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Study on the impacts of AIS application on aids to navigation system in Zhanjiang Port

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STUDY ON THE IMPACTS OF AIS APPLICATION ON AIDS TO NAVIGATION SYSTEM IN ZHANJIANG PORT

By

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DECLARATION

I certify that all the material in this research paper 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 research paper reflect my own personal views, and are not necessarily endorsed by the University.

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ABSTRACT

Title of Research Paper: **Study on the Impacts of AIS Application on Aids to Navigation System in Zhanjiang Port**

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As an effective method of navigation safeguard, Aids to Navigation (AtoN) have worked for thousands years in different forms. With the discovery and development of Automatic Identification System (AIS), maritime safety began to be guaranteed by more advanced modern methods; and AtoN entered a new era of E-Navigation with the joint efforts of international organizations such as International Maritime Organization (IMO), The International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA) and International Telecommunications Union (ITU). AIS, one of the major applications widely used in marine transport for years, has made a revolutionary impact on traditional AtoN system.

Zhanjiang Port, an important hub of national integrated transport located in South China Sea, is equipped with more than 600 traditional AtoN to ensure the safety on the sea. After AIS being installed in this port 10 years ago, the obsolete constructions and management methods of the whole AtoN system have been greatly changed. This paper, taking the application of AIS in Zhanjiang Port as example, tries to explain the impacts of AIS application on traditional AtoN System.

Starting with the background of AIS technology and the base situation of AtoN system in Zhanjiang Port, the paper analyzes the impacts and limitations of AIS application from the efficiency on navigation and management for the Authority, and makes recommendations for the future application and development of AIS in AtoN

through the analysis of working principle of AIS on AtoN and the practice in Zhanjiang Port.

Key Words: AIS, Application, Zhanjiang Port, Aids to Navigation, Impacts, Navigation, Management, Limitations

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LIST OF ABBREVIATIONS

AIS	Automatic Identification System
ARPA	Automatic Radar Plotting Aid
AtoN	Aid(s) to Navigation
CSTDMA	Carrier Sense Time Division Multiple Access
DGNSS	Differential Global Navigation SATELLITE System
ECDIS	Electronic Chart Display and Information System
ENC	Electronic Navigational Charts
FATDMA	Fixed Access Time Division Multiple Access
GIS	Geographic Information System
GNSS	Global Navigation Satellite System
GPRS	General Packet Radio Service
GPS	Global Positioning System
GSM	Global System for Mobile Communication
HTTP	Hyper Text Transfer Protocol
IALA	The International Association of Marine Aids to Navigation and Lighthouse Authorities
IEC	International Electrotechnical Commission
IHO	International Hydrographic Organization
IMO	International Maritime Organization
ITDMA	Incremental Time Division Multiple Access
ITU	International Telecommunications Union
MID	Maritime Identification Digits
MMSI	Maritime Mobile Service Identify
MSA	Maritime Safety Administration

VHF	Very High Frequency
RACON	Radar Beacon
RATDMA	Random Access Time Division Multiple Access
RTU	Remote Terminal Unit
SAR	Search And Rescue
SOTDMA	Self-Organized Time Division Multiple Access
VDL	VHF Digital Link
VTS	Vessel Traffic Service

Chapter 1 Introduction

1.1 Study Background

1.1.1 The development of AIS Application in AtoN

With the development of shipping industry and marine transportation, it has been increasingly difficult for the traditional communication modes of radar, Automatic Radar Plotting Aid (ARPA) and Very High Frequency (VHF) to satisfy the demand of safe navigation; therefore, the technology of AIS has emerged under the continuous research and development experimentation of IMO and IALA as the times require. AIS is a ship and shore-based data broadcast system operating in the VHF maritime band for the exchange of information including ship position, direction and speed. After the expanding scope of AIS application for decades, AIS has been used for navigation aid, Search and Rescue (SAR) aircraft station and rescue transmitter with great potential in the aspect of marine management, traffic regulation and marine safety.

AtoN are defined as a device or system external to vessels, which is designed and operated to enhance the safe and efficient navigation of vessels and/or vessel traffic by IALA. IALA has anticipated the prospect of AIS application on AtoN and has devoted to the practice and technical specifications of AIS along with ITU for years;

then, *IALA Recommendation A-126* has given guidelines and recommendations for the use of marine AtoN services, and ITU has specified the AIS message dedicated to AtoN. The application of AIS in AtoN has completely changed the navigation aid method of paper chart, visual observation and radar observation at sea, and provided a new full-time navigation aid method of shipborne radar, AIS and Electronic Chart Display and Information System (ECDIS) observation; therefore, a technological revolution has been brought to shock the traditional AtoN by the development of AIS application. (IALA, 2007)

Moreover, IMO considered and adopted the concept of E-Navigation proposed by IALA in the year of 2007; and the concept of digital AtoN came out as well. In recent years, E-Navigation has been vigorously developed and promoted to provide efficient and reliable information, to ensure seamless transmission of information between ship and ship, or between ship and shore authorities, and to make navigation safer and cheaper. As part of E-Navigation, AIS application would play an important role in not only navigation aids but also AtoN service. With the popularization of AIS devices and ECDIS on vessels, the digital AtoN which can be shown on the devices is ready to demonstrate incomparable superiority in the navigation guarantee service.

1.1.2 Overseas Practice of AIS Application

Many scholars have made great efforts to investigate the application of AIS on AtoN aboard. As early as the year of 2003, the AIS AtoN Akari-AIS-400 with newly designed AIS message 6 was developed by Japanese company ZENI-LITE and then accepted in *IALA Recommendation A-126*; later in 2005, Akari-100 AIS AtoN was announced with new standard and technology. An increasing number of AIS

products have been produced, developed and applied on AtoN worldwide for various channels, ports and wharfs.

1.1.3 Domestic Practice of AIS Application

The domestic practice of AIS application began from the 16th IALA conference in May, 2006, putting forward the integrated construction of maritime information system from telemetry and tele-control of AtoN to coastal integrated navigation service system, As the obsolete, instable and unreliable telemetry and tele-control technology mainly relies on the technology (i.e. Global System for Mobile Communication (GSM), General Packet Radio Service (GPRS), and Beidou satellite) from the third party, the AIS application, not only fully managed by the Maritime Safety Administration (MSA) but also able to communicate with ships, shall play a more important role in the integrated construction and realization of E-Navigation.

Ministry of Transport is responsible for the construction and management of coastal integrated navigation service system. As early as 1990s, China MSA under Ministry of Transport began its participation in international AIS related meetings, as well as the research and plan of AIS in China; then the construction of AIS project in Yangtze River Estuary and Pearl River Estuary was completed in 2003, the construction of AIS project in Bohai Bay and Qiongzhou Strait was completed in 2004, and the backbone network of China coastal AIS was started in the year of 2005 gradually. Therefore, the AIS signal coverage of major coastal area in China was realized quickly. In 2012, three subsidiaries in Ministry of Transport, Navigation Guarantee Center of North, East and South China Sea, were officially established in charge of technical support and service support for the construction and maintenance of AtoN, and surveying and mapping of channels, as well as the safety communication on water.

Except for the efforts by Authorities, indigenous technology and production in China have developed rapidly during the past 20 years. AIS terminal and AIS AtoN lights have been produced and developed by companies of Lighthouse, Spaceon, Xuchuang and so on, and operated in order in the coastal areas of China.

1.2 Objective of the Study

The questions that to what extent has AIS application influenced navigation and whether AIS AtoN can replace the traditional AtoN, have been debated for a long time. Taking the Zhanjiang Port as example, this study is aimed at researching the impacts of AIS applications on the efficiency and management of AtoN system and bringing some recommendations for the future development and management of AIS applications through analyzing the operational principle of AIS, the information and data of Zhanjiang Port, and the existing AtoN system in this port. It is hoped that this study will be able to offer clear analysis and exploration for the managers of navigation guarantee service.

