Ministry of Foreign Affairs

Green and Smart Shipping Market in China

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Report on

Green and Smart Shipping

By Marine Technology & Innovation (MT&I) group, 2022

Content

1. ABSTRACT

The shipping industry has been playing a significant role in the global economy. With its great advantage on volume and cost-benefit, over 90% of the cargo is transported by sea. In recent days, there is a strong motivation for green and smart shipping to be realised, to improve the industry to achieve a green, sustainable, and efficient model of development. China, as a key player in the global shipping industry and the related research and development, is eager to join the trend and welcomes collaborations with all the partners to advance the development of the industry. This report gives an overview of the various aspects of the shipping industry in China, its opportunities, and challenges on smart and green shipping, to provide a good reference for the interested entrepreneurs and stakeholders to take part in the process.

This report addresses the promising collaboration areas between the Chinese and the Dutch shipping industry on the topic of smart and green shipping in the following aspects:

- Remote sensing and surveillance of maritime pollution
- Advances in autonomous shipping and collision avoidance for the era of autonomous waterborne transportation
- Opportunities and challenges of clean energy for inland shipping

To obtain a general and insightful picture for future collaboration and business opportunities in the following fields, we have analyzed the current shipping industry of China and the related background on the policies and regulations. Based on the aforementioned analysis, the promising innovation domains, related technologies, and potential Chinese partners are also pointed out.

In general, green and smart shipping is one of the future topics which is highly welcomed in the Chinese shipping industry. The 13th Five-Year Plan for Economic and Social Development of the People's Republic of China and related plans and regulations for smart shipping and environmental protection has pointed out that a cleaner and smarter transportation system is highly encouraged for the future development of China, among which, the shipping industry is also included. In the recently released 14th Five-Year Plan, the Chinese government has continued to take solid steps in green, low-carbon and sustainable development and to promote green development of the Yangtze River Economic Belt. Besides the policy aspects, the R&D activities focusing on the technologies for green and smart shipping, such as remote sensing technologies for shipping pollution, advanced collision avoidance decision-making systems for the smart ship are highly active in the Chinese research facilities and universities. Such background has provided a good foundation for possible marketizations in the related fields for business opportunities. However, one should note that for some fields included in the report, many emerging technologies are required, which are not fully developed in the form of products that are frequently seen in the market. Such a challenge requires the business counterparts to fully understand both the policies in China and also the technological perspective for the development of green and smart shipping.

In this report, some details on the technologies and possible business opportunities are analysed, and we sincerely wish that the results could be beneficial for both parties to further strengthen the collaboration for greener and smarter shipping.

2. INTRODUCTION

China has become the largest shipbuilding country in the world. In recent years, the international market share of China's three major shipbuilding indicators has maintained the leading position in the world. In 2020, China undertook 25 ships equipped with various types of marine engineering, with a value of 2.04 billion US dollars, accounting for 35.5% of the global market share. At the same time, China's shipping industry has made major breakthroughs in the R&D of smart ships in recent years. China has been an important player in the global economy and transportation with its huge market and strong advantage on R&D and industrialization. In the shipping industry, the trend for smart and green shipping that supports sustainable development, environment protection, and advanced automation has drawn much attention from stakeholders worldwide. The Netherlands, as a country and the economic entity that has a long history of waterborne transportation and is also a key player on R&D in this industry, would like to seize such opportunities and strengthen the collaboration with the Chinese counterparts on the promising business opportunities for the smart and green shipping sector. Therefore, this report will show the general overview of the shipping industry in China, the governmental regulations for its development, and also the possible areas for collaborations that could prosper for the interested stakeholders.

Between China and the Netherlands, this kind of G2G collaboration has a long history. The Netherlands Embassy is continuously exploring the opportunities for collaboration between the Chinese and Dutch business sectors in the maritime and shipping industry, to stimulate innovation in the future research and development of the business. On the Dutch government side, the Ministry of Infrastructure and Water Management (IenW), Rijkswaterstaat (RWS), and Netherlands Enterprise Agency (RVO) have close ties with China in the field of inland and sea shipping. The China Waterborne Transport Research Institute (WTI) of MoT has undertaken the work of a pilot project of Intelligent Shipping Innovation in Qingdao, which is also supported by the Ministry of Science and Technology. In May of 2019, WTI had a Mission visit the NL and gave an introduction on China’s smart shipping development, especially for that pilot project. RWS arranged the visiting program for the Mission. In Dec of 2020, the Counsellor of IenW from the Embassy of the NL in Beijing visited the pilot project and Shandong Ports Group in Qingdao together with many Dutch companies, to explore the cooperation opportunities for Dutch companies. These events and collaborations have shown strong ties between the business sector of China and the Netherlands.

As the second-largest economic entity and the largest shipping industry participant, the advantages in the global shipping industry are of great significance for economic development and global competition. With the advances in technologies and the awareness of environmental protection and sustainable development, the idea of smart and green shipping has been drawing much attention from both academia and industry. The Chinese government has published various regulations and guidelines to facilitate the improvement of the business environment on such sections and welcomes collaborations from partners overseas. In the meantime, however, since the smart and green shipping industry is relatively new, the related information on business opportunities is not commonly known to interested entrepreneurs. Considering such a situation, it is, therefore, necessary to have a general understanding of the current development of the business sectors on smart and green shipping.

3. BACKGROUND

The shipping industry plays a key role in the global supply chain and transportation network with its significant advantage on volume and cost. According to the statistics from UNCTAD, over 90% of the cargo is transported by sea. However, with the awareness of environment protection, the advances of technologies on automation and artificial intelligence, the demand for clean and efficient shipping has been continuously increasing, e.g., the slogan of the International Maritime Organization (IMO) has changed to “Safe, secure and efficient shipping on clean oceans”.

China has taken such a trend as great opportunities to strengthen its development on technology and economy, and also improve their contribution on the environment protection for sustainable development. Therefore, many more policies and plans have been made to facilitate the development of smart and green shipping, such as autonomous ships, LNG-powered ships, etc. These policies have provided solid foundations for the business sectors to prosper.

For example, Zhejiang provincial government has achieved remarkable results in the prevention of pollution from ship and port in the Jiaxing City. The full coverages have been developed for port and wharf environmental protection access, port and wharf receiving facilities and ship sewage installations. The entire process of receiving transshipment, and disposal supervision is well established. Considerable shore power supply on ports and terminals greatly decrease emissions caused by ship berthing at port. In South China, the Guangdong Authorities are ambitious to launch a Green Pearl River Initiative to upgrade all the existing ships into LNG powered ones.

As for smart shipping, China is strongly encouraging the application of artificial intelligence, intelligent manufacturing, big data, and autonomous systems in the shipping industry, e.g. the Yangshan deepwater port district (Phase 4) is a fully autonomous port district. The Yangshan deepwater port project started construction in 2002, and the first to third phases have been completed with a total of 16 deep-water container berths of 70,000-150,000 tons. The government and industry associations have published various guidelines on the development of autonomous and energy-saving ships. As for green shipping, according to plans and regulations of China, such as the 13th Five-year plan for economic and social development, China will wage an "energy revolution," by ramping up the exploration of clean, safe resources to replace coal and other fossil fuels. Such policies have opened huge opportunities for the R&D of clean and efficient energy applications in the shipping industry to replace the use of fossil fuels to reduce the emission of greenhouse gases.

Within such a transition towards a smarter and greener shipping industry, China welcomes collaborations with partners around the world. The Netherlands has always been a leading player in both technology and business in the industry. Out of the expectation for facilitating the business entrepreneurs of both countries for better collaborations, we want to identify promising fields and products for a good reference for the future.

