ESCAP PROJECT

“Improving the safety of navigation and the sustainability of shipping through the introduction of innovative autonomous shipping technologies in the Asia-Pacific region”

SHIPPING AND AUTONOMOUS SHIPPING TECHNOLOGIES DEVELOPMENT - STUDY REPORT OF VIETNAM

Hanoi, May 2023
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1. General
About 80 percent of the maritime accidents were contributed by human errors, directly or indirectly. One of the concepts, that may support to reduce the direct human errors is the application of autonomous shipping technology.

Autonomous technology is not new to transport industries, including maritime, as it has been touched a half of century ago. But now a day, with the rapid evolution of technologies, including Artificial Intelligence (AI), Internet of Things (IoT) and machine deep learning, autonomous technology can get more and more concern and progress. In fact, autonomous technologies have already been implemented successfully in several contexts such as container terminal operations, manufacturing systems, warehouse operations, self-driving cars, diver-less metro-rail service, airplane autopilot mode, drone, UAV etc.

Maritime Autonomous Surface Ship (MASS) currently is defined as “a ship which, to a varying degree, can operate independently of human interaction, and broadly laid out levels of autonomy.” From a development and operation perspective, maritime autonomous surface ships (MASS) is quite feasible, largely due to the currently available and rapidly progressing technology background, as well as the operating environment of fewer physical objects (e.g., other vessels) in the high seas.

The International Maritime Organization (IMO) has identified four degrees of autonomy for MASS as follow [1]:

- Degree one: Ship with automated processes and decision support: Seafarers are on board to operate and control shipboard systems and functions. Some operations may be automated and at times be unsupervised but with seafarers on board ready to take control.

- Degree two: Remotely controlled ship with seafarers on board: The ship is controlled and operated from another location. Seafarers are available on board to take control and to operate the shipboard systems and functions.

- Degree three: Remotely controlled ship without seafarers on board: The ship is controlled and operated from another location. There are no seafarers on board.

- Degree four: Fully autonomous ship: The operating system of the ship can make decisions and determine actions by itself.

Theoretically, the application of autonomous shipping technologies has several advantages, that not exhaustively may include:

1. Crew Safety: Reduction of Human Error and enhancement of Human Safety resulted from limited number or no crew onboard, where many hazardous works exist; Enhanced ability to operate in harsh or hazardous or dangerous environments, as autonomous ships can be remotely controlled.

2. Operational Effectiveness and Operativity: Basically, autonomous technologies allow the possibility for 24/7 operation. The autonomous ships will have increased capacity for cargo, as they can be designed without the need for accommodations for crew members. Besides, autonomous ships can also have improved cargo handling and loading due to advanced cargo handling systems that can reduce the time and effort required to load and unload vessels. In navigation, autonomous ship may have increased efficiency through better route planning; From the financing point of view,
autonomous ships have lower cost of construction due to removal of the accommodation structure and equipment and lower operating costs as the result of reduction of fuel consumption, crew expenses and salaries.

3. Safety of Navigation: Autonomous ships have improved ability to monitor and enforce maritime safety regulations, based on the technologies that can detect and report on vessels operating in violation of safety rules. Advanced sensors and technologies provide a more complete picture of the vessel’s surroundings, hence help to enhanced navigational and situational awareness. Autonomous ships can follow predetermined routes and schedules more consistently than vessels with human crews.

4. Security: Autonomous ships can be equipped with advanced security systems and can be remotely monitored and controlled. The sensor systems and other technologies help to detect and effectively respond to potential threats. Autonomous ships may be constructed in such a way that the pirates can hardly access or manually operate them. No crew means no hostages and ransom.

5. Environment Protection: Autonomous shipping technologies can help to reduce fuel consumption and emissions; They may improve the ability to monitor and enforce environmental regulations related to shipping, as autonomous ships can be equipped with advanced sensors and other technologies that can detect and report on environmental violations. Limited or no human crew onboard contributes to reduction or removal of crew generated waste. Opportunity for use of low carbon or alternative fuel/electricity/renewable energy for autonomous ships is the advantage as well.