1.3 Outline of the Study

To achieve the objective of the study, the paper is divided into six chapters for the research and analyze:

Chapter one introduces the background information of the study, including the development of AIS technology in shipping industry, the application of AIS in AtoN motivated by IMO and IALA, and the practices worldwide. In addition, the development, management and technical support by the Authority and companies of research and development are also briefly introduced.

Following the background of AIS development, Chapter two gives the operational principle of AIS in AtoN, including the device, the categories and the signal transmission to describe the working process of AIS AtoN, an essentially different method of navigation aid service.

For the sake of analysis, Chapter three introduces the essential navigation information of Zhanjiang Port and the traditional AtoN system there to show the operating order and efficiency of navigation under traditional AtoN system in Zhanjiang Port.

Correspondingly, Chapter four describes the application of AIS AtoN which complies with the above operational principle in Zhanjiang Port, and analyzes the limitations of the technology.

Then Chapter five elaborates the impact of AIS application on AtoN system compared with the traditional method described in Chapter three from the aspect of efficiency and management. This part is the key point of the study.

Lastly, from all the elaboration and analysis above, Chapter six concludes the study and makes some recommendations for the better use and management of AIS application in the future so as to achieve a more effective AtoN system.

Chapter 2 Operational Principle of AIS in AtoN

AIS, born in 1990s, is a new type of navigation aid system. On the basis of Global Positioning System (GPS) navigation technology, AIS is able to: 1) send continuous static data (name and nationality of the ship, IMO number, call sign, MMIS number, the length and width of ship, ship type and the position of GPS on board), dynamic data (position, speed, heading, navigation state, steering speed and heeling angle), navigation related information (draft, dangerous cargo type, port of destination and navigation plan) and security information (Vessel Traffic Service (VTS) information, weather reports, real-time hydrographic data, Electronic Navigational Charts (ENC) corrections, navigational warnings and emergencies) automatically; and 2) receive this static and dynamic information from ships around and exchange information with the coast stations on maritime VHF band automatically. Nowadays, AIS has been used for AtoN under the impetus of IALA.

2.1 Physical Structure of AIS

The physical structure of AIS in AtoN system mainly consists of AIS to navigation monitoring subsystem, navigation-aids information platform and navigation-aids information release subsystem as shown in Figure 2-1:

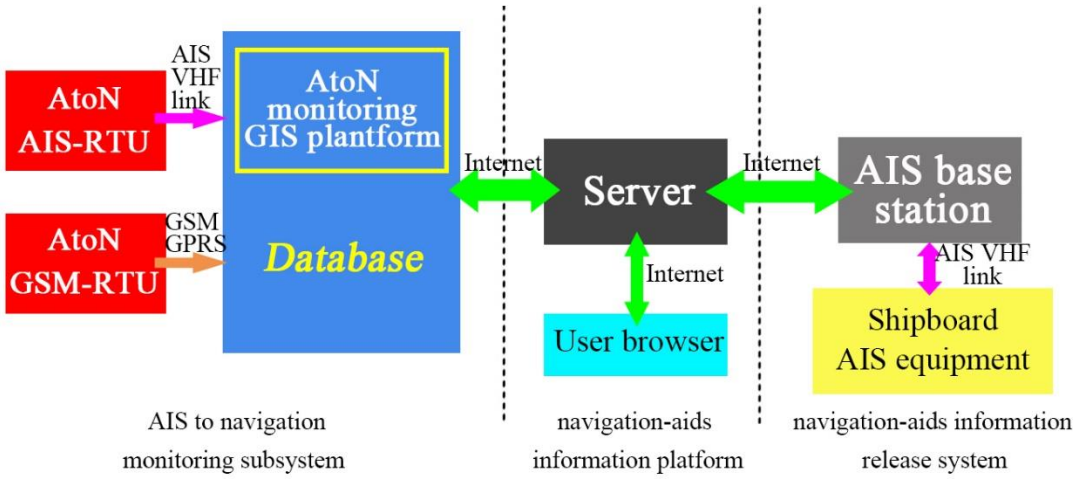

Figure 2-1 Physical Structure of AIS in AtoN system

Source: Compiled by the author

The net of the whole system is linked by the communication network of AIS VHF, network of GSM/GPRS and internet for the information transmission of three subsystems and platform.

(1) AIS to navigation monitoring subsystem

The subsystem includes GSM-Remote Terminal Unit (RTU), AIS-RTU on AtoN, communication network of AIS VHF and monitoring center.

GSM/GPRS AtoN integrates GPS, GSM, Geographic Information System (GIS) and computer network technology. GSM RTU includes GPS positioning module, communication module, data acquisition module and power module to realize the acquisition and processing of AtoN data. GSM/GPRS mobile communication network provides a communication link between the GSM-RTU and the monitoring center. Different from GSM-RTU, AIS-RTU is responsible for the collection of information about working conditions, parameters, speed, latitude and longitude of

AtoN, and information about operating conditions including flash, current, operating voltage, charging voltage, etc. The communication network of AIS VHF is responsible for the communication between the monitoring center and AIS-RTU via AIS message 6 by sending the AIS status report to the monitoring center. When the RTU has no abnormity, the data is sent at the predefined time interval; while once abnormity happens, the system sends the alarm data to the monitoring center. The monitoring center is responsible for processing, storing and distributing AtoN data. Moreover, the database also gathers the efficient, real-time, all-weather information about ships equipped with AIS from AIS and WEB-ECDIS. The database of monitoring center also integrates AtoN monitoring GIS platform. (Li, 2011)

(2) Navigation-aids information platform

The platform can display AtoN and ship equipped with AIS in the form of ENC, which will help the Authority release safety information of AtoN in time. The Navigation-aids information platform consists of user browser, the network server, the application server and the database server. When the database is responsible for the operation of AtoN, AIS ship data and chart data, the network server shall process the Hyper Text Transfer Protocol (HTTP) request. After processing the user request, the network server can transmit it to the application server and convert the result returned by the server to a web page and send it to the user browser. The user browser, on one hand, can provide the visual page to the user, and on the other hand, is able to send HTTP protocol request which will be sent to the network server.

(3) Navigation-aids information release subsystem

Navigation-aids information release subsystem is set to realize the integration of AIS ship data and monitoring data, and realize the publishment of AIS message 6, AIS

message 8, AIS message 12, AIS message 14, and AIS message 21. The message will be shown on the shipboard AIS equipment.

2.2 Information Processing in AIS Device

RTU is composed of radio frequency module, baseband module, equipment power control module, built-in VHF antenna and satellite receiving antenna. During the autonomous working stage after starting up in an AIS-RTU or GSM-RTU of AtoN, the power control module is responsible for collecting the exterior working state data including the current and voltage of light, the current and voltage of the solar panel and the working state of the battery; moreover, it is able to collect parameters from meteorological and hydrological sensors on AtoN in the later stage. AIS-RTU uses Fixed Access Time Division Multiple Access (FATDMA) and Random Access Time Division Multiple Access (RATDMA) to access the AIS network and transmits AIS message 21 firstly.