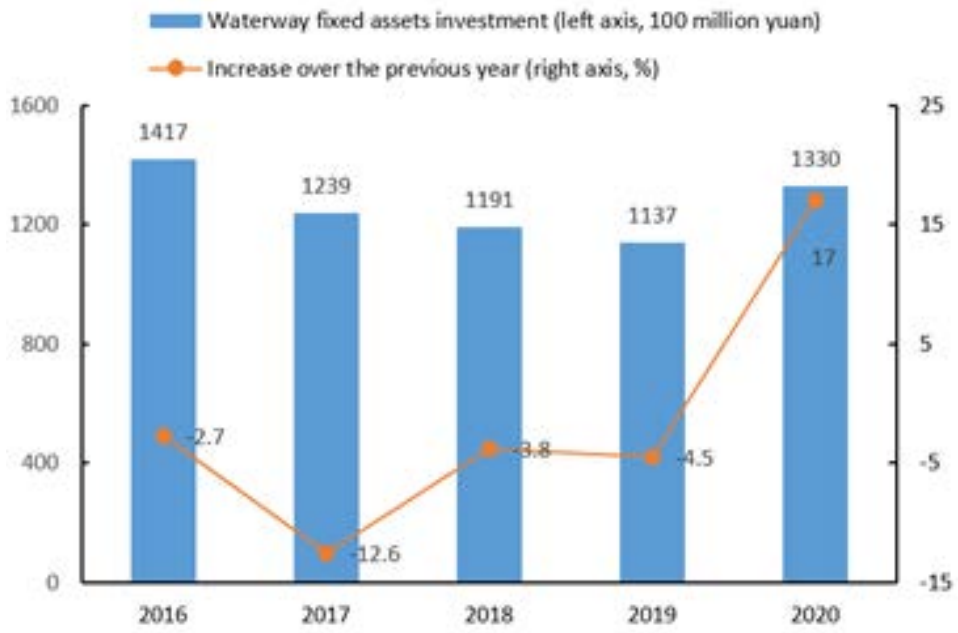
4. THE SHIPPING INDUSTRY IN CHINA

In 2020, China occupied seven of the top ten ports in the world, with huge cargo throughput and rapid development of ports. Among them, the cargo throughput of Ningbo-Zhoushan port ranked first in the world.

The cargo throughput of the world's top ten ports in 2019 and 2020

2019/2020	Name of port	Throughput in 2019	Throughput in 2020	growth rate
1/1	Ningbo-Zhoushan Port	74400	80978	8.84%
2/2	Shanghai Port	73600	77600	5.43%
3/3	Port of Singapore	53801	55958	4.09%
4/4	Tianjin Port	47700	50000	5.04%
6/5	Guangzhou Port	43500	45512	4.87%
7/6	Suzhou Port	42800	45430	6.14%
8/7	Qingdao Port	41465	45000	11.94%
10/8	Tangshan Port	36500	44620	24.6%
5/9	Port of Rotterdam	44153	44046	-0.24%
9/10	Dalian Port	37400	40840	9.49%

Investment in fixed assets in waterways from the Chinese government and enterprises reached 133 billion yuan in 2020, an increase of 17.0% over the previous year. Among them, the investment in inland rivers reached 70.4 billion yuan, and that in coastal areas reached 62.6 billion yuan.

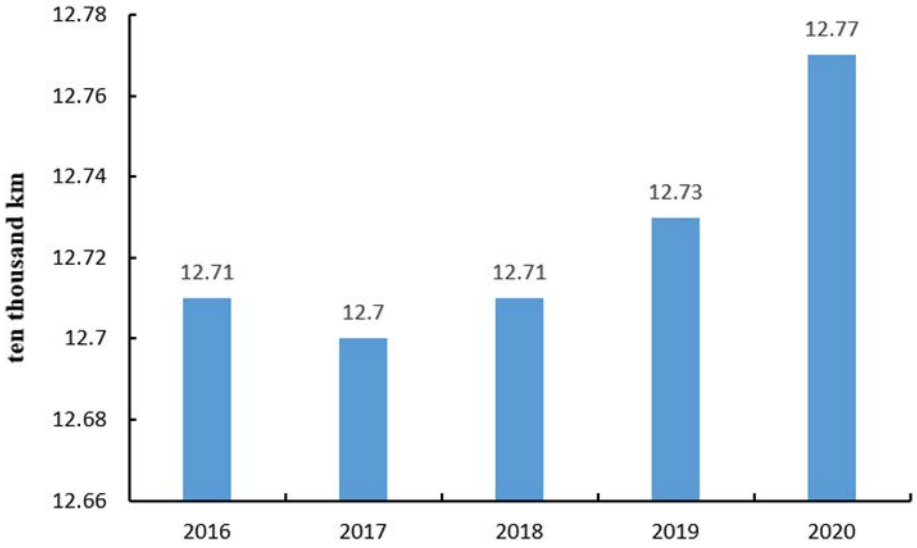


Investment and growth rate of waterway fixed assets from 2016 to 2020

China has a long length of inland waterways. By the end of 2020, China had 127,700 kilometres of inland waterways, of which 67,300 kilometres were Class III waterways, accounting for 52.7 percent of the total, and 14,400 kilometres were Class III waterways and above. The following table is China's National standard of inland waterway, where Class III denotes a channel with a usual minimum of 2.0-2.4 meter water depth and which is normally navigable by vessels of up to 1000 tonnes. There are economies of scale in vessel sizes, with generally lower costs/ traffic unit for larger vessels. In the range up to 1,000 tonnes, there is a very steep fall in the average costs/tonne-km of operating larger barges. Thus, in recent years, China accelerates the upgrade of inland waterways, Class IV to Class III.

China's National Standard of Inland Waterway specifies the waterway classification in corresponding to vessel tonnage and water depth

Channel Classification	Ⅰ	Ⅱ	Ⅲ	Ⅳ	Ⅴ	Ⅵ	Ⅶ
Vessel Tonnage (t)	3,000	2,000	1,000	500	300	100	50
Water Depth (m)	3.5-4.0	2.6-3.0	2.0-2.4	1.6-1.9	1.3-1.6	1.0-1.2	0.7-0.9



Navigable mileage of inland waterways in China, 2016 to 2020

With the rapid development of ports, the number of terminal berths keeps increasing. By the end of the year, there were 2,592 berths of 10,000-ton class and above. Among them, there are 2,138 berths of 10,000-ton class and above in coastal ports; 454 berths for inland ports of 10,000-ton class and above.

The number of berths of 10,000-ton class and above in China's ports

Berth tonnage	Total number of ports in China	Year-on-year increase	Number of coastal ports	Year-on-year increase	Number of inland ports	Year-on-year increase
Total	2592	72	2138	62	454	10
1-3 million tons (excluding 30,000)	865	6	672	2	193	4
3-5 million tons (excluding 50,000)	437	16	313	16	124	0
5-10 million tons (excluding 100,000)	850	28	725	22	125	6
100,000 tons and above	440	22	428	22	12	0

As of December 31, 2019, China's major shipping companies, led by China Cosco Shipping Group Co., Ltd. operated a large number of international, coastal, and container

fleets. Cosco Shipping Group is far ahead of other terminal operators in the global terminal container throughput ranking, ranked first. Among them, Cosco Shipping Group, China Merchants Group, Shandong Shipping Co., Ltd., and other large shipping companies are all state-owned enterprises, whose capital is owned or controlled by the state, and their behavior is determined by the will and interests of the government.

Fleet Size of Major Shipping Companies in China (as of December 31, 2019)

Rank-ing	Company Name	Number of ships	Ten thousand dwt	State Owned Enterprise
1	CHINA COSCO SHIPPING GROUP	1315	10455	Y
2	CHINA MERCHANTS GROUP	686	4212.4	Y
3	SHANDONG SHIPPING CORPORATION	41	555.9	Y
4	FUJIAN GUOHANG OCEAN SHIPPING(GROUP) CO., LTD	57	361.8	N
5	SHANGHAI ZHONGGU LOGISTICS CO. LTD.	112	248.7	N
6	SHENHUAZHONGHAI SHIPPING CO.,LTD	40	218.0	Y
7	SITC INTERNATIONAL HOLDINGS CO.,LTD	88	199.0	N
8	SHANGHAI LEADING ENERGY SHIPPING CO.,LTD	25	197.0	Y
9	GUANGDONG YUDEAN SHIPPING CO.,LTD	24	172.0	Y
10	SHANGHAI TIME SHIPPING CO.,LTD	28	166.2	Y
11	NINGBO MARINE COMPANY LIMITED	32	162.9	Y
12	QINGDAO SEACON SHIPS MANAGEMENT CO., LTD.	32	156.9	N
13	DONGGUAN HAICHANG CO.,LTD	18	137.0	N
14	FUJIAN PROVINCIAL COMMUNICATION TRANSPORTATION GROUP CO.LTD	32	130.6	Y
15	NANJING OCEAN SHIPPING CO.,LTD.	22	120.0	N
16	ZHEJIANG SHIPPING CO.,LTD	24	105.3	Y
17	JIANGSU OCEAN SHIPPING CO.,LTD	35	101.8	Y
18	FUJIAN HAITONG DEVELOPMENT CO.,LTD.	19	100.8	N
19	QUANZHOU ANSHENG SHIPPING CO.,LTD	32	95.8	Y
20	HUAYUAN STAR SHIPPING CO., LTD.	18	91.0	Y

All major ports in the world are carrying out intelligent construction and transformation with intelligent container terminals as the main objective. China's Shanghai Port, Qingdao Port, Shenzhen Port, Guangzhou Port, and Ningbo Port have all introduced IoT technology to build intelligent ports. For example, China's shipping "Internet of Things" project of Shanghai Port is based on "China Container Electronic Tag System" and RFID technology. Then, Qingdao Port applies RFID, infrared, video, and other technologies to carry out projects such as port intelligent production management system, intelligent port supervision, regional logistics center, and professional service platform relying on the industrial chain. Shekou Industrial Zone of Shenzhen Port also built The Internet of Things application demonstration industrial park. Especially, Guangzhou Port's application of RFID technology in the management of ro-ro automobile terminals has created a domestic precedent.[1]

On June 22, 2019, the world's first 308,000-ton ultra-large smart tanker (VLCC) "New Journey" (New Journey), ordered and built by China Merchants Shipping, was successfully delivered at Dalian Shipbuilding Group, and awarded smart navigation, smart engine room, and smart liquid cargo management. The five additional signs for smart ships, energy efficiency management, smart cargo management, and smart platform, indicate that China has the ability to develop highly intelligent large ships.

