access and process AIS system data, ship database, hydrology, meteorology, maritime management and other data, providing three-dimensional and comprehensive navigation information services for platform users, as well as ship dynamic application services for mobile end users, which has effectively improved the level of maritime supervision and comprehensive service (Xia, 2020, 30).

Based on IMO's e-navigation concept, according to the latest development results and construction experience of international e-navigation, shore-based services for ship users, and as the supplement and support of "AIS information service platform"

of MSA, the main construction contents of integrated navigation service system should include:

4.2.1 Strengthening the modernization of aids to navigation, nautical hydrography and maritime communication services

To build an integrated navigation service system, we must first lay a solid material foundation, and its strategic choice is to adhere to the "full time domain, multi-dimensional" service strategy, and continue to promote the modernization of navigation service. The specific ways include:

(1)Coordinating the integrated development of the three major businesses and regional resources, continuously strengthening infrastructure and capacity level by means of entrepreneurship and innovation, forming a facility and equipment system with advanced functions, complete supporting facilities, and sufficient quantity; fully adapting to the development of system reform, further changing the service concept, innovate service measures, enriching service products, expanding service fields, building external public service platform, forming a public service system with perfect functions, convenient, efficient, and rich characteristics, and providing users with standardized, digital, and network security information services. Strengthening the research on international performance, development policies, application of advanced technologies, and the construction of laws, regulations, standardized system, and comprehensively improving the ability of innovation and performance, so as to laying a policy foundation for the construction of the system (Li, 2019, 54).

(2)In the aspect of aids to navigation construction, we shall adhere to the concept of "three-dimensional navigation assistance" and promote the construction of integrated navigation facilities system of "Air, Space, Ground and Sea". Aiming at the construction of "integrated navigation service system", it is important to improve the

station layout, consolidate the traditional visual aids to navigation and optimize the allocation of AtoN; developing modern digital aids to navigation, promoting the construction and modernization of AtoN in key routes and sea areas, focusing on promoting the application of satellite-based navigation, fully realizing the network of AIS and DGPS/DBD, building a multi-coverage and hierarchical three-dimensional navigation service network from distant sea areas to coastal sea areas, and providing all-time, all-weather, high-precision and intelligent integrated navigation service for the safety of ships (Zhang, 2018,88).

(3)In terms of nautical hydrography, we should adhere to the "global hydrography" strategy, strengthen the nautical hydrography of navigation environment and geographic information services, comprehensively improve the public welfare surveying ability of traffic waters and the hydrographic ability of far-reaching sea area, and lead the maritime nautical hydrography transformation and development from coastal port and waterway to port and trunk routes and even related international key routes. We should enrich maritime books and materials, establish a diversified nautical hydrographic product service system and emergency service system, and provide perfect maritime basic geographic information services.

In terms of maritime communication construction, we should adhere to the "multiple communication" strategy, optimize the layout of communication business, establish a standardized information service system, promote the construction of digital coastal radio station and information platform, and build a multiple communication information network based on performance communication and focusing on information service. To realize the comprehensive transformation of communication from "analog to digital", "pipeline to network" and "adaptation to guidance", form a barrier free communication service pattern with regional coordination, diverse means and efficient services, and provide high-quality and efficient communication services

for navigation users.

4.2.2 Establishing a shore-based navigation service system based on CSSA

To meet the needs of the "AIS service platform" of the China MSA, according to the e-navigation CSSA technical architecture, a unified shore-based integrated navigation service system shall be established, forming a distributed service platform and network based on the navigation service centers, providing real-time online regional support services for users such as water vessels, as well as necessary data support for the "AIS service platform" (Xia, 2021, 14). The main contents include:

(1)Establishing a integrated navigation service information perception network, further improving the construction of related data acquisition system in navigation service system, mainly including: high precision navigation and positioning support system (including RBN-DGPS + DBDs and CORS), AIS, VTS, CCTV, AtoN telemetry and remote control, multi-function AtoN, hydrological network, visibility, port, channel and anchorage geographic information system, etc. At the same time, we should actively study the use of modern data sensing technologies such as remote sensing to continuously expand the scope of data collection for ice observation and pollution monitoring, and improve the efficiency and accuracy of data collection, so as to establish a integrated navigation service information sensing network, and realize real-time, automatic and comprehensive perception of hydrology, meteorology, water resources in ports, navigation channels and other jurisdiction waters. The real-time dynamic navigation aids and traffic information of surrounding navigable ships can realize the automation of environment perception, and promote the real-time good interaction between ships and all kinds of navigation resources.