As a kind of communication and navigation system, the capacity of communication link of AIS system will directly affect the performance of the system. The allocation rule of ITU for AIS slot time is to divide one minute into 2,250 periods, and the number of available slot time is 4,500 under dual channel operation mode. Currently, algorithm of AIS slot selection includes the following methods: 1) RATDMA used for broadcasting aperiodic messages whose length should not exceed 3 consecutive slots; 2) Carrier Sense Time Division Multiple Access (CSTDMA) used for broadcasting aperiodic messages whose length should not exceed one consecutive slot; 3) Incremental Time Division Multiple Access (ITDMA) used for logging in network; and 4) FATDMA, the access protocol adopted by AIS digital beacon for launching message 21, allocates slots at the beginning of the frame; the allocation of each slot time is preset by the Authority and cannot be changed during the whole

period of the work until reset. The most widely used communication mode adopted in AIS system is Self-Organized Time Division Multiple Access (SOTDMA) which has the capability of automatically handling link overloads. The greatest feature of SOTDMA method is that each of the stations' messages is set with the next slot, so that other stations on the link are not notified to transmit the information. So it is easy for SOTDMA to calculate the number of simultaneous transmitters, and thus when the AIS link is overloaded, the effective distance will be gradually reduced, and the system will work properly at the expense of distance without system collapse. (Zheng, 2016)

2.3 Signal Recognition of AIS AtoN

The messages used in AtoN are mainly divided into the following three types: message 21, message 8, and message 6. Message 21, the message for AtoN exclusively, is used by vessels and VTS centers within the range of AtoN. It shall be broadcasted autonomously every 3 minutes or in the situation of external commands and VHF Digital Link (VDL) designated command. The contents of message 21 include the standard location of AtoN, the scale of AtoN, the indication of navigation mark shift, the accuracy of position, the name of AtoN, the type of positioning equipment, the location of AtoN, and the type of AtoN, etc. Sometimes the frequency can be reduced or increased considering the capacity of VDL and the energy consumption of AtoN. Message 8, binary broadcast information used by vessels within the range of AtoN, is set to show environmental information related to AtoN, such as meteorological and hydrographic data. Message 6, binary addressing information, is used by vessels within affected area. Through the messages, the signals of AtoN are received and processed. To identify different AtoN, every AIS AtoN own an exclusive Maritime Mobile Service Identify (MMSI) code guided by ITU. The MMSI code is specified as number 99 followed by a 3bit Maritime

Identification Digits (MID) code (in China the MID code shall be 412, 413 or 414) and a 4bit specific identification code. In company with MMSI code, every AIS AtoN should have a name within the length of 20 characters (the length can be appended up by 14 characters at most). (Lu, 2010, p.463)

Thus the contents of AIS AtoN which shall be shown in public is consisted of the type, name, location, accuracy indication, AtoN category identification, scale, reference position and status of AtoN through the messages and exclusive codes.

2.4 Symbol Display of AtoN

The most intuitive way to identify the AIS AtoN is through shipboard ECDIS or other system of management in the Authority. On the screen or software, AIS AtoN is plotted in particular symbol pattern. And IMO, International Electrotechnical Commission (IEC) and International Hydrographic Organization (IHO) are responsible for the development of related standards for AIS AtoN symbols: IMO is in charge of setting up the performance standards of the equipment, IEC formulates the corresponding test requirements, testing procedures and test results that should be achieved according to the performance standards from IMO, and lastly, IHO is responsible for the formulation of the relevant specifications of the chart information including symbols of AIS AtoN. From the standards and regulations, the sign of original AIS AtoN is a black diamond shape with a cross in the center, and the intersection point of the cross is the actual location of the AtoN in normal working conditions. Thus in actual display, there could be three kinds of AIS AtoN symbol: firstly, the original pattern of black diamond with cross indicating normal AtoN; secondly, a red diamond with cross indicating that the AIS AtoN has been shifted to another position; thirdly, a black diamond covered by a bigger fork indicating the signal is missing.

Chapter 3 Overview of Zhanjiang Port and Traditional AtoN System

3.1 Overview of Navigation Environment in Zhanjiang Port

3.1.1 Location

Zhanjiang, located in the southernmost Peninsula in mainland China, is one of the 25 major ports along the coast of China. As an important hub of national integrated transport, and the main unloading port of iron ore and crude oil in Southern China, Zhanjiang occupies an important position in marine transportation.

Zhanjiang Port, the first modernized port designed and built after the founding of The People's Republic of China, opened on May 1st, 1956. As the waterway goes straight to all the coastal areas of China and ports worldwide, Zhanjiang Port turns to be one of the ports which own the shortest voyage from China mainland to Southeast Asia, Middle East, Africa, Europe and Oceania, and has been opened to navigation with more than 100 countries and regions. After 50 years of development, Zhanjiang Port achieved a historic breakthrough. By the end of 2011, 125 productive berths and 34 deep-water berths were established in Zhanjiang Port, with annual design capacity of goods reaching up to 104,710,000 tons. The construction and development of Zhanjiang Port has played an important role in promoting the national economy and social progress in Zhanjiang city. (Shipping China, 2017)

Zhanjiang Port, at around 21°11′11″N 110°24′21″E, is one of the ports in Zhanjiang prefecture as shown in Figure 3-1:

Figure 3-1 Location of Zhanjiang Port

Source: Zhanjiang Municipal Government, (2013). Master plan of Zhanjiang Port.

3.1.2 Climate and Hydrology Condition

Zhanjiang, a region surrounded by sea on three sides, is accompanied by perennial high temperature, severe advection fog, high humidity at 83% and thunderstorms of over 100 days per year but without wintertime. Referring to the wind, northerly winds prevail from October to March while southerly winds reign from April to September; and there shall be 72 days a year when the wind force is over 6 gales averagely. Moreover, Zhanjiang is often affected by typhoon; the strongest tropical storm *Mujigae* attacked Zhanjiang in October, 2005, leading to an instantaneous maximum wind speed at 50m/s. The average data of climate is shown in Table 3-1:

Table 3-1: Average annual data of climate in Zhanjiang

Item	Unit	Maximum	Minimum	Historical Average
Temperature	Centigrade(°C)	38.1	2.8	23.5
Precipitation	Millimeter(mm)	2,411.3	743.6	1,313.2
Fog	Day	44	10	28.8

Source: Compiled by the author using Statistics from Annual Report of Zhanjiang Meteorological Bureau, (2015).

In terms of hydrology condition, it can be described from the following aspects:

(1) Tide: irregular semidiurnal tide. The tidal currents propagate into the bay mouth of Zhanjiang Port through the approach channel and then deform, leading to an increasing tidal range. In addition, the highest tide level is 7.1m and the lowest tide level is -0.57m while the average mean level of the sea is 2.2m from Theoretical Lowest Low Water.

(2) Flow of the tide: basically reciprocating along the deep groove and not affected by the river. The duration of flood at about 7 hours is larger than that of ebb at

5.5 hours while the current velocity of ebb at 1.95m/s is faster than that of flood at 1.54m/s averagely.

(3) Wave: small waves that are benefited from ideal shield conditions. Within the harbor area, general wave height fluctuates between 0.3m and 0.8m and the strongest one at 1.0m happens only in the period of typhoon; in addition, strong surges occupy a dominant position for a maximum height at 6m outside the harbor area. (Zhanjiang Meteorological Bureau, 2015)

3.1.3 Channel, Anchorage, Harbor District and Obstruction

The overall length of Channels in Zhanjiang Port is 185.37km, of which the main approach channels occupy 61.21km. Moreover, the main approach channels can be divided into 2 parts as shown in Table 3-2:

Table 3-2: Index of main channels in Zhanjiang Port

Item	Start	End	Length	Width	Depth	Origin
300000dwt channel	Longteng Channel	Dongtoushan Channel	54.9km	310m (Bottom)	-21.6m	Artificial
60000dwt channel	Maxie Channel	Tiaoshun Harbor	16.9km	/	-13m	Natural

Source: Compiled by the author using Statistics from Sailing Directions, (2015)

Around the channels, there are 34 anchorages in Zhanjiang Port: 26 anchorages above 100,000 tons' class occupy the area of 133.6km^2 at the depth from -18m to -10m, and 8 small ship anchorages locate beside the 60,000dwt channel. According to the function, all the anchorages can be divided into the types of Pilotage Anchorage, Quarantine Anchorage, Production Anchorage, Dangerous Goods

Anchorage, Lying Anchorage and Small Craft Anchorage. (Zhanjiang municipal government, 2013)

As a first class port of China, 6 main harbor districts are established for the production to ensure the normal operation of Zhanjiang Port: Xiashan Harbor, Xiahai Harbor, Baoman Harbor, Potou Harbor, Tiaoshun Harbor and Donghai Island Harbor. In the 6 harbor districts, there are over 80 berths, including seven 50,000 tons' berths; and the overall length of wharfs reaches up over 14,000m. The development of harbor districts is still growing to meet the needs of local economy and marine economy.