In recent years, Chinese Port has worked hard to integrate green development into the entire process of port planning, construction, and operation, and actively build a resource-saving and environment-friendly port green development system. For example, Qingdao Port of Shandong Port has carried out active exploration and practice to win the battle of port pollution prevention and control, and guarded the blue sea and blue sky with national and even world-leading explorations; the intelligent container terminal in section c of Beijiang Port of Tianjin Port is the whole field all equipment uses clean energy, zero emissions, and zero pollution, creating a "zero-carbon" terminal.

The Shanghai Port has made great efforts to promote the green and smart development of the international shipping center, as well as accelerate the pace of transformation and upgrading. In this way, the Shanghai Port has achieved many achievements, including promoting the application of shore power technology, the implementation of ship pollutant emission control, promoting the pollution control of non-road mobile machinery in the port. At the same time, the port service level has been improved through information technology.

As a subsidiary of China Merchants Group, China Yangtze Shipping Group is the largest inland waterway shipping enterprise in China and is known as the "Yangtze River National Team". For the implementation of the national development strategy of the Yangtze River economic belt and promotion of the construction of the Yangtze River water washing station, the group set up a special washing station project construction headquarters. The headquarters take the initiative to assume the Yangtze 13 washing station layout for the construction of the five tasks, with a total investment of more than 1.4 billion. Those stations can meet the 3000 ships ship tank cleaning, as well as reduce the reception and disposal of chemical wastewater by more than 400,000 tons per year.

[1] https://safety4sea.com/building-global-intelligent-ports/
https://www.chinadaily.com.cn/a/201910/28/WS5db69c01a310cf3e35574012.html

To conclude, China's shipping industry is developing rapidly, and the government has vigorously supported and invested. China's shipping companies are also developing rapidly, with increasing fleet size and container throughput. In this context, all ports in China are committed to the development of intelligent and green ports, including the development of new technologies and systems to create smart and green ports. The development of China's shipping industry also provides opportunities for exchanges and cooperation with other countries in terms of technology and management.

5. GOVERNMENT POLICIES ON SMART AND GREEN SHIPPING

In order to promote the green, intelligent and high-quality development of the shipping industry, the Chinese government issued several policy documents, including the Guidance of the Ministry of Transport on Promoting the Development of Green Shipping along the Yangtze River Economic Belt (August 10, 2017), the Guidance on the Development of Intelligent Shipping (May 9, 2019), and the 14th Five-Year Plan for the Development of Maritime Systems (May 27, 2021), and definitely formulated the targets and main tasks for the future development of the shipping industry. The Special Administrative Measures for Foreign Investment Access (Negative List) (2021 Edition) states that domestic water transportation companies must be controlled by the Chinese party. In the "Catalogue of Industries Encouraged for Foreign Investment (2020 Edition)", the design of intelligent ships and the research and development of related intelligent systems are mentioned.

Foreign companies are welcome to invest in the industry of smart and green shipping. There are preferential treatments in terms of finance, taxation, and land use under laws, administrative regulations or the provisions of the State Council. On October 12, 2021, the Ministry of Commerce released the "14th Five-Year Plan" Foreign Capital Utilization Development Plan, which clearly put forward the guiding ideology, development goals, and key tasks for China's utilization of foreign capital during the "14th Five-Year Plan" period. The full text includes development background, general ideas, promoting higher-level opening to the outside world, optimizing the structure of foreign investment utilization, strengthening the function of the open platform, improving the service level of foreign investment promotion, improving the foreign investment management system, optimizing the foreign investment environment, and promoting the liberalization and convenience of international investment. Ten sectors of chemical and safeguard measures. These planning policies provide an effective reference for foreign investors to invest in business activities. In order to standardize international maritime transport activities and maintain the order of the international maritime transport market, China revised and promulgated the Regulations of the People's Republic of China on International Maritime Transport in 2013, which is of great significance to the healthy development of China's international maritime transport industry.

It is reported that during the period of the "13th Five-Year Plan"(2016-2020) and the beginning of the"14th Five-Year Plan"(2021), the oil spill removal capacity of specialized ships in key coastal waters and important inland river sections reached 1,000 tons and 200 tons respectively, and the emissions of sulfur oxides and particulate matter from ships in the national ship emission control zone were significantly reduced. The prevention and control of ship pollution achieved remarkable results. First, the pace of construction and renovation of ships' domestic sewage collection and treatment devices has been accelerated. Since 2020, provinces and cities along the Yangtze River have completed the construction and renovation of 22,000 ships' domestic sewage collection and treatment devices. Second, positive progress has been made in the construction of port pollutant receiving facilities. This year, 12,000 new ship pollutant reception facilities have been built, and the ship waste reception facilities in 11 provinces and cities in the Yangtze River Economic Belt have been fully covered. The third is to gradually increase the promotion and use of shore power. In 2020, the ports in the provinces

and cities along the Yangtze River have used shore power about 110,000 times, 1.09 million hours, and 24.56 million kWh. The number of ships in the provinces and cities along the river has reached more than 12,000, and the utilization rate has steadily increased. According to the 14th Five-Year Plan for the maritime system, the emissions of nitrogen oxides and sulfur oxides from operating ships will be reduced by 7% and 6% respectively by 2025 compared with 2020.

According to Guidance on the Development of Intelligent Shipping, by the end of 2020, China will basically complete the top-level design of intelligent shipping development. The top-level design is to use the method of system theory to make overall planning for all aspects, levels, and elements of a task or a project from a global perspective, to concentrate effective resources and achieve goals efficiently and quickly. By 2025, breakthrough a number of key technologies restricting the development of intelligent shipping, and become the global intelligent shipping development innovation centre. By 2035, more comprehensively grasp intelligent shipping core technology, and improve the system of intelligent shipping technology standards. By 2050, form a high-quality intelligent shipping system playing a key role in the construction of a powerful transportation country.

The Chinese Government proposes the following basic principles:

• Guided by government and dominated by market

The Chinese government adopts a government-led market economy policy. The government-led market economy means that although resources are also allocated according to the principles of a market economy, the government exerts strong plans and policies to influence resource allocation in order to achieve certain short-term and long-term growth goals.

• Led by technology and driven by innovation

The Communist Party of China points out that innovation is the first driving force for development. Following the "innovation-driven development" strategy proposed at the 18th National Congress of the Communist Party of China, the report of the 19th National Congress of the Communist Party of China further proposed the goal of "building a strong country in science and technology". This conclusion puts forward new requirements for scientific and technological innovation. Scientific and technological innovation should also focus on quality and efficiency, focus on original innovation, meet the needs of national development and adhere to the core position of innovation in the overall situation of my country's modernization drive.

• Open sharing based on national conditions

It is pointed out that more attention should be paid to improving the quality and use efficiency of scientific and technological resources, establishing a full-chain scientific and technological resource management service system that is coordinated by the state, departments, and localities, strengthening the support and guarantee of scientific and technological resources for national development strategies, major scientific research, innovation, and entrepreneurship, and further improving The level of sharing and utilization of scientific and technological resources in the whole

society lays a solid foundation for the construction of an innovative country and a world power of science and technology.

• System layout and driven by demonstration

It is pointed out that the overall layout should be strengthened, and the top-level design and optimization of the technology platform in the new era should be done well. In-depth study and implementation of the innovation-driven development strategy, deepening the reform of the scientific and technological system, and promoting high-quality development and other new needs, clarify the connotation, positioning, key layout, and implementation measures of the new era of science and technology basic conditions platform, and strengthen coordination with base construction, science, and technology plans, etc., and give full play to the supporting role of the platform in building a world science and technology power.