6. Enhanced role of women: Autonomous shipping technologies may create more favourable working environment for women involvement into the maritime industry. The work at Remote Control Centre ashore can be a good example.

The IMO Maritime Safety Committee (MSC) first discussed automation in shipping at the 8th session in March 1964. Since then, development and research on the automation of ships have been ongoing, and getting the technological breakthroughs in last few years, with the support from leading governments such as EU, UK, Russian, US, Korean, Japan etc....

Several MASS research projects have been developed, conducted and are ongoing globally, namely: Maritime Unmanned Navigation through Intelligence in Networks, DNV-GL Revolt, Kongsberg maritime autonomous shipping, NYK Maritime Autonomous Surface Ships Trial, Korea Autonomous ship project, Yara Birkeland.A number of the autonomous ships are now on the trail stage in practice, i.e: Rail/vehicle carriers Marshal Rokossovsky and General Chernyakhovsky (Russian Federation) [2], ferry Soleil [Nippon Foundation – Japan], LNG carrier Prism Courage ( Korean) [3], the Mayflower Autonomous Ship (US) and Maju 510 tug (Singapore) etc...

In order to keep up with the developments in the industry already taking place and to address the challenges, that various research projects and studies on MASSs are facing, The IMO’s Maritime Safety Committee (MSC) approved the framework and methodology for the regulatory scoping exercise (RSE) on MASS during its 100th session held on December 3-7, 2018 [4]. The exercise involved assessing a substantial number of IMO treaty instruments
under the remit of the MSC and identifying provisions which are related to MASS issues and may need to be created, amended or clarified.

The MSC, at its 103rd session in May 2021, has completed the RSE. The outcome highlights a number of high-priority issues to be addressed, cutting across several instruments, that involve, for instance, the development of MASS terminology and definitions, and addressing the functional and operational requirements for the MASS operation. It is suggested that the best way forward to address MASS in the IMO regulatory framework could, preferably, be in a holistic manner through the development of a goal-based MASS instrument. Such an instrument could take the form of a "MASS Code", and address the various gaps and themes identified by the RSE. The project for non-mandatory MASS Code currently is being underway.

Despite the challenges, autonomous shipping technologies continue to be a trend of future maritime industry evolution. As the fact of strategy, the stance of Vietnam is obviously keen with the innovations, that could make modern maritime economy contribute more and more to the development of the country, especially with the support from the international sources.

The United Nations Economic and Social Commission in Asia and the Pacific (ESCAP) promotes cooperation in pursuit of solutions to sustainable development challenged among its 53 member States and 9 associate members in the Asia-Pacific region by providing technical assistance and capacity-building services, including on transport related-matters, in support of the implementation of the 2030 Agenda for Sustainable Development. ESCAP’s Transport Division is implementing a project on “Improving the safety of navigation and the sustainability of shipping through the introduction of innovative autonomous shipping technologies in the Asia-Pacific region” with the involvement of several beneficiary countries in Asia and the Pacific, including India, Indonesia, Malaysia, Thailand, and Viet Nam.

This study report is made at the very first stage of autonomous technology consideration for shipping and shipbuilding sectors in Vietnam. The objective is to provide a brief overview of the current situation in the maritime industry and the potentials for future application of such technologies, including proposal for building framework and plan for realisation.

The study report has been created based on the literature review on the public domain and analysis of the information and data provided by the stakeholders during the meetings, interviews and via electronic messaging. The Author would like to express special thanks for the great support and collaboration to:

1. UN ESCAP Project Team
2. Vietnam Maritime Administration (Vinamarine)
3. Vietnam Register (VR)
4. Vietnam Maritime University (VIMARU) and Ship Science and Technology Institute (SSTI)
5. Vietnam Shipowner Association (VSA)
6. Ho Chi Minh City University of Transport (UT-HCMC)
7. Shipbuilding Industry Corporation (SBIC)
8. Vietnam Maritime Corporation (VIMC)
2. Autonomous Shipping Technologies in the context of Vietnam