When sailing in Zhanjiang Port, the navigators and pilots should pay attention to the obstructions around the channels, anchorages and harbor districts. Firstly, concentrated shoals and reefs exist in southeast of Naozhou Island, internal and external joint of Longteng Channel and the entrance of Zhanjiang Port; secondly, shipwrecks are still lying beside Nansan Island and Naozhou Island; thirdly, Zhanjiang Bay Bridge stretches over Maxie Area with the main navigable width of 380 meters, navigable clearance height of 48 meters, the highest navigable water level of 4.54 meters, the surplus height of less than 2m when ships and facilities pass through the bridge, and the design class of the passing ships being 500 tons.

In addition, Zhanjiang Port is equipped with warehouses of 227,000 m^2, yards of 1,334,000 m^2, oil tanks of 542,000 m^3, 11 mooring buoys for precautions against typhoons, 22 harbor crafts including tugboats and pilot boats, and loading and unloading machinery for over 770 sets. (Shipping China, 2017)

The distribution of main approach channels at 30,000dwt class, production anchorages, 6 harbor districts and Zhanjiang bay bridge in Zhanjiang Port are shown in Figure 3-2:

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Figure 3-2 Distribution Map of Main Channels and Anchorages in Zhanjiang Port

Source: Compiled by the author

3.1.4 Arriving Vessels in Zhanjiang Port

Cargo-handling capacity of seaports in Zhanjiang Port mainly consists of coal, oil and products, metal ore, iron. The main modes of transportation are water, roads, railways and pipelines. Marine economy in Zhanjiang Port has raised for years and arriving vessels shows a large-scale development trend; taking the year of 2009 and 2011 as example, the number of arriving vessels in Zhanjiang Port was 5,282 and 6,151 respectively, and the average dead weight ton was 15,668.33t and 19,616.81t respectively; thus the number of arriving vessels increased by 869 and the average dead weight ton increased by 3,948.47t in the two years. And the large-scale development trend of vessels is mainly reflected in the transportation of offshore bulk cargo and crude oil, including vessels importing iron ore at the range of 70,000tons to 300,000tons and international vessels importing crude oil at the range of 70,000tons to 300,000tons. (China MSA, 2016)

3.2 Traditional AtoN System of Zhanjiang Port

AtoN, different from navigation aids, are operating external to vessels. Before AIS application used on AtoN, traditional AtoN mainly has three types: Visual Aids to Navigation, Radio Aids to Navigation and Sound Signals. In the traditional AtoN system of Zhanjiang Port, all of the three types of AtoN have been worked together for the safety of navigation.

3.2.1 Visual Aids to Navigation

Visual marks for navigation, which have been used in navigation for hundreds of years, are defined as natural or man-made objects by IALA, including structures specifically designed as short range aids to navigation, and conspicuous features such as headlands, mountain-tops, rocks, trees, etc. Among the visual marks, the visual AtoN are defined as purpose-built facilities that communicate information to a trained observer on a vessel for the purpose of assisting the task of navigation.

Furthermore, visual AtoN have two types: fixed AtoN and floating AtoN. (Guo,2016)

(1) Fixed AtoN

It is defined as the fixed artificial AtoN, recognized by its shape, color, pattern, topmark or light character, or a combination of these above. The application of fixed AtoN in Zhanjiang Port is common and comprehensive, including lighthouse, leading lines, beacon and sector light.

When sailing into Zhanjiang Port, vessels should pass through the Naozhou Island from north to reach the entrance of the port. Here the Naozhou Lighthouse has been standing at the northeast peak of the island since the year of 1898. With the light height of 103.0m and the range of 26n miles, Naozhou Lighthouse has turned into an important landmark in Zhanjiang Port. (Zhanjiang municipal government, 2013)

The most featured navigation facility in Zhanjiang Port is a series of leading lines. Leading lines, a system consisting of two constructions, can be aligned when watching them from centerline or deepest route along the strait channel. There are 10 pairs of leading lines standing from the outermost Naozhou Island to the innermost Tiaoshun Harbor and pointing out the centerline of channels, the deepest route of the channels and the entrance of the port. Including entrance channel, almost every channel of Zhanjiang Port is guided by a pair of leading lines in different patterns, marks and lights. The status that the light heights of these leading lines all exceed 15m and reach up to the maximum of 64.6m, and the range from 5n miles to 15n miles protect the navigation safety of the main channels effectively. (Zhanjiang municipal government, 2013)

With the development of Zhanjiang economy, more and more harbors, wharfs and docks are built to satisfy the need of transportation. To indicate the location of the land, obstructions and dangerous objects, the turning point of channels or waterways and the location of harbors, wharfs and docks, over 90 beacons are established for the navigation of vessels, ships, harbor crafts and fishing boats. The beacons, generally made of steel or fiberglass, are usually much smaller than lighthouses in size and shorter in range.

Apart from the lighthouses, leading lines and beacons, sector light is also used to make up for lack of leading lines. The longest main channel, Longteng Channel, is indicated by Longteng leading lines; when the rear structure stopped working due to transformation, the front structure of Longteng leading lines was installed on the sector light of three color lights. And for bridge, bridge marks are also used as a kind of fixed AtoN inlaid in the surface of Zhanjiang Bay Bridge.

(2) Floating AtoN

Floating AtoN shall be used for position indication like fixed AtoN. However, they are more likely to be set in or around water, sand bars and wrecks for they cost much less than fixed AtoN do and to construct them is much faster and easier than to build fixed AtoN. In Zhanjiang Port, floating AtoN are widely used including lightvessels and buoys.

Buoys occupy the largest number of all the AtoN in Zhanjiang Port; there are 67 buoys floating beside all the main channels from Longteng Channel to Tiaoshun Harbor especially around turning points and boundaries of channels; the harbors, wharfs and passenger terminals with concentrated ships or vessels are often equipped with buoys to guide the approach; and the boat channels used for fishery

transportation are guided by buoys to ensure the safety; for local enterprises, including logistics enterprises and shipping enterprises, it is necessary to require a series of buoys for the operation of safe and orderly production. All the buoys are built and managed according to the regulations from IALA and domestic laws.

Moreover, two lightvessels, Donghai Island Lightvessel and the bigger Zhanjiang Port Lightvessel, are floating at the entrance of port. Zhanjiang Port Lightvessel is a red navicular floating AtoN lying at the boundary of Zhanjiang Port with the length of 22.5 meters and the range of 10n miles. It is also the signature of this port. While Donghai Island Lightvessel is a mark at the left boundary of port entrance to guide the waterway into inner port. (Wan, 2013)

The major fixed AtoN and floating AtoN are shown in the Figure 3-3 (the total number of Visual Aton exceeds 200 and impossible to be shown wholly in one figure).

Figure 3-3 Distribution Map of Visual AtoN around Main Channels

Source: Compiled by the author from the statistical data, (2017)

3.2.2 Radio Aids to Navigation

The coverage of Radio AtoN is wider than that of Visual AtoN; and when more ships or vessels equipped with corresponding receivers or devices, the Radio AtoN shall gain more proceeds than Visual AtoN. As time goes by, some old-fashioned Radio AtoN are eliminated, and only radar reflectors and Radar Beacon (RACON) keep working on existing Visual AtoN as supplements and enhancement for ships. Moreover, a RACON is set on the Zhanjiang Bay Bridge to strengthen the function of marking and avoiding collision between ships and the bridge.

3.2.3 Sound Signals

Due to the heavy fog in Zhanjiang, a traditional fog signal has been kept on Naozhou Island for 61 years. This fog signal, also the last fog signal in South China Sea, is standing at the northeast corner of the island to make sound signals during the fog season from every December to next April. When the visual AtoN are almost invalid under the fog, sound signals can be an effective supplement for the efficiency of AtoN system.