(2)Establishing a integrated navigation service cloud data center: collect and store navigation service perception network data; integrate existing business system

database; establish integrated navigation service cloud data center; make full use of cloud computing, big data, Internet of things and other modern information technology; strengthen data processing and fusion, and realize intelligent management and application of data information. It provides comprehensive data services for all kinds of navigation service application systems and users, and is the basis of research and application based on navigation service big data. On the basis of automatic perception of the environment, the environmental data is converted into a unified data format. Combined with the relevant data model and information standard of nautical hydrography S-100, the digital environment of the geographical environment of the areas under the jurisdiction of ports and waterways is established, which provides the digital electronic chart model for the modern development of navigation service and various applications, and realizes the digitization and Intellectualization of ports and waterways Intelligent (Liang, 2017, 69).

The "Internet plus" maritime cloud information transmission network shall be built: using the Internet plus technology, according to the concept of e- maritime maritime cloud, thus constructing the maritime security information between the maritime agencies and navigation service centers, between the ship-shore and various applications. A seamless, fast and reliable data transmission network with sufficient security mechanism shall be established to realize seamless information transmission.

4.2.3 Research on a diversified ship-shore communication system led by VDES

We shall make full use of the advantages of maritime safety communication business, consolidate and transform the application of traditional communication technology, vigorously develop the application of maritime mobile communication, public network, satellite communication and low-power Internet of things technology based

on aids to navigation, especially strengthen the latest VDES and NAVDAT technology and application research, and actively participate in the research and development of international VDES technology (Liang, 2019, 67). It can provide diversified data communication between ship and shore, and ensure "visualization" and good interaction between ship and ship, ship and aids to navigation.

4.2.4 Research and formulate the navigation service information standard based on S-100

IMO has determined to use S-100 as the general information standard of e-navigation system, so as to realize the information sharing among various systems. Obviously, the integrated navigation service system should also use S-100 as the general information standard. Therefore, we shall make full use of the technical advantages of nautical hydrographic department and aerial surveying science and technology center, actively track and study the latest development of international S-100 series standards, carry out domestic research on international S-100 series standards, develop our own navigation service information standards, and provide unified information support for the development of integrated navigation service system.

4.2.5 Develop the integrated navigation service products based on the needs of users

Carrying out user demand analysis and research scientifically, and strengthening the actual application. In accordance with the concept of Maritime Service Portfolios (MSP) proposed by IMO for the realization of e-navigation service, we shall integrate navigation service data resources, develops general shore-based service products and personalized service products, establishes customized navigation service mode, and provides users with timely, efficient, comprehensive and intelligent integrated navigation service system. At that time, ship users can not only

realize the interaction with navigation service centers through ship borne e-navigation equipment or mobile intelligent terminal, but also automatically receive navigation safety information, electronic chart update, channel real-time information graphic display and other services provided by navigation service centers through MSP and other means. Other users can also access various navigation service systems to customize and receive intelligent integrated navigation services, so as to realize the modernization of navigation services and enhance the social image of navigation services.

4.2.6 Establish intelligent and high-level integrated navigation service management system

Strictly speaking, the integrated navigation service system includes internal integrated management system and external service system. According to the concept of e-navigation, the integrated navigation service system can not only provide users with modern and intelligent integrated navigation services, but also provide the basis for the establishment of intelligent and high-level integrated navigation service management system. Based on the automatic perception of various business information and environmental information within the jurisdiction, through the safe, high-speed and seamless data transmission network, and using the powerful cloud computing and big data analysis capabilities of the data center, it can not only realize the information management of all elements of navigation service(such as people, ships, marks, charts and communication facilities) and the whole process of business production. In addition, it can also realize "visual" management of regional environment. This needs to be based on the needs of daily support management, unified development of intelligent management and maintenance application system and emergency support system and many other specific application systems, so as to realize the intellectualization of navigation service business management, and greatly

improve the level and efficiency of navigation service business management.

CHAPTER 5 CONCLUSION

The efforts made by IMO and ENAV committee from IALA, and the 13th five-year plan have drawn up a blueprint for us to build a integrated navigation service system, and the international e-navigation development has provided us with the latest concept to realize the integrated navigation service system. It can be believed that under the correct leadership of the China Maritime Safety Administration and Navigation Service Center, only by adhering to innovation driven, taking the initiative, giving full play to the advantages of navigation service resources, taking the user demand as the guidance, and actively promoting the construction of intelligent integrated navigation service system in accordance with e-navigation concept and technical system, can we better enhance the ability to perform duties and perform contracts, and provide full-time, global and comprehensive services for the safe navigation of ships. The all-weather and whole process security services will make greater contributions to the construction of "smart maritime" and regional economic and social development.

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