To achieve the green and intelligent development of the shipping industry, the Chinese government has formulated the following main tasks:

Main tasks of green shipping

• Building eco-friendly green shipping infrastructure

Including the following two parts: promoting the construction of green channels and building green ports.

• Promoting clean and low-carbon green shipping technology and equipment

Including the following two parts: continuously improve the ship energy conservation and environmental protection level; strengthen the port machinery and equipment energy conservation and clean energy utilization.

• Innovating energy-saving and efficient green shipping organization system

Including the following two parts: vigorously developing green transportation organization and further improving transportation organization efficiency.

• Enhancing capacity for green shipping governance

Including the following four parts: strengthening the revision of laws and regulations; strengthening the economical and intensive use of port resources; strengthening the supervision of energy conservation and environmental protection; intensifying the research and popularization of science and technology.

• Launching a special campaign to develop green shipping

Including the following five parts: strengthening the special treatment of chemical tank washing; vigorously promoting the use of shore power for ships that call on the harbor; actively promoting the construction of LNG-powered ships and supporting docks; strengthening the

safety treatment of dangerous chemical transportation; organizing the special treatment of ship pollution prevention and control.

Main Tasks of Intelligent Shipping

• Improving the informatization and intelligence level of port terminals and shipping infrastructure

Including tasks such as improving the ability of intelligent port technology and system integration to improve the efficiency of port operation; Pilot projects for smart ports will be carried out.

• Promoting the application of intelligent ship technology

Including tasks such as promoting the mature smart ship technologies in container ships, bulk carriers, and oil tankers

• Strengthening the innovation of intelligent shipping technology

Including tasks such as promoting the innovative application of artificial intelligence and other high-tech in the shipping field.

• Accelerating the construction of intelligent navigation security systems for ships

Including tasks such as improving the intelligent navigation communication network, promoting the special application of Beidou navigation and other systems; accelerating the digital transformation of traditional navigation facilities, and expanding the scope of the E-navigation project pilot.

• Improving ports and the design and construction (manufacturing) capacity of their major equipment and intelligent shipping instruments, equipment, and systems

Including the research and application of artificial intelligence technology, improving the iterative design capabilities of ports and their equipment; optimizing the process of port construction and port equipment construction, and realizing intelligent control of the construction process and other tasks.

• Cultivating new business models of intelligent shipping services

Including tasks such as supporting the establishment of intelligent shipping information service institutions.

• Preventing the security risks of intelligent shipping

Including the research of ship intelligent navigation safety risk prevention and control technology, construction of safety risk monitoring system, and other tasks.

• Strengthening the construction of intelligent shipping regulation standards and regulatory mechanisms

Including tasks such as studying and putting forward proposals for revising international maritime conventions and rules to adapt to the development of intelligent shipping.

• Strengthening the cultivation of intelligent shipping talents

Including tasks such as adjusting and optimizing the professional education structure of relevant colleges and universities; accelerating the development of complex and applied talents training required for the development of intelligent shipping.

6. INNOVATION DOMAINS

6.1. Innovation domain 1: Surveillance of shipping pollutions

For a long time, China attaches great importance to the issue of emission reduction in the shipping industry, and the measures to promote the high-quality development of shipping are clear and specific, to achieve carbon compliance for the shipping industry as soon as possible. In response to pollution caused by the shipping industry, China, as one of the parties to the International Convention for the Prevention of Pollution from Ships, plays an important role in maintaining, implementing, and developing the Convention. In this part, this report is mainly divided into two parts: the first is Remote sensing of ship exhaust pollution; the other is the Emergency response for oil spillage in the waterways.

6.1.1. Remote sensing of ship exhaust pollution in China

Due to the limitation of objective water conditions, such as remote sensing technology being susceptible to weather and wind direction interference, the traditional law enforcement mode requires on-site oil sampling. Otherwise, it is difficult to effectively monitor the use of low-sulfur oil during ship navigation. Remote sensing monitoring systems of ship exhaust overcome the disadvantage of traditional law enforcement methods, require on-site extraction of oil samples, and have the advantages of convenience, rapidity, and wide applicability.

The remote sensing monitoring system of ship exhaust gas is a remote sensing technology of ship atmospheric emissions based on the sniffer method. The continuous monitoring system of air quality (including at least CO2, SO2, and NOx analyzers) is installed near the waterway. Once the ship passes and the exhaust gas spread to the monitoring point, the system can monitor the signal of pollutant concentration first increases and then decreases. According to the principle of material balance (the ratio of the concentration of each pollutant in the tail gas is consistent with the proportion of each corresponding element in the fuel), the concentration change signal can be used to inverse the sulphur content of the fuel and the emission of sulphur oxides and nitrogen oxides per unit of fuel, to monitor the index data of ship exhaust emissions. In the field of ship exhaust monitoring, there is no mature non-contact optical imaging remote sensing monitoring equipment for ship exhaust.

In 2020, through a large number of field research visits and full research and demonstration, Tianjin Maritime Bureau innovatively proposed the construction called 'land, sea, sky and man' in Tianjin Port, an integrated ship air pollution prevention and control supervision method. It is aimed to realize all-around and all-weather intelligent supervision of ship air pollution prevention and control and provide a 'Tianjin scheme' for scientific prevention and control of ship air pollution and accurate supervision. Compared to the previous regulatory means, the data acquisition of the method is more abundant and diverse. It includes a shore-based sniffing system, sea patrol ship mobile tail gas sniffing system, UAV (Unmanned Aerial Vehicle) carrying sniffing equipment, ship AIS positioning and tracking, and on-site fast inspection equipment. By using ship exhaust telemetry and intelligent analysis and comparison of big data analysis platforms, it can realize accurate and comprehensive monitoring of ship air pollution prevention and control.

As for the business opportunities in the field of remote sensing of ship exhaust pollution, the end-users of such products are more likely to be the law enforcement departments and governmental stakeholders. It would be suggested to operate in collaboration with Chinese companies to manufacture related equipment and such collaboration is also highly welcome in China. For those companies, they are not only looking for products (equipment and software) but also looking for opportunities to cooperate in the development of new techniques. Every year, many showcase events are held, performing as one of the most important communication platforms with new industry trends, new technologies and products, and business opportunities. Marintec China is poised to be the definitive event and is undoubtedly a must-attend marine exhibition for all involved in the maritime industry. Launched for over 40 years, Marintec China has become renowned as the most authoritative B2B platform for the International Maritime Industry. Organised with the professional expertise of China's largest trade exhibition organiser–Informa Markets–in conjunction with the Shanghai Society of Naval Architects & Marine Engineers (SSNAME), Marintec China is set far apart from other platforms in connecting businesses and distilling insight for Asia's maritime industry.

6.1.2. Emergency response for oil spillage in the waterways in China

To make an effective emergency response to sudden oil spill accidents, minimize oil spill pollution damage and protect the marine environment, on the one hand, China actively joined relevant international conventions, increased investment in oil spill emergency facilities and equipment, and improved compliance capacity. On the other hand, it is necessary to accelerate the improvement of relevant laws and regulations, establish a national oil spill emergency response system, formulate pollution emergency plans, and improve the oil spill emergency response capacity.