3.2.4 DGNSS Broadcast Station

There is one Differential Global Navigation SATELLITE System (DGNSS) broadcast station built next to Naozhou Lighthouse for the purpose of reducing the signal deviation of Global Navigation Satellite System (GNSS). The user equipped with receiver can get the messages of positional errors and satellite integrity (health) information, thus enhancing the positioning accuracy in Zhanjiang Port.

3.2.5 Management and Effectiveness of Traditional AtoN System

In traditional AtoN system of Zhanjiang port, Visual AtoN occupy the dominant position of navigation service while Radio AtoN and sound signals are used as supplements. Thus the operation condition of Visual AtoN basically determines the

quality of service in Zhanjiang port. However, whether the Visual AtoN work well is influenced by a series of factors, including the position of AtoN, the distance from observer, the visibility of atmosphere, the backdrop and the reliability of AtoN.

Therefore, in order to keep the normal operation of AtoN, the Authority of Zhanjiang AtoN set up 4 compass of competency and corresponding subordinate institutions, and a maintenance center in the very beginning; thus no matter where the abnormity of AtoN happened, at least one of the 4 institutions could go to the rescue and repair. However, the management required a great deal of manpower, resources and work to complete the monthly inspection when there were only three workboats and several trucks used for transportation and inspection. The workload did not reduce until telemetry and tele-control started using.

On such a premise, the navigation in Zhanjiang Port is mainly depended on vision, and supplemented by sound and radio signals with DGNSS information. The traditional AtoN system, especially the establishment of the series of leading lines, worked well for the navigation service for quite a long time; however, with the development of economic constructions, especially the real estate industry, more and more lights of Visual AtoN have been overwhelmed by crowded city lights. Fortunately, this problem can be solved by the application of AIS in the navigation aid industry.

Chapter 4 AIS Application in Zhanjiang Port AtoN System

4.1 Category of AIS as AtoN

AIS AtoN, a navigation mark equipped with AIS equipment or AIS equipment that exists and works independently, is a kind of AtoN that can be used for ship navigation. The information of the AIS AtoN can come from the message produced and broadcasted directly by the AtoN itself, or from an AIS device other than the AtoN. Accordingly, the AIS AtoN can be divided into three types as depicted in Figure 4-1:

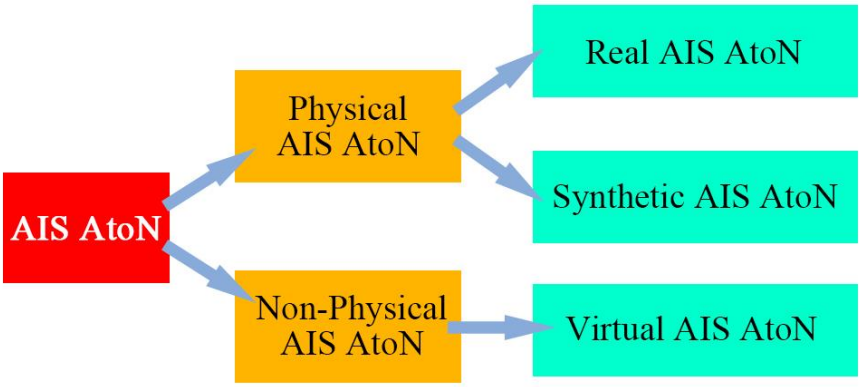

Figure 4-1 Category of AIS AtoN

Source: Compiled by the author according to IALA

4.2 Real AIS AtoN in Zhanjiang Port

4.2.1 Principle of Real AIS AtoN

Real AIS AtoN means installing the AIS device directly on traditional AtoN to collect local real-time data from AtoN and produce corresponding AIS information. When a ship within the coverage area of VHF sends out an interrogation signal, AIS navigation will automatically send a response signal corresponding to the received information; and AIS navigation information can be shown in the display of AIS equipment on board or radar and ECDIS on the ship to ensure the safety of navigation. Real AIS AtoN is able to send real-time information about the location, nature, and working status of the AtoN so that ships equipped with AIS, ECDIS and radar can find AIS AtoN more intuitively to read the name, number, nature and working state of the AtoN at a longer distance.

Real AIS AtoN can be a separate AIS transponder installed at sea or a combination of an AIS transponder and traditional AtoN. Thereinto, the working method of the separate AIS transponder is quite similar to ordinary shipboard AIS equipment, but it does not have input devices and display devices; and is only able to use AIS message 21 to broadcast the position information for ships passing by, but impossible to achieve the functions of visual color, shape and flashing light as the AtoN. Thus, the combination of an AIS transponder and traditional AtoN is more likely to be used in practice for the visual function and the acquisition unit collecting all of the information about AtoN, RACON and sensors. (Zhang, 2011, p.54)

4.2.2 Design of Real AIS as AtoN

In the process of the design and selection of Real AIS as AtoN, attention must be paid to the following aspects:

AIS Link: the most widely used method of SOTDMA is not applied in AIS AtoN system. Nowadays, in the AIS AtoN, there are three kinds of real AIS AtoN: the first one is the simplest, cheapest and most energy-efficient, operating in FATDMA mode and launch function exclusively; the second type is added with a receiver to realize remote settings and controls; the last type is the most complex one which consists of two receive units participating in the AIS link processing. That means, in addition to FATDMA, it can also work in RATDMA mode. Thus the last type of AIS AtoN with the complete structure of the AIS can operate without AIS base station.

Telemetry and Telecontrol: the AIS device shall be equipped with the function of automatic management of charging and discharging process, automatic regulation of operating voltage, operating environment temperature detection, monitoring on working voltage and current, turning on or off the light remotely, information report and alarm of abnormal status. Sometimes acquisition and broadcast function of meteorological and hydrological information are also needed. (Lin, 2011, p.71)

Appearance and Structure Design: due to the operation environment of harsh sea or waterway, it is common to see equipment failure with inconvenience of maintenance, so the appearance and structure design should take reliability, waterproof, and working stability into account. Work energy consumption should be reduced as much as possible when the work of whole AtoN mainly depends on solar panels and batteries; the circuit design is scalable and compatible for epitaxial circuit later; visual navigation effect of the light buoy cannot be affected in structure, and the design shall be as much convenience as possible for the maintainers.

4.2.3 Application of Real AIS AtoN in the Port

The application of real AIS AtoN in Zhanjiang Port has just lasted for less than a decade. With the construction of two AIS base stations in Donghai Island and Naozhou Island, real AIS AtoN started to appear among the crowded traditional AtoN. Subject to water and experience restrictions, the existing real AIS AtoN are set at important turning point of channels, along with the limited navigation channels or beside major obstructions; such as the real AIS AtoN on two lightvessels, the real AIS AtoN set on the buoys beside the Zhanjiang Bay Bridge and the real AIS AtoN on the aquatic beacon beside Doulong channel to show the drainage below the water. In addition, the real AIS AtoN on lightvessels are able to provide hydrological and meteorological services.

4.3 Synthetic AIS AtoN in Zhanjiang Port

Synthetic AIS AtoN is another kind of physical AIS AtoN. It is used for economical and practical purpose when installing AIS equipment on existing AtoN is not necessarily appropriate. The AIS message of the AtoN is simulated from another place while the AtoN is actually located in the place where the AIS message displays. The synthetic AIS AtoN have two types: monitored synthetic AIS AtoN and predicted synthetic AIS AtoN. Monitored synthetic AIS AtoN actually exist and send message 21 from the AIS station far away from the AtoN through a AIS link between them; the link confirms the location and the status of AtoN; but the predicted synthetic AIS AtoN is not able to confirm the location and status. At present, the two kinds of synthetic AIS AtoN are all not applied in Zhanjiang Port when there is a better choice of AIS AtoN.