2.1 Current Shipping Industry and Technology overview

2.1.1 Sea going fleet of Vietnam

Sea transport is an important link in the logistics service chain and contributes significantly to the economy of Vietnam as a country with a long coastline and locates closely to important international maritime routes. The volume of goods through Vietnam's seaports has grown rapidly and stably in recent years. In the context that the world is facing negative impacts from the Covid-19 pandemic, Vietnam continues to grow in the seaport good throughput. According to the Vietnam Maritime Administration, in 2020, the volume of goods through the seaport system of Vietnam reached 692 million tons, that comprised 4% higher in comparison to 2019. Among which the container cargo volume reached 22.4 million TEUs, that comprised 4% higher in comparison to 2019. The volume of goods through the seaport in 2021 reached more than 706 million tons, that is 2% over the same in 2020. In which, the volume of container cargo reached nearly 24 million TEUs, that is 7% higher in comparison to 2020. The national fleet has taken over almost 100% of the domestic freight by sea, and mainly operates on short international routes such as China, Southeast Asia, Northeast Asia, India. [5].

As of December 2021, the fleet of ships flying the Vietnamese flag (including a dedicated shipping fleet and a fleet of other purpose vessels) has 1,502 ships (excluding the data of ships under construction), with a total tonnage of about 7,145 million GT and total Deadweight is about 11.7 million tons. In which, dedicated transport fleet has 1,032 vessels with a total tonnage of about 6.3 million GT and deadweight about 10.6 million tons, mainly comprises of small size (from 5,000 GT or less) and medium (from over 5,000 GT to 10,000 GT) ships. In 2021, the total tonnage of Vietnam's shipping fleet has increased rapidly, a number of Vietnamese enterprises have invested in large tonnage dedicated ships, such as crude oil tankers with a tonnage of up to 300,000 DWT, gas carrier... According to statistics of the United Nations Trade and Development Forum (UNCTAD), Vietnam's fleet currently is at the 3rd rank in the ASEAN region (after Singapore, Indonesia) and at the 22nd in the world.

Vietnam's national fleet has been tending to restructure, reducing the total number of ships but increasing the number of large tonnage vessels, the total tonnage and deadweight of the fleet changes in an upward direction in recent years. According to Vietnam Register, in the period 2016 - 2020, the number of transport fleets decreased by over 200 ships, equivalent to a decrease of 17.2%. However, the total tonnage and total deadweight of the transport fleet have increased by over 6%. Out of a total of 1,032 dedicated cargo ships, the number of general and bulk cargo ships are 724 (equivalent to 77%), followed by oil and chemical tankers with 186 ships (equivalent to 18%). The container carrier fleet has only 39 ships (equivalent to 3.77%). For ship sizes above 30,000 GT, there are only 14 bulk carriers, 27 oil and chemical tankers. For the range of less than 5,000 GT, there are mainly 585 general and bulk cargo ships, followed by 95 oil and chemical tankers, 63 passenger ships, 17 gas carriers and finally 07 container ships [6].

The average age of Vietnam's dedicated cargo shipping fleet is 16.5 years old, that is 5 years younger than the world's average ship age (according to UNCTAD, the average age of the world fleet is 21.9 years old). The group of ships with the youngest average age is passenger
ships (7.9 years old), the group with the oldest age is gas carrier (23.6 years old); the average age of container carrier group 17.7-year-old and 17.6-year-old for chemical oil tankers.

Vietnam has about 600 ship owners of all economic sectors, of which only 33 ship owners operate the fleet with a total tonnage of over 10,000 DWT, the rest are small vessel fleets of private and small enterprises located in Hai Phong, Thanh Hoa, Thai Binh, Can Tho. Among the 33 large ship owners, there are 25 ship owners belonging to 4 bigger economic groups such as Vietnam National Shipping Lines Corporation (VIMC), Vietnam Oil and Gas Group (Petrovietnam or PVN), Vietnam National Petroleum Group (Petrolimex) and Shipbuilding Industry Corporation (SBIC). Other ship owners are small businesses, the number of ships owned by them are small in quantity and tonnage. There are companies that only own 1 ship. The trend of Vietnamese enterprises investing in foreign-flagged ships, mainly ships with large tonnage, is increasing, accounted up to 37.8% of the national fleet's tonnage in 2020. In 2021, several enterprises have invested in specialized ships for transporting liquefied petroleum gas, large tonnage crude oil vessels (over 300,000 DWT), aged between 15 and 20, and proposed to fly the Vietnamese flag. Besides, Vietnam has an well growing import and export goods market, that attracts major shipping lines in the world to form container freight services environment with very high competition. Currently, there are about 34 foreign container shipping lines (100% foreign capital) operating import and export goods in Vietnam, with the 10 famous brands such as MSC, Maersk, CMA - CGM, Hapag - Lloyd, O.N.E, OOCL, Evergreen, COSCO, HMM and Yang Ming.