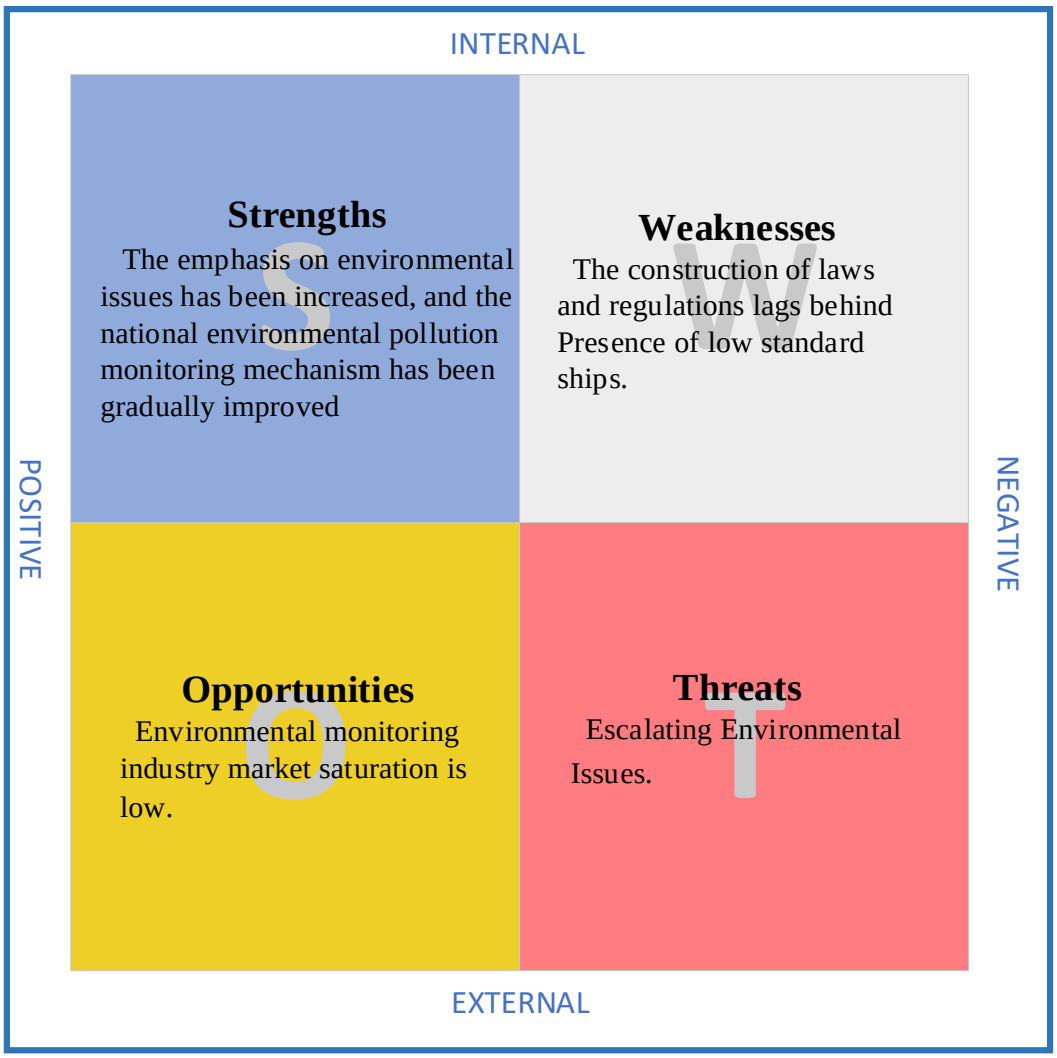
At present, China's marine oil spill emergency response system has been initially established. Including relying on maritime search and rescue command systems and maritime information systems, with a certain ability to organize command and decision-making. Then relying on maritime patrol force, with a certain monitoring ability. It has initially possessed the emergency ability to control and eliminate oil spill accidents of medium and small ships in the port area and nearshore waters of the main coastal ports, as well as cultivating a number of oil spill emergency command talents and more skilled cleaning operators.

Chinese marine oil spill emergency capacity is still very fragile, far from meeting the requirements of marine pollution emergency capacity. The current marine oil spill emergency system is not perfect, the level of the emergency plan is low, anti-pollution equipment and facilities are backward, the layout and structure of emergency forces are not reasonable, the personnel quality and business level of emergency teams are uneven, and there is a lack of emergency response capacity to deal with major ship pollution accidents. Similar to the aforementioned section, the end-users of such equipment and services for emergency oil spill protection are more likely to be port authorities, maritime safety administration and governmental departments, etc. It is also suggested to start the collaboration with Chinese companies to access the market with good facilitation. As for the companies which are doing such business. The companies which are called "Zhejiang Manyang" are active in such a field. The product of these companies includes oil spill collection materials, emergency oil spill

accident cleaning services, and ship manufacture. It would be interesting to contact and seek collaboration between Dutch companies and Chinese companies.

To sum up, the analysis results for Dutch partners in 'Surveillance of shipping pollutions' through SWOT analysis are shown in the following table.

SWOT analysis matrix of 'Surveillance of shipping pollutions'



6.2. Innovation domain 2: Advances in autonomous shipping and intelligent collision avoidance

Navigation is a complicated process that requires experienced Officers On Watch (OOW) to perform complex actions to maintain the safety of the ship. For the era of autonomous shipping, such a process would require extensive R&D investment to fulfill its goal. In general, the following areas would be the key points to facilitate the development of smart shipping in China and the world, which have been researched in the project:

- The autonomous sensing technology for the ship navigation

- Intelligent ship collision avoidance decision-making system
- Remote piloting technology for the ship
- Intelligent route planning technology for the ship

To achieve the function of smart shipping, the unmanned ship, which is also often referred to as Maritime Autonomous Surface Ship (MASS), is required to conduct the navigation autonomously. This means the ship can navigate to the destination by herself and successfully avoid the risk of accidents, such as the collision between ships under the supervision of experienced operators ashore, or controlled by the intelligent control module onboard the ship. With the reduction of human factors from the system, the efficiency, safety, and also operation cost of such an autonomous ship would be improved to a large extent. In the meantime, such a system is a totally new field that is still under development worldwide, new technologies such as remote sensing, artificial intelligence, etc. must be developed for its embodiment in the industry.

On this aspect, as aforementioned, the Chinese government has adopted a series of new policies and regulations to stimulate the R&D environment to accelerate its process, which can be seen in the detailed analysis in the following sections.

6.2.1. The autonomous sensing technology for ship navigation in China

The sensing and detection technology, in general, is a type of technology that can facilitate the Officers On Watch to perform a lookout to obtain necessary information about the navigation environment and traffic situations during the voyage.

For traditional ship navigation in the waterways, such function is embodied with the equipment such as Radar, ARPA (Automatic Radar Plotting Aid), ECDIS (Electronic Chart Display and Information System), Electronic chart, AIS (Automatic Identification System), an echo sounder, etc. These types of equipment obtain information of the navigation environment, such as the obstacles in the waterways, e.g. rock or sinking ship, and the movement information of the ships in the vicinity. After the information acquisition process, such navigation-related data will be processed and displayed to the OOW for their knowledge and let them decide on navigation and accident avoidance.

However, for smart shipping in current days and near future, such conventional sensing technology will not be sufficient for the safe navigation of the ship, as few or no OOW will be onboard to make such decisions and the safe navigation will heavily rely on the ship herself with its autonomous navigation function embedded in the system. To achieve this, new environment sensing technologies, such as lidar, video camera integrated artificial intelligence for target detection and tracking, augmented or virtual reality workstation for remote operators would be necessary to be explored to facilitate the development of the sensing technologies of the smart ship.

As for the new technologies aforementioned, they have not been extensively explored in the field of waterways transportation yet, as smart shipping is at its early stage. However, one should not ignore such a trend towards cleaner and smarter shipping for the sustainable development of the industry, and it should be considered as a much promising field for

business operation, as it is higher supported by the local law and regulations. In the meantime, according to our knowledge and experience, we believe such innovations will be seized by the companies with profound experience and insights into the industry, which are normally the companies that are already in the playfield.

In China, various companies manufacture the equipment and technologies for the aids of navigation. The product of these companies ranges from GMDSS (Global Maritime Distress and Safety System) related equipment, radar, navigation instrument, electronic chart, compass, echo sounders, etc. The R&D of the domestic companies focuses more on the modernization of GMDSS equipment, Integrated Navigation System (INS), Integrated Communication System (ICS), E-navigation-related equipment such as NAVDAT, VDE, etc. Various projects on their innovations have been approved and foundered by different stakeholders in the industry and the level of advancement has reached the top tier in the global competition. However, the standard for the new technologies has not been determined and regulated by the IMO, the direction of marketization is yet to be clear. Considering the direction of the smart shipping development and the need for the upgrade of equipment of the existing market, these directions would definitely be the major trend in the near future.

As for the players in the Chinese market, the following companies can be considered as the influential participants: China state shipbuilding corporation limited(CSSC), China Electronics Technology Group Corporation (CETC), Shanghai Advanced Avionics, Suzhou New Sunrise co. ltd (NSR), Nanjing Ninglu Technology Co., Ltd. (Abbreviated as Ninglu Tech), Beijing Highlander Digital Technology Co., Ltd., China Navigation Association, Xinnuo Information Technology (Xiamen) Co., Ltd, etc. The first three companies are state-owned companies and the rest of them are private companies that are listed in the New Third Board in the Agency Share Transfer System of the Shenzhen Stock Exchange. Among them, the Suzhou New Sunrise is the only company that acquired the type of approval adopted by DNV-GL (EC/MED) and has a large international and domestic retailing and cooperation network, which covers southeast Asia, the middle east, the Mediterranean, and European areas. Currently, these companies are actively focusing on the research and development of Integrated Communication System onboard ship and advanced radar, which could be a good reference for future cooperation in such fields. Among them, the type of cooperation will be: 1) Joint research of Sino and Dutch institutions; 2) Invest/buy Chinese Company. It is open: 1) High level research funding; 2) Stock market or communication on some Expos.