4.4 Virtual AIS AtoN in Zhanjiang Port

4.4.1 Principle of Virtual AIS AtoN

Virtual AIS AtoN, a kind of AIS AtoN established to send message 21 without entity, is the integrated application of computer technology, satellite navigation and positioning technology, network technology and AIS technology in navigation aids. It is set to inform the dangers of navigation, safe routes, careful driving areas and evading waters through the location information and the type of AtoN. In the process of virtual AIS AtoN operation, AIS base station sends message to AIS equipment aboard firstly, then the equipment receives the message and displays the virtual AIS AtoN on the screen through software process; moreover, the received message can also be shown on the ECDIS and marine radar display. Virtual AIS AtoN can be set instead of entity AtoN when entity AtoN would become an obstruction, or when entity AtoN cannot be set up in time due to weather or other reasons. In addition, virtual AIS AtoN is especially suitable for the waters that are not easy or not allowed for entity AtoN. (Tong, 2012)

4.4.2 Application of Virtual AIS AtoN in the Port

Similar with the application of real AIS AtoN, the virtual AIS AtoN in Zhanjiang Port has lasted for about 9 years as well. Virtual AIS AtoN are adept at dealing with wreck accidents, and most of the existing virtual AIS AtoN in Zhanjiang Port are set to indicate the exact location of wrecks, no matter they are newly created or sunken ships for many years. Moreover, virtual AIS AtoN are also good at indicating any change in marine environment. Some temporary virtual AIS AtoN were set during channel changes, water area surveying, special operation in the sea, hydrological and meteorological changes or physical AtoN shifting, then these temporary AtoN were cancelled after the exceptions disappeared.

4.5 Management of AIS AtoN

Compared with the traditional method of management for AtoN, the management of AIS AtoN is quite simple without periodic artificial work at sea or frequent ship operations. Including the temporary AIS AtoN, there have been over 40 AIS AtoN in Zhanjiang Port for the past 10 years. The AIS AtoN requires the construction and maintenance of network and software system with the developed manufacturer of AIS equipment. As all the data and information of AIS AtoN can be observed from software and screen by the Authority in the office, the method of management becomes an institution of 24 hours on duty to observe the situation of AIS AtoN for investigation and analysis after the occurrence of abnormities; then the Authority arranges maintenance when there are equipment problems, or requires solution from the base station management department and research and development department if there are system problems. Besides, the establishment and removal of temporary AtoN are also included in the content of 24-hour duty. (Yan, 2015, p.48)

Chapter 5 Impacts of AIS Application on AtoN System in Zhanjiang Port

5.1 Impacts on Efficiency of AtoN System

5.1.1 Increase of Reliability

The increase of reliability is mainly reflected in the following aspects:

General observation of AtoN system: the propagation characteristic of AIS can make up for the shortcomings of traditional AtoN and enrich the identification methods of AtoN when AIS transmits data in VHF maritime band. The AtoN integrated with AIS can be all-weather recognized on the AIS display so that a ship equipped with a ship berth AIS or the shore station with AIS, and the AtoN situation in the region is clear to be obtained on the screen. This is especially important for Zhanjiang Port with dense shipping volume. The supplementary function has effectively strengthened the security of AtoN system when the main channels with lots of turnings are surrounded by shoals, rocks and nearshore fishery areas; and make Zhanjiang Port easier to be found in the exposed waters of South China Sea.

AtoN display is more clear and intuitive: the number, name and navigation properties are easily to be identified directly on the screen in shipborne AIS equipment by a ship at a distance and thus allowing the driver to identify the channel intuitively; and the identification function of marine radar is also enhanced. The AIS

AtoN on important traditional AtoN, including the Donghai Island lightvessel at the port entrance and Zhanjiang 57# AIS AtoN at the intersection of ships, should reduce the probability of collision between ships and AtoN or among ships, and reduce the possibility of ships grounding beside the channel. For the AIS AtoN installed on visual floating AtoN, even when the lights go out but AIS is still working normally, AIS is able to find the position of the real AtoN in time and avoid collision. In addition, the operator staff on board can avoid the occurrence of the ship grounding or struck against the rocks by referring to the position information from AIS AtoN when the buoy has been displaced.

Remedy for visual AtoN's lack of effectiveness: according to the division of districts by the government of Zhanjiang, part of the visual AtoN are established close to city buildings and factories, and some of the visual AtoN are standing behind the woods; but it is hard for the Authority of AtoN to relocate the buildings and woods that in the jurisdiction of other equal departments. Thus lights from buildings and factories have overshadowed the lights of fixed AtoN with the development of the city, and growing trees and tall buildings have blocked the fixed AtoN as well. Limited by funds and manpower, it is impossible for the Authority to heighten or rebuild all the affected fixed AtoN; and the AIS AtoN have turned to be the simplest, cheapest, but most effective solution for the visual AtoN's lack of effectiveness.

5.1.2 Improvement on Timeliness

The improvement on timeliness is mainly used in the following situations:

Repair of abnormal AtoN: The Authority can monitor the status of AIS AtoN in real time under the 24 hours on duty and report system; so once a AIS AtoN is displaced for a certain distance from the default location or aroused for the extinction of light,

the alarm will appear in the system. Thus the Authority is able to issue navigational warnings in time and arrange for personnel to check abnormal conditions and repair the AtoN quickly.

Marking of new abnormal AtoN: here the example of one of the worst typhoons happened in Zhanjiang can be used for illustration. In 2014, Typhoon *Rammasun* at the maximum wind level of 18.9 caused displacements and damages on almost half of the buoys in main channels, and several serious displacements and damages at the very beginning of Longteng channel which is the farthest away from work ships, staff of maintenance and supplementary equipment. As it was not possible to complete the restoration of buoys in a short period of time, the competent Authority set up AIS AtoN instead of the buoys which were unable to resume normal work temporarily to remind the passing ships sailing in accordance with the correct channels and waterways. The establishment of these virtual AIS AtoN only cost less than two hours.

Marking of new shipwreck or operation at sea: due to dense shoals and reefs around the main channels, wreck is a comparatively frequent occurrence in Zhanjiang Port. When a wreck happens in the night or too far from the dock of the operational vessel and the yard of the emergency buoy, the temporary visual AtoN is not available but a virtual AIS AtoN can be immediately set up using the AIS network system to show the position of the wreck. The setting or changing of AIS AtoN is very fast even within 10 minutes, and the advantages of the AIS AtoN will be more prominent in the case of the need for rapid setting.

5.1.3 An Irreplaceable Solution in Setting Scheme of AtoN

The appearance of the virtual AIS AtoN in the AIS AtoN provides a new solution for the plan layout of AtoN design. In the past, the construction of physical AtoN, especially buoys, in complex waters, could not meet the satisfaction of all parties; it was unlikely to ensure the safety of navigation, or even have a negative effect that hinders the normal sailing of the ship, and be contrary to the function and purpose of AtoN design. Fortunately, virtual AIS AtoN have brought a perfect solution.