<table>
<thead>
<tr>
<th>Year</th>
<th>Quantity</th>
<th>Increasing/ reducing in quantity (%)</th>
<th>Deadweight (DWT)</th>
<th>Increasing/ reducing in deadweight (%)</th>
<th>Gross Tonnage (GT)</th>
<th>Increasing/ reducing in GT (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2016</td>
<td>1.267</td>
<td></td>
<td>7.588.447</td>
<td></td>
<td>4.602.861</td>
<td></td>
</tr>
<tr>
<td>2017</td>
<td>1.194</td>
<td>-5,8</td>
<td>6.933.450</td>
<td>-8,6</td>
<td>4.213.173</td>
<td>-8,5</td>
</tr>
<tr>
<td>2018</td>
<td>1.147</td>
<td>-3,9</td>
<td>7.101.152</td>
<td>2,4</td>
<td>4.150.596</td>
<td>-1,5</td>
</tr>
<tr>
<td>2019</td>
<td>1.047</td>
<td>-8,7</td>
<td>7.192.694</td>
<td>1,3</td>
<td>4.300.013</td>
<td>3,6</td>
</tr>
<tr>
<td>2020</td>
<td>1.049</td>
<td>0,2</td>
<td>8.045.815</td>
<td>11,9</td>
<td>4.787.224</td>
<td>11,3</td>
</tr>
<tr>
<td>2021</td>
<td>1.032</td>
<td>-1,6</td>
<td>10.610.730</td>
<td>31,9</td>
<td>6.310.352</td>
<td>31,8</td>
</tr>
</tbody>
</table>

Note: Ships with length over 20m and Main Engine power output over 37kW

Source: Vinamarine
Table 2. Sea going ships of Vietnam split in domestic and international voyages

<table>
<thead>
<tr>
<th>Year</th>
<th>Ships on Domestic voyages</th>
<th>Ships on International voyages</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number</td>
<td>GT</td>
</tr>
<tr>
<td>2015</td>
<td>848</td>
<td>870.407</td>
</tr>
<tr>
<td>2016</td>
<td>824</td>
<td>1.047.811</td>
</tr>
<tr>
<td>2017</td>
<td>807</td>
<td>1.091.983</td>
</tr>
<tr>
<td>2018</td>
<td>806</td>
<td>1.077.876</td>
</tr>
<tr>
<td>2020</td>
<td>704</td>
<td>1.072.730</td>
</tr>
<tr>
<td>2021</td>
<td>671</td>
<td>904.313</td>
</tr>
</tbody>
</table>

Source: Vinamarine

The general assessment shows that the Vietnamese shipping fleet has satisfactorily taken on the role of domestic transport of goods, including most of the market share of LPG, gasoline, oil and basically dominates the import and export general cargo transport market. The transport capacity of Vietnam’s seagoing fleet has continuously increased in recent years, despite the decreasing in the number of vessels. The total tonnage of the fleet has increased in recent years by replacing a number of small ships with fewer but larger ships. The ship type component of the seagoing fleet has been changed rapidly in recent years, in which the strongest growth rates are in the groups of coastal passenger ship, LPG carrier, oil and chemical tanker. The number of bulk carriers and general cargo ships has decreased. The fleet of ships flying foreign flags owned by Vietnamese ship owners continued to increase in both quantity and tonnage. By 2020, many shipping companies have overcome difficulties and made profits, therefore have invested in buying more new ships and expanded the operation market. The dominant ownership of the fleet has shifted strongly from governmental to the private sector. However, the fact shows that the national seagoing fleet is old enough, especially regarding the gas carrier group. Small size bulk and general cargo ships still dominate. Vietnam's shipping fleet is mainly suitable for costal, domestic routes or short international voyages in the region, unable to compete in the wider international shipping market with large ships at more optimized operational costs.