6.2.2. Intelligent ship collision avoidance decision-making system in China

Ship collision avoidance is one of the fundamental and also the most important tasks for the safe navigation of the ship. As for the conventional ship navigation, the decision of collision avoidance is normally made by the experienced OOW, considering all the information obtained with the aids to navigation and their watch duty, and also the regulations on collision avoidance, e.g., COLREGs (International Regulations for Preventing Collisions at Sea) and other domestic and local laws and regulations. During the process, the experience of the ship officers, and the understanding of the navigation environment are of great significance for the success of collision avoidance. As for smart shipping, the requirement for an intelligent ship collision avoidance decision-making system has been drastically increasing, as the ship would rely more on herself to perform such a task or operate under remote supervision.

The key technology for the intelligent ship collision avoidance decision-making, based on the understanding of the authors, lies in the following areas: accurate and efficient detection of the navigational environment including the traffic in the vicinity; human-like encounter situation determination and collision risk analysis, and a rule-adaptive collision avoidance operation decision-making function. The first part of the technologies can be improved with the advanced remote sensing technologies mentioned in the previous section.

The encounter situation determination and collision risk analysis, especially a human-like method, requires technologies that process the information acquired and analyse the encounter between ships following the logic of the OOWs. Considering the method that is developed, the following technologies should be considered for the development in this part: artificial intelligence focusing on the analysis of ship behaviours during collision avoidance; pattern recognition of decision-making process of OOW; rule-based encounter situation and collision risk analysis model; Big data and deep learning focusing of ship navigation, etc. On top of the accurate determination of the encounter situation and the risk of collision, the collision avoidance decision can then be accurately made by either the OOW or the autonomous control module onboard the smart ship. As for this section, most of the technologies required are similar to those in the encounter situation determination and collision risk analysis.

As for the companies that are focusing on intelligent ship collision avoidance decision making, most of them in China are collaborating with the research facilities and Universities to develop the function of collision risk analysis and decision making in their products, such as Zhejiang University, Dalian University of Technology, Wuhan University of Technology, etc. The companies, research facilities, and universities are as follows: Beijing Minic Hi-Tech Co., LTD, Shanghai University, Zhuhai Yunzhou Intelligent Technology Co., Ltd, Nanjing Banqiao ferry, Changjiang Waterway Bureau Survey Center, Wuhan University of Technologies, etc. Most of these companies and research facilities focus on the R&D development of MASS in different scales, e.g. based on the collaboration between Zhuhai Yunzhou Intelligent Technology, CO., Ltd and Wuhan University of Technology, a civilian-grade MASS was developed to be applied in the surveillance of water quality, and Search & Research operations, etc

6.2.3. Remote piloting technology for the ship in China

With the development of intelligent ships towards unmanned and autonomous, remote control will be applied as an indispensable key technology. In order to realize the ship remote control function, the following key technical support is needed.

• Communication transmission technology. In order to realize the 'real-time' control of the ship-borne system by the shore-based system, a large number of audio and video data signals are continuously transmitted between them.

• Environmental perception technology. Remote control requires a set of mature sensing system to obtain external environment information and monitor and diagnose internal equipment status.

• Positioning and navigation technology. The remote control needs to monitor and obtain the dynamic information and position parameters of the ship in real time through radio signals, satellite positioning, or the combination of various ways.

• Auxiliary control technology. The auxiliary decision-making of remote control systems is mainly reflected in route auxiliary planning and emergency autonomous control.

•Over-the-horizon control technology. Provides a highly immersive control environment and accurate operational guidance for shore-based controllers.

In May 2019, Intelligent Navigation (Qingdao) Technology Co., Ltd. demonstrated the remote driving function of 'Zhiteng' at the intelligent shipping technology innovation and comprehensive experimental base in Qingdao Blue Valley. In November 2019, ZhuhaiYunhang Intelligent Technology Co., Ltd. tested the remote driving system on the 13 m long ' Jindouyun 0 'and completed the remote berthing and bridge navigation of the ship under the command of the captain at the shore-based control centre.

As for the ship remote driving technology, the commercial needs and development opportunities mainly include the following three aspects: 1) telemetry technology of ship status and environmental information; 2) ship remote control and driving technology; 3) research and development of ship remote driving platform.

6.2.4. Intelligent route planning technology for the ship in China

Intelligent route planning is an intelligent route planning and design for ships from the starting port to the destination port. Its goal is to select the optimal navigation path to achieve the shortest path, the optimal time, the best security, and the minimum energy consumption.

The ship route optimization problem can be abstracted as a multi-objective dynamic optimization problem with complex constraints. By constructing the ship route optimization response model and solving it, the optimization algorithm is obtained to realize the dynamic optimization of the route.

The basic idea of route planning is to roughly plan the global planning route from the starting port to the destination port. In the process of navigation, AIS, VTS, radar and other sensors are continuously used to obtain and update the environmental information and traffic information of the sea area. On this basis, the global route to the destination port and the local route from the current position to the surrounding area are re-planned online.

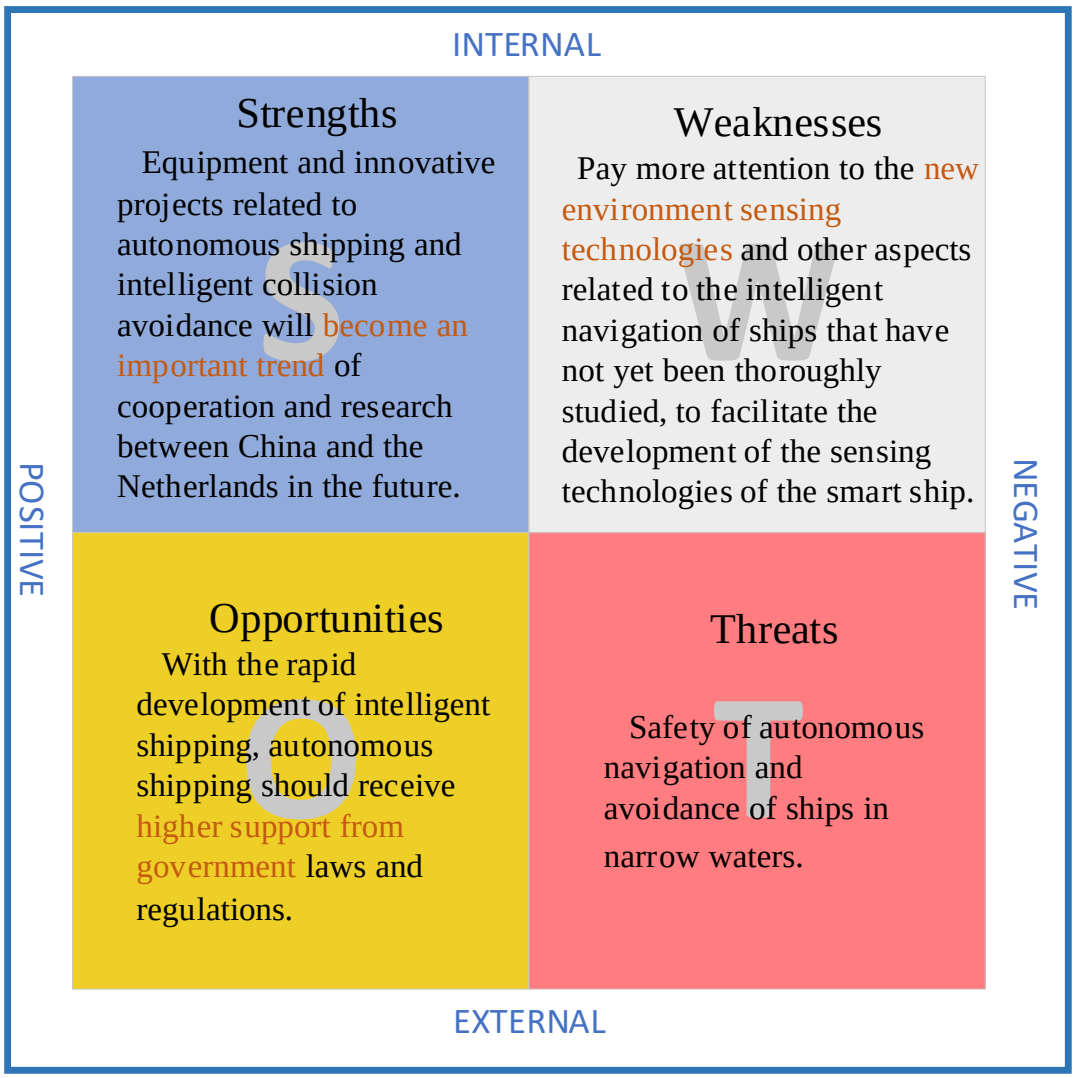
At present, the research and development team of Hailanxin company has basically completed the research of comprehensive optimization of route and speed. Chinese first transport cargo ship ' Zhifei ' for commercial operation, with intelligent navigation ability, can realize the intelligent perception of navigation environment, autonomous tracking and autonomous route planning.