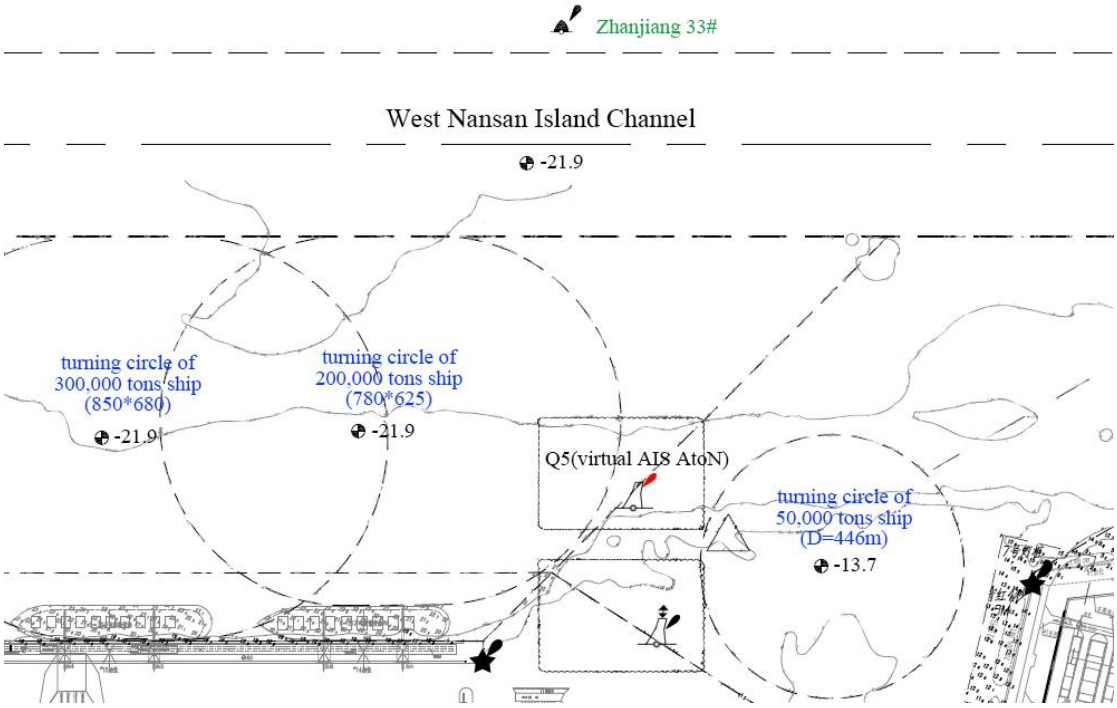

Figure 5-1 The Application of AIS AtoN in Design

Source: CCCC-FHDI ENGINEERING CO., LTD, (2014). Design scheme of supporting facilities for wharf and supporting project of Baosteel Guangdong Zhanjiang iron and steel base

Here the example of design for wharfs and supporting projects in Baosteel Corporation can be used to illustrate this solution visually. The West Nansan Island channel and the AtoN in it have been established and used for years; the wharf,

channel and turning area of Baosteel Corporation have just been built and excavated to design depth as shown in Figure 5-1. To the south of the turning circles of 300,000 tons' ship and 200,000 tons' ship there were berths for vessel operation, and to the southeast of the turning circle of 50,000 tons' ship there was a harbor basin. Due to the different depth of turning circles and types of ships in the future, it is necessary to set an AtoN to distinguish the boundary between two waters, guiding ships in different drafts running into each berth and preventing grounding of ships. However, a buoy or beacon in water would hinder the vessels in the harbor basin sailing to the berth and taking loading or unloading operation. Here a virtual AIS AtoN can solve the problem when it can be observed by ships equipped with AIS equipment and will not affect ship handling. However, the similar situation has occurred in Zhanjiang Port before the application of AIS but got no solution. (Zhanjiang aids to navigation department, 2016)

5.1.4 Realization of Hydro-meteorological Service

Meteorological and hydrological information plays an active role in the realization of E-Navigation with the supplement of dynamic and real-time through AIS messages. As the technology of collecting meteorological and hydrographic information is already mature, the information can be demodulated and broadcasted after the data acquisition equipment connected to AIS AtoN terminal, thus achieving the public service of meteorological and hydrographic information for passing ships. The service has already realized on Zhanjiang Port lightvessel to provide meteorological data on wind, rain, fog and visibility, and hydrological data on currents, swells and tides. The information also can be used as references for work assignment of operation ship in the Authority of AtoN to avoid the situation of course reversal for serious operating conditions when the operation ship has to carry a large number of buoys, equipment and diesel oil with huge labor and economic costs. Moreover, the

extensive application of meteorological and hydrographic information from AIS is promising to improve the response to accidents at sea and the effectiveness of search and rescue services by MSA

5.1.5 Uncertainty in Practice

The impact of AIS AtoN on the navigation effectiveness of traditional AtoN system is beyond doubt. However, there are still some uncertainties in the effectiveness for navigation aid at the beginning of the development of AIS AtoN. Firstly, the positioning precision of general real AIS AtoN is kept within the range of 10m when civil GPS chips are equipped as the positioning source of the devices. Therefore, the error between the position shown on the screen and the actual position of buoy is universal in practice, causing the driver to misjudge. Secondly, AIS AtoN also has certain limitations when shipboard AIS devices must be installed and work normally, and marine radar and ECDIS must be incorporated with AIS information, otherwise AIS AtoN will not be detected by marine radar and ECDIS; moreover, not every brand or model of ship radar and ECDIS can find all of the AIS AtoN. Thirdly, AtoN with a longer Chinese name often have a name over 20 characters; in this case the whole characters may not be shown up integrally on the screen. Fortunately, these uncertain situations are all technical problems, and there are already solutions to be implemented.

5.2 Impacts on Management of AtoN System

5.2.1 Reduction in the Cost

The Authority of AtoN, namely three subsidiaries of Ministry of Transport, Navigation Guarantee Center of North, East and South China Sea, is the department responsible for the management and maintenance of Chinese AIS base network system. While the real AIS AtoN only require one traditional AtoN and an AIS

transponder, and the virtual AIS only requires input operation on the system, the establishment of virtual AIS AtoN will not lead to any excess costs. Moreover, compared with the traditional telemetry and telecontrol devices with the network transmission of GSM/GPRS, AIS have saved the cost on public network of operators including China Mobile, China Unicom and China Telecom. Therefore, the AIS AtoN itself has the advantages of short construction cycle, low cost investment and convenient operation. The technical unification of the whole maritime AIS communication system can reduce the cost of maintenance and management, and realize the seamless connection of the radio monitoring system throughout the country.

In addition to the above charges, the reduction in cost is most evident in the reduction of traditional AtoN and repeated labor of transportation. This kind of transportation is brought by virtual AIS AtoN. As virtual AIS AtoN can be used for marking wrecks, abnormal traditional AtoN and temporary marine activities or facilities, almost all of the traditional AtoN transported and established for these purpose have been canceled. Thus there is no longer a cost of buoys and transportation. In the practice of Zhanjiang Port, the value of one buoy with floating buoy, anchor chain, sink, lamp and power supply system ranges from 80,000 RMB to 120,000 RMB according to diameter of floating buoy; the operation ship requires two voyages with massive fuel consumption from buoy yard to launching area in one delivery and recovery operation. Thus only the virtual AIS AtoN could save hundreds of thousands at least in Zhanjiang Port in one single year. (Zhanjiang aids to navigation department, 2016)

5.2.2 Reduction of Regional Restrictions

The impact of reduction of regional restrictions is mainly led by virtual AIS AtoN. Unlike real AIS AtoN which still require voyage for the installing, the establishment of virtual AIS AtoN is a process of software operation. Theoretically, as long as the AIS base station can cover, the virtual AIS AtoN can be established. There are 8 AIS base stations under the management of Zhanjiang Authority at present, and it needs only two AIS base stations, namely, Donghai Island AIS base stations and Naozhou AIS base stations, to realize the full coverage of Zhanjiang Port.

5.2.3 Radical Change in Monitoring and Maintenance

AIS application in AtoN system has brought two changes in monitoring and maintenance. Firstly, in the past, staff for maintenance took the inspection of all the AtoN once or twice a month and repaired the abnormal AtoN after finding problems; if problems had not been found, or appeared after monthly inspection, then the abnormal AtoN could not be solved or repaired until the next monthly inspection or report from MSA or ships. Different from the passive maintenance in the management of traditional AtoN, the Authority now can perform a real-time monitoring by AIS and telemetry and telecontrol, and react to abnormal conditions immediately. Therefore, the inspection period is extended from once or twice a month to the period of two months. Secondly, compared with the telemetry and telecontrol widely used in Zhanjiang Port, the GSM/GPRS transportation link which is managed and maintained by the three operators in China can be replaced by AIS transportation link managed and maintained by the Authority itself. Thus the errors including signal missing and line interruption can be investigated at the first time. Thirdly, monitoring information shown on the monitor control interface by AIS and AIS devices equipped on operation ship can be kept for a long time, so that managers of the Authority can not only directly take the real-time inspection of the work condition of operation ship based on inspection plan and AIS buoys nearby,

but also verify the operation capacity from recording playback. Therefore, the monitoring and maintenance turn into an immediate and active regulatory behavior which is no longer limited by geographical, meteorological and external links as shown in Figure 5-2.