The level of application of automation technology on ships in Vietnam is still very limited. The number of ships classified with the M0 machinery automation system is very small. The automatic and remote-control technologies applied on board are just for specific function such as the autopilot system, the liquid cargo control system, the anchor monitoring system, the dynamic positioning system, etc. and there is basically no foundation for integrated autonomous shipping technology. In order to meet the development needs, Vietnam's shipping fleet still needs a lot of investment in finance, technology and legal framework, coming from domestic and international partners and providers. This policy is emphasized in the Project on Development of Vietnam’s shipping fleet approved by the Ministry of Transport under Decision No. 1254/QD-BGTVT dated September 28, 2022.
2.1.2 Inland water transport fleet

Waterway transport has the advantages of lower fee rates, higher safety and lower environmental pollution impact than other modes of transport. Vietnam has 2,360 rivers and canals with a total length of about 42,000 km and with 9 major river systems flowing into the sea through 120 estuaries. The total length of the country's waterways being managed and exploited is more than 17,000 km, which is very potential for the development of inland waterway transport. According to Vietnam Inland Waterway Administration - VIWA, inland water transport currently takes over for about 19% of the total transported volume of domestic goods. That means for every 5 tons of goods in circulation, 1 ton of goods is transported by waterway in Vietnam (the rate in the Red River Delta is 45%, the Southeast region 47.5% and the Mekong River Delta region accounts for nearly 79.7% respectively. There are currently 34 waterway transport routes from the shore to the islands, which have been announced in service, contributing to socio-economic and tourism development in the coastal provinces (According to Circular No. 30/2021 of the Ministry of Transport on management of waterway transport routes from shore to islands in Vietnamese waters). Vietnam has many famous sea tourism destinations such as Ha Long Bay, Nha Trang, Phan Thiet, Phu Quoc...with beach resorts invested and operated by prestige domestic and international corporations such as Vin Group, Sun Group ... At those locations, short-distance coastal passenger cruise ships are often invested in modern and environmentally friendly ways to bring the best experience to visitors. This kind of ship is very potential for application of autonomous technologies.

According to statistics from the Vietnam Register, by September 2022, there are about 237,000 inland water vessels nationwide, with a total deadweight of more than 22.2 million tons. However, in general the inland water vessels are still mainly of small size, operated on short routes, with low efficiency. The connection between inland water transport and other modes of transport, especially by road and seaport, is not convenient and effective. In Vietnam, waterway transport enterprises are mostly private, spontaneous developed, fragmented, with low financial capacity and old equipment. Vietnam's inland waterway vessels have basically not applied automatic technologies, including primary automation such as auto pilot, monitoring, or machinery. There is no platform for autonomous shipping technologies for inland water transport yet and this is the potential to build a legal, financial, and technological basis for the application of new science and technology for further improving economic efficiency and the role of inland waterway transport.

2.1.3 Seaport system

Vietnam's seaport system in recent years has developed synchronously and modernly to welcome the world's largest seagoing ships. Basically, the current seaport system satisfies the needs of ships entering and leaving the port, with the very low waiting time, efficient throughput of import, export and domestic goods. According to the announced list of Vietnamese seaports approved by the Prime Minister in Decision No. 804/QD-TTg dated July 8, 2022, Vietnam's seaport system consists of 34 seaports with a total 299 port facilities, with about 94,486 km of total wharf length, and with a total capacity of over 700 million tons/year. Vietnam's seaport system has been synchronously invested in infrastructure: wharves, mooring buoys, cargo handling equipment. The seaport system has been planned, developed, operated spread across the country coastal centers, making them the most favorable conditions and contributing for the socio-economic development of coastal areas.
and the whole country. Most seaports are currently owned and operated directly by state-owned enterprises and other investors. There are 04 major ports invested with the state budget. Vietnamese seaports in Hai Phong, Ho Chi Minh City. Ho Chi Minh City, Ba Ria - Vung Tau have entered the list of 50 seaports with the largest cargo throughput in the world in 2022. Gateway ports such as Lach Huyen (Hai Phong), Cai Mep (Ba Ria - Vung Tau) are capable of serving the largest container ships in the world today (over 200,000 DWT).

Vietnam's seaports are also in the trend of modernization and increasingly applying automation and digitization technologies. Several seaport operators have provided services for deploying electronic seaport applications (E-ports), smart seaports (Smart Port, Port 4.0) technology, application and deploying port software systems such as: operating and planning software system (TOPX), container data management software (TOPO), new container management software (TOPOVN) etc. in operation, helping to increase efficiency performance and safety. Tan Cang-Cai Mep International Port (TCIT), Cai Mep International Port (CMIT), Gemalink are currently operating the E-RTG cranes with 100% grid electricity (fully electrical), applying semi-automatic or integrated automatic load control (ALC) technology and smart control cabin with DGPS system, integrated with modern port management software CATOS. The increasingly modernized seaport system is a good opportunity and condition for increasing the application of automated technologies, including autonomous shipping.

2.1.4 Shipbuilding and repairing industry

In the "Strategy for sustainable development of Vietnam's marine economy to 2030 with a vision to 2045" [8], Vietnam identifies the marine economy as a driving force for the development of other economic sectors, thereby creating fundamental changes in the economy, hence improve and comprehensively restructure the marine economy in the direction of industrialization and modernization. An important task for the implementation of the Marine Strategy is to develop the shipbuilding and ship repair industry. The shipbuilding industry plays an important role in providing vehicles and technical equipment for freight - passenger transport by sea/river, for defense, oil and gas, fishing industries. Shipbuilding industry is identified in Vietnam as a key mechanical sector, that plays important role in the country's industrial development structure. Over the past 50 years of establishment and development, the shipbuilding industry in Vietnam has become a key industry with a system of large and small shipyards throughout the country, including joint ventures with foreign investors. Vietnam's shipbuilding industry has accumulated a lot of achievements, has built cargo ships of deadweight up to 53,000 tons, car carriers with capacity of 4900 cars, container ships, etc. In recent years, Vietnam's shipbuilding industry has made great progress and is gradually asserting itself in the international market. During and after the Covid-19 pandemic, many Vietnamese shipbuilding enterprises have well grasped the opportunity and made drastic changes. Typically, the case of Dung Quat Shipbuilding Industry Company (DQS) was once in a difficult situation, and the production situation is very good. According to statistics from DQS, in the first quarter of 2022, the company received and repaired the number of ships equal to twice the number of ships in 2018 and 2019 combined. According to Shipbuilding Industry Corporation (SBIC - formerly Vinashin), all shipyards across the country had a higher order of ship repair than before, both in terms of the number of ships repaired and revenue value. The demand for shipping by sea is increasing, so the shipbuilding industry will have expanded market opportunities. In particular, the demand for transportation has increased in recent years, when Vietnam is
promoting exports and the opportunities for economic integration become more and more extensive, Vietnam has identified and pursued a different position of shipping and shipbuilding. Vietnam currently has 82 shipyards, providing services throughout the country. Of which, there are 21 facilities for building, converting, and repairing ships for ships of 10,000 DWT or more. There are 8 shipyards belonging to SBIC and 1 joint venture between SBIC and a foreign investor. Hyundai-Vietnam Shipbuilding Co. Ltd., Dung Quat Shipbuilding Industry Co., Ltd. and NOSCO Shipyard Joint Stock Company are among the shipyards that have the capacity to build and repair large and modern ships for domestic and export demand in recent years.

According to Vietnam Register, in 2022, there are 17 new ship designs have been reviewed and approved (with a total GT of 36,928, total deadweight of 51,645 tons, and total capacity of 1,390 passengers). In comparison to 2021, the design of new ships does not increase in number, but the new ships are slightly bigger in size. In the whole country, there are 66 new ships under construction. From the beginning of the year to November 30, 2022, 18 ships were officially awarded with class (including newly built and converted ships. There are 38 ships under construction projects suspended and delayed for more than 2 years [6].

In fact, Vietnam’s shipbuilding industry is also facing many challenges. A number of shipyards are not properly invested and managed in terms of technology and infrastructure and therefore cannot accept large and modern ships in. In the consequence, many Vietnamese ships must be repaired in shipyards abroad. On the other hand, insufficient development of supporting industries hardly makes the domestic shipbuilding industry satisfactory to the clients, because many details, materials and equipment cannot be made by the shipyard itself. According to the Vietnam Association of Mechanical Enterprises, the supply of materials and equipment for Vietnam’s shipbuilding industry currently account for only about 20-30%. In which, Vietnamese pure products only account for about 10-15%, the rest are foreign products processed in Vietnam, or must be imported. In addition, many shipbuilding enterprises are facing financial difficulties and barriers due to large investment debts at banks from crisis in 2008-2010 period that have not been restructured. With that respect, the investment in new equipment and technologies for shipbuilding from foreign partners is a priority and solution to respond to challenges.

Table 3. Ship designs approved in 2022

<table>
<thead>
<tr>
<th>Particulars</th>
<th>Quantity</th>
<th>Total DWT (tons: ∑ DWT)</th>
<th>Total Gross Tonnage (GT: ∑GT)</th>
<th>Total number of pax (passenger)</th>
</tr>
</thead>
<tbody>
<tr>
<td>New building design</td>
<td>17</td>
<td>51.645</td>
<td>36.928</td>
<td>1.390</td>
</tr>
</tbody>
</table>

Source: Vietnam Register
2.1.5 Human resource in shipping

Maritime human resources and crew are always the most important factors in the marine economic development strategy of the country. In recent years, Vietnam’s fleet has increased rapidly in both number of vessels and total deadweight, that entails an increased demand for human resources. With a population of nearly 100 million and a high percentage of young labor force, this is an opportunity to bring great socio-economic benefits. Currently, Vietnam has 7 education and training institutions for maritime field and seafarers, such as Vietnam Maritime University, University of Transport of Ho Chi Minh City, Maritime College No.1, and Maritime College No.2, Hai Phong Polytechnic College, College of Waterway Transport No.2, Duyen Hai College. According to the Vietnam Maritime Administration, for the last 10 years of implementing the provisions of the International Convention on Standards of Training, Certification and Watchkeeping of Seafarers 1978, revised 2010 (the STCW Convention 1978/2010), the number of seafarers has grown up significantly. As of October 1st, 2022, Vietnamese has more than 54,000 seafarers, that is about 11,000 more than in comparison with year 2012. However, it is noted that the number of low rank seafarers, such as able seamen and oilers has increased more rapidly than the rank of officers and engineers. For example, in 2012 the number of graduated officers and engineers at operational level is 1,503 people and at management level is 1,282 people. But in 2022 these figures are just 1,503 and 702 respectively. In the tendency of increasing domestic and export demand for seafarers, the scale of training at all levels of ship crew members tends to decrease.

In the country, insufficient number of seafarers is still a main challenge to be dealt with. Maritime sector is a specific industry with the hard environment, while crew members have to be far from their families most the time, with the salary level is not higher than that of other professions onshore. Many seafarers no longer want to stick with the works onboard and prefer to find other jobs onshore or switch to work oversea with more favorable salaries, hence making the shortage of seafarers even more serious. In this case, one of the solutions to meet human resources for the maritime sector is to apply advanced technologies with less labor utilization and better working conditions for personnel, such as autonomous navigation.

2.1.6 The role of women

The current Vietnamese law has many priorities for women to ensure gender equality as well as encourage employers to create better conditions for female employees to have regular and continuous jobs. Labor Code 2019, Article 153, stipulates equal working rights of female employees such as: equal rights between female and male employees in recruitment, training, salary, reward and promotion, social security and health insurance, working conditions and safety, working and rest time, welfare regimes, and the other physical and mental benefits. The Government encourages employers to prioritize employing and recruiting women to work when they meet the conditions and standards for doing jobs suitable for both men and women and implement better policies towards female workers than those prescribed by law.

It is noted in Vietnam for the recent years, more and more female seafarers have been trained and graduated from maritime schools. According to the Vietnam Maritime Administration, since 2013 there are 30 female students have been trained and graduated nationwide in the major of ship navigation. In Vietnam, there have even been also female
captains of inland waterway vessels. However, most of them joined the works in the field of ship management and maritime business onshore afterward. The reason is that the provisions of Circular No. 26/2013 of the Ministry of Labor, Invalids and Social Affairs (MoLISA) previously specified the jobs onboard ships as hazardous and therefore not allowed to employ female workers. Another reason is the barrier of traditional culture of the Vietnamese people, which consider the seagoing is not appropriate for women. However, currently, Circular No. 26/2013 has been replaced by Circular No. 10/2020 and it accordingly no longer restricts women’s right to work in various occupations, including working onboard ships. This is an important breakthrough for female workers to have the opportunity to challenge the seafaring profession. In 2022, the Vietnam Maritime Administration has recognized and awarded the Certificates of Competency (CoC) to the first female seafarers in Vietnam, affirming that female workers are fully capable to work onboard ocean-going ships, fulfilling the commitment of “Empowering Women in the Maritime Community” by IMO in year 2019. Thereafter, more and more female seafarers have been awarded with CoC, including the first female engineer in 2023.

It should be noted that the application of advanced autonomous shipping technologies can definitely contribute to creating job opportunities suitable for women in maritime sector, because they no longer have to directly deal with the hazardous environment onboard ships.

2.2 National Legal Framework

For industrialization and modernization of the economy in general and for the marine economy in particular, Vietnam has paid great attention to development and application of modern science and technology as a consistent leading direction. Many policies and strategies have been issued to support these processes, that can be seen as examples below:

Resolution No. 29-NQ/TW, adopted November 17, 2022, at the Sixth Plenary Meeting of the 13th Central Committee of the Communist Party of Vietnam, addressing on-going acceleration of the country's industrialization and modernization until 2030, with a vision to 2045 [7] has made the important guiding direction, which determines that the industrialization and modernization of the country will be based mainly on the development of industry and services on the basis of science-technology, innovation, and harmonization between economic development and environmental protection, taking digital transformation as a breakthrough new method to shorten the process of industrialization and modernization. The resolution sets a target that by 2030, Vietnam should have basically achieved the criteria of an industrialized country, being in the group of 3 leading ASEAN countries in terms of industrial competitiveness with an industrial share of over 40% of GDP the value of high-tech industrial products of over 45% of GDP, and the proportion of the digital economy is reached about 30% of GDP. The resolution identifies the core process of industrialization and modernization of the country in the 2021-2030 period is to promote strong application of science-technology and innovation, especially achievements of the industrial revolution 4.0, to create breakthroughs in productivity, quality, efficiency and competitiveness of all sectors and the whole economy, to implement a comprehensive digital transition to green, low-carbon industries. To achieve that goal, specific solutions are given including: prioritizing the development and creation of a legal framework for the development of smart manufacturing, issuing national standards on smart manufacturing, improving mechanisms and policies for science-technology development and innovation in line with Vietnam's context and international practices; encouraging enterprises to invest in
R&D activities, creating favorable conditions for setting up and effectively using investment funds for science, technology and innovation for enterprises, adopting incentive tax policies to encourage scientific-technological development and innovation in line with the goal of promoting the development and application of new prioritized technologies, establishing a legal framework for the development of the digital economy, digital society and digital government, promulgating pilot policies and mechanism for activities of developing, testing and applying digital technology-based products, service solutions, and business models on digital platform. Priority is given to attracting investment in hi-tech projects and technology transfer. The government will allocate the resources and promote an advanced incentive mechanisms to develop foundational industries, including shipbuilding and digital technology sectors, focusing on a number of key industries such as manufacturing robots, automatic operation equipment, remote control, intelligent electronic and automation equipment.

Under the Resolution 29-NQ/TW, a set of legal instruments has been specifically adopted, i.e the Law on High Technology 2008, the Law on Science and Technology 2013, Decree No. 08/2014/ND-CP dated January 27th/ 2014 detailing and