In terms of ship intelligent route planning, the current needs and the possible cooperation direction between Chinese enterprises and the Netherlands can be divided into the following

two parts: 1) Information collection technology, including the latitude and longitude data of departure and destination, ship parameters, departure time, meteorological data and chart data; 2) Optimal route planning technology, including two key technologies of route generation and route optimization.

To sum up, the analysis results for Dutch partners in 'Advances in autonomous shipping and intelligent collision avoidance' through SWOT analysis are shown in the following table.

SWOT analysis matrix of 'Advances in autonomous shipping and intelligent collision avoidance'



6.3. Innovation domain 3: Green and clean energy for the future shipping industry

With the issuance of increasingly stringent environmental policies such as nitrogen oxide emission limits, "sulphur restrictions" and carbon emission targets, the shipping industry must accelerate decarbonization and actively promote the clean energy transition. Countries all over

the world have boosted "green shipping" and opened up "green business opportunities". Under this development trend, research on the following aspects is crucial for the development of green shipping in China and the world:

- Low oil consumption diesel engine for ships
- LNG and its utilization as clean energy for the ship
- Electricity-powered ships

6.3.1. Low oil consumption diesel engine for ships in China

The diesel engine is superior to the steam engine and gas turbine because of its large power range, high efficiency, low energy consumption, and convenient maintenance. It has established a dominant position in civil ships and small and medium-sized ship propulsion devices.

The overall structure of the marine diesel engine and its parts and components have been continuously improved, especially the application of electronic technology and automatic control technology in diesel engines so that its technical indicators have been continuously innovated. There are a number of products with good performance, low fuel consumption, large power range, and exhaust gas emission conforming to statutory standards and high reliability in the market.

At present, the intelligent low-speed and high-power marine diesel engines produced by Dalian Marine Diesel Engine Factory, Hudong Heavy Machinery Co., Ltd., and Yichang Marine Diesel Engine Factory represent the contemporary international advanced level and fill the domestic void. In the meantime, driven by the regulations and plan for sustainable development and environmental protection of China, the government is eager to facilitate the shipping industry to develop a cleaner and energy-saving power system.

6.3.2. LNG and its utilization as clean energy for the ship in China

Liquefied Natural Gas (LNG) is clean and efficient energy. Advanced natural gas engines reduce CO2 emissions by about 25 % and NOx emissions by about 80 % compared with conventional fuel engines, and basically do not emit sulfur oxides and solid particles. It is energy-saving and environment-friendly. As clean energy, the use of LNG instead of fuel can adjust and optimize the energy structure of water transportation, alleviate the contradiction between supply and demand of oil in China, achieve the goal of energy-saving and emission reduction, realize green shipping, and promote the implementation of China's environmental protection strategy.

The earliest domestic research on LNG-powered ships started in 2010. To promote the development of the industry, the transportation department carried out two pilot demonstration projects of LNG ships in September 2014 and October 2016, involving 1432 LNG ships and 37 LNG filling terminals, and achieved the following positive results. As of March 2018, China has built 279 LNG ships (19. 4 % of the total completed plan), including 276 inland ships and 3 sea ships;162 newly built ships and 117 rebuilt ones; 169 dual-fuel ships; mainly dry cargo

ships, container ships, and port tugboats. There are 17 built inland LNG filling terminals (73.9 % of the total number of completed plans), including 9 shore ships and 8 barge ships, which are mainly distributed along the Yangtze River, the Beijing-Hangzhou Canal, and the Xijiang River. Among them, in December 2021, the first shore-based LNG bunkering station in the inland river was completed and put into trial operation in the Wuhu section of the Yangtze River. It will accelerate the large-scale application of LNG in the water transportation industry in the Yangtze River, and promote the improvement and introduction of relevant standards, which is of great significance to promoting the green development of inland shipping in the Yangtze River.

As the core shipbuilding enterprise under China State Shipbuilding Corporation and the only large LNG carrier construction base in China, HUDong Zhonghua has always carried forward the pioneering spirit and realized the rapid iterative development from the first generation LNG carrier to the fourth generation LNG carrier. At present, in the process of building the whole LNG industry chain, Hudong China has started the third "10-year development period". During this period, the company has developed a complete spectrum of LNG vessels ranging from 20,000 cubic meters to 270,000 cubic meters, and its product line has been expanded to LNG refueling vessels, FLOATING LIQUEFIED natural gas storage and regasification units (LNG-FSRU), LNG-powered vessels, and refit LNG power systems of traditional fuel oil vessels, making it the only large-scale LNG vessels built in China. And it has the LNG whole industry chain equipment expansion capacity of shipbuilding enterprises.

6.3.3. Electricity-powered ships in China

At present, there are three main working modes of ships driven by electric power:

• Diesel power drive: diesel generator generates electricity, and electric power drives the electric engine, thereby driving the propeller of the ship.

• Hybrid drive: in addition to the assembly of internal combustion engines, there are also batteries on board. On the one hand, when peak power is required, the battery can be connected in a short time. On the other hand, they can store excess energy, which enables ships to navigate only by electricity for a period of time.

• All-electric drive: No internal combustion engine is installed on the ship, all energy comes from the battery.

It is reported that electric ships (Pure electric) in China are mainly inland cargo ships along the Yangtze River and the Pearl River, and their application fields are urban ferries, sightseeing ships, and port tugboat markets along the river coast. At present, there are about 130,000 inland ships in China, and the total number of inland ships only in the Yangtze River and the Beijing-Hangzhou Canal is more than 60,000. In contrast, the number of electric ships is very small, and the number of built inland electric ships is only more than 20.

Power battery is the core component of an electric ship. Lithium iron phosphate battery has become the optimal choice of ship power battery at this stage due to its high safety, long life, low cost, and balanced performance. In recent years, Shanghai Ruihua, Zhongchuan

Heavy Industries, and other shipbuilding enterprises have begun to design and manufacture electric ships. Power lithium iron phosphate battery manufacturers such as Ningde Times, BYD, and Yiwei Lithium Energy have also arranged electric ships and made substantive explorations in the development of technical products, standard formulation, and industrial layout of marine power batteries.

At present, inland shipping has the initial conditions of electrification, but there are four major obstacles to be broken through， including challenges and future development opportunities brought by technology, policy, market, and management.

From a technical point of view, the core technology of electric ships has breakthrough innovations, but it still needs continuous improvement. In terms of batteries, power batteries are the core components of electric ships. Lithium iron phosphate batteries have become the best choice for ship power batteries at this stage due to their high safety, long life, low cost, and balanced performance. However, the cruising range and charging speed of electric ship batteries are still insufficient, providing opportunities for the sustainable development of electric ships in the future.

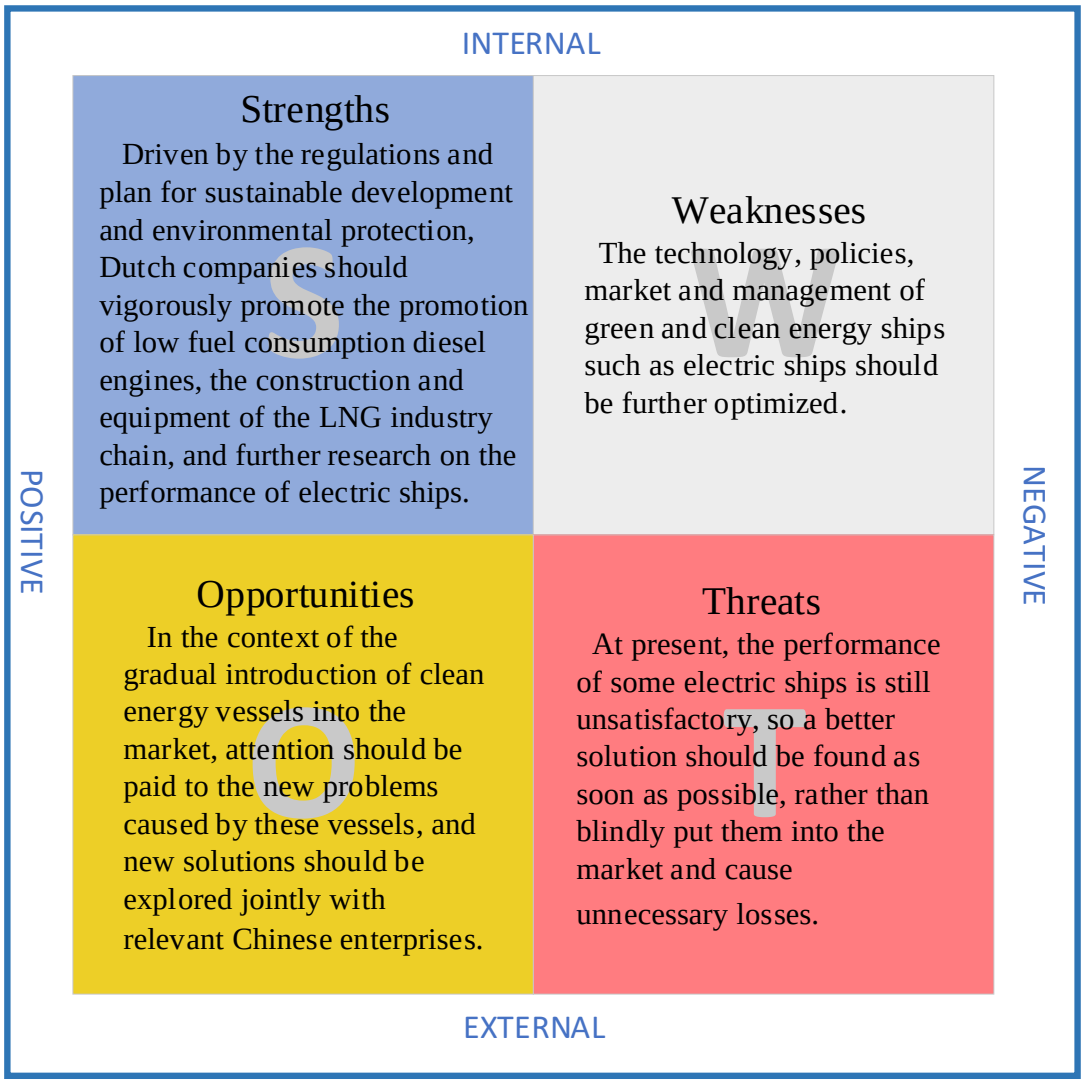
From the perspective of policy, China supports industrial development, but the economy of ship electrification is still insufficient. On the one hand, the construction cost of electric ships is high. And the service life of lithium batteries is generally only 10 years, while the service life of ships is 30 years. At the same time, the cost of replacing batteries is relatively high. On the other hand, the operating cost of electric ships has not been reduced. The advantage of shore power price is not obvious, and the fuel cost for providing the same electric energy is not different from the power price, which reduces the application power of electric ships. From the market point of view, the current business model of electric ships is not mature, and most of them adopt the operation mode of bare ship sales/battery leasing, which alleviates the high cost of some whole ship sales. But few enterprises provide ship power battery technology and battery leasing, which has not yet formed a scale.

From the perspective of management, the current top-level design for the overall promotion of electric ships is not enough; the standard system is imperfect. And the technical standard system for electric ships has not yet been established. The standards for interconnection between ships and shore power are imperfect, and the standards for ship-shore communication interfaces are inconsistent. The lack of laws and regulations to promote the development of the electric ship industry results in no legal basis for the development of electric ships.

Therefore, there are still key bottlenecks in the development of China's electric ships that need to be broken through. In the future, the improvement of power battery safety, endurance, and other performance will become the focus of cooperative research between China and Dutch companies. At the same time, the strong support of the state, the active exploration of business models, and the establishment of relevant laws and regulations will also be crucial to the development of electric ships.

To sum up, the analysis results for Dutch partners in ‘Green and clean energy for the future shipping industry’ through SWOT analysis are shown in the following table.

SWOT analysis matrix of 'Green and clean energy for the future shipping industry'



7. CONCLUSIONS AND OPPORTUNITIES

The shipping industry is one of the fundamental industries that support global economic development. In recent years, the concept of green and smart shipping has been drawing much attention from both academia and industries, as it provides a promising and sustainable future for a better industry and also profound opportunities for the business sectors.

China and the Netherlands are both important players in the shipping industry. The driving force for green and smart shipping stemmed from both the global trend and also the business opportunities that have facilitated such two economic entities to cooperate in various aspects. Out of the call from the Dutch government for a business opportunities analysis on the green and smart shipping market in China, to seek promising business opportunities and collaborations between the participants in both countries, the authors have analysed the general situation of the Chinese shipping industry, the government policies on green and smart shipping, and also the possible innovation domains for collaborations.

In general, China is one of the largest participants in the global shipping industry with its huge volume of cargo transportation and strong outlook for increasing. In the meantime, its enormous domestic shipping market also attracts various international players to do business. The advantage of such a background is that the shipping market of China is open for business collaboration in various sectors, including green and smart shipping. As may be known to some extent, the law and regulations (such as the 14th Five-Year Plan for the Development of Maritime Systems; The Special Administrative Measures for Foreign Investment Access (Negative List); Catalogue of Industries Encouraged for Foreign Investment, etc) in China play an important role in the operation and planning of the business sector. The Chinese government is open and has a long plan to establish a sustainable, clean and intelligent shipping industry in the near future. Out of such a background, the related laws and regulations are very open and friendly for the innovations and collaborations in the fields such as surveillance of ship pollution, advances in autonomous shipping, and also green and clean energy for the shipping industry.

In this report, we have analysed the technologies needed for the innovations in the three domains and provided information about the companies in China that are working on such business. In detail, we think as, for the surveillance of ship pollution, the remote sensing technologies such as UAV-based systems and autonomous emergent oil spillage collection ships and related equipment could be promising sectors for the Dutch companies to collaborate with the Chinese counterparts. As for the advances of autonomous shipping and intelligent collision avoidance systems, the Netherlands has excellent research teams in research facilities such as TU Delft and also good collaborations with China. We think remote sensing technologies, human-like decision-making systems and related autonomous control algorithms could be promising collaboration fields. Please be noted that such sectors are suggested to collaborate with the Chinese companies that are working on shipping equipment as aforementioned to better understand the related regulations and the insights of the existing markets. As for the green and clean energy for shipping, LNG and electricity-powered ships and their related facilities are the most promising fields for green shipping in China, as the current plan and regulations strongly encourage such applications.

To summarize, the following opportunities exist:

1. Surveillance of shipping pollutions.
    a) Remote sensing of ship exhaust pollution
    b) Emergency response for oil spillage in the waterways
2. Autonomous shipping and intelligent collision avoidance.
    a) The autonomous sensing technology for ship navigation
    b) Intelligent ship collision avoidance decision-making system
    c) Remote piloting technology and Intelligent route planning technology
3. Green and clean energy for the future shipping industry.
    a) Low oil consumption diesel engine for ships
    b) LNG and its utilization as clean energy for the ship
    c) Electricity-powered ships

It should also be noted that, for smooth and efficient cooperation between the two counterparts, the openness and rule-based communication and operation model should be upheld for all the companies. We sincerely hope that the reported information could be beneficial for the future collaboration between China and the Netherlands for a greener and smarter shipping industry in the near future.

Appendix. List of abbreviations and meanings

Abbreviations	Meanings
IenW	The Ministry of Infrastructure and Water Management
RWS	Rijkswaterstaat
RVO	Netherlands Enterprise Agency
WTI	The China Waterborne Transport Research Institute
IMO	The International Maritime Organization
UAV	Unmanned Aerial Vehicle
SSNAME	Shanghai Society of Naval Architects & Marine Engineers
OOW	Officers On Watch
MASS	Maritime Autonomous Surface Ship
ARPA	Automatic Radar Plotting Aid
ECDIS	Electronic Chart Display and Information System
AIS	Automatic Identification System
GMDSS	Global Maritime Distress and Safety System
INS	Integrated Navigation System
ICS	Integrated Communication System
CSSC	China state shipbuilding corporation limited
CETC	China Electronics Technology Group Corporation
NSR	New Sunrise co. ltd
Ninglu Tech	Nanjing Ninglu Technology Co., Ltd
COLREGs	International Regulations for Preventing Collisions at Sea
LNG	Liquefied Natural Gas
LNG-FSRU	FLOATING LIQUEFIED natural gas storage and regasification units
WUT	Wuhan University of Technology
STC	Shipping and Transport College Group

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Netherlands Enterprise Agency
Prinses Beatrixlaan 2
PO Box 93144 | 2509 AC The Hague
T +31 (0) 88 042 42 42
Contact us
www.rvo.nl

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