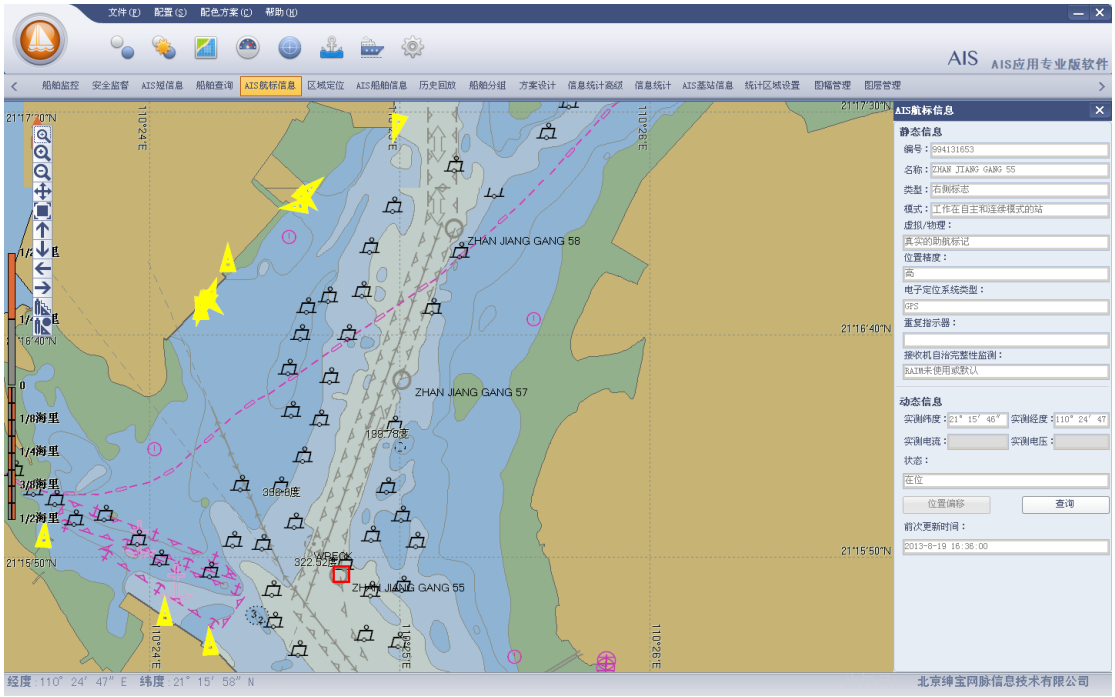

Figure 5-2 the Monitoring Interface of AIS System

Source: AIS Center in Zhanjiang

5.2.4 Realization of Accident Investigation Between Vessels and Buoys

As the ship's navigation path and the historical data of each AIS AtoN can be kept in AIS system for 3 months to 6 months, the accident investigation between vessels and buoys turned to be feasible. As the buoys beside the channel boundaries, shoals, and turning points are most likely to be collided by ships, some AIS equipment have been set on the buoys repeatedly collided in Zhanjiang Port. Thus when a ship sailing too close to be beyond the alert from the AIS AtoN, alert will be sent to the monitoring center immediately; and once a collision happens between a ship and a

buoy, the historical trajectory of all the ships equipped with AIS and the AIS AtoN can be played back in the form of animation in AIS system, and ascertain the information of the offending ship as the basis of the claim for buoy insurance and to reduce the economic losses caused by collision. During the past 10 years, each investigation from the AIS application has reduced economic losses by 100,000 to 300,000 RMB averagely in Zhanjiang Port. (Zhanjiang aids to navigation department, 2016)

5.2.5 Limitation and Unnecessary Extra Workload

However, AIS AtoN have not been applied rapidly on a large scale in Zhanjiang Port when the Authority are remaining on the sidelines to a certain extent for there are some negative impacts on the management of AIS system.

Firstly, energy consumption is likely to become a serious problem especially in fog weather. Traditional AtoN are powered by battery; when sunlight is enough, solar panels and batteries work together to convert solar energy into electricity, while the solar panels stop working but the batteries drive the lights shining when the sunlight is poor. But an AIS equipment, working for 24 hours a day, requires energy consumption to ensure sending one message per 3min for 24h a day as well; the low power operation mode and rated power consumption continuous working mode consume 1W and 4W power respectively for a general AIS equipment on AtoN. Thus extra work for replacement of full batteries and extra voyage of operation ships have appeared to maintain normal work. In rainy season and fog season, this emerging energy demand is more obvious. Thus the Authority has to take steps of increasing the power of solar panels and operating the AIS equipment in low power operation mode as far as possible; even thorough it may cause waste of resources.

Secondly, false alarms from AIS equipment have affected its reliability in the management in practice. The false alarms may involve the working status information and location information of AIS AtoN. Part of the faults occur in the control circuit of the energy system, ending up with errors in wrong voltage and abnormal solar charging, while the other part of the faults occurs in the positioning system. Sometimes there is a continuous position alarm displayed on the system but actually the AtoN or buoy is still at the right position in the safe range with certain water depth and length of anchor chain. These false alarms can cause doubts to managers, and may lead to wrong judgment and repair measures, resulting in unnecessary waste of human resources.

In addition, the danger of link congestion may hinder the wide application prospects due to the working principle of AIS. According to ITU, there are 4,500 slot time in one minute; with more ships (even including fishing boats nowadays) taking up the slot time with the working mode of SOTAMA, the left slot time available for AIS messages with the working mode of FATAMA and RATDMA shall be on the decrease as the communication between ships must be maintained preferentially.

Chapter 6 Conclusion

This research paper takes Zhanjiang Port as example, analyzes the impact of AIS application on traditional AtoN system from the aspect of AtoN efficiency and AtoN management. It is obvious that the application of AIS which has the advantage in communication and intellectualization, is able to increase the reliability, timeliness and service content of AtoN; moreover, AIS application has effectively reduced the cost and limitations of traditional AtoN with fundamental changes in management method even though it may also have some technical shortcomings and potential problems after over exploitation.

AIS application on AtoN has been practiced for less than 20 years in the maritime; however, its overall impact on traditional AtoN system is undoubtedly positive on the whole. As a newly applied technology, AIS has broad application prospects in the aspect of marine safety guarantee and E-Navigation. It should be a powerful supplement and assistance for the AtoN but not a radical replacement of traditional AtoN for the operation of AIS is depended on base stations, link communication, uninterrupted energy and even the traditional AtoN itself. Therefore, it is necessary to develop the AIS application as much as possible in the company of existing traditional AtoN. Some recommendations can be proposed for the development in the next stage:

Firstly, and urgently, the equipment of AIS-RTU should be developed in energy consumption design and positioning system not only to solve the main problems and errors in practice, but also to increase reliability of AIS message in the future. It is the requirement from both the Authority and the navigator.

Secondly, for the fact that AIS message cannot be shown on the AIS equipment or radar aboard, or the AIS signal cannot be displayed normatively on these equipment, it is necessary to upgrade the equipment aboard and publish unified and standardized display standards and icons for the main beneficiary of AIS and marine safety.

Lastly, the design of monitoring system shall be improved to reduce the error messages and false alarms from AIS equipment. It is of great benefit for reducing the waste of human and material resources caused by misjudgment from error messages and false alarms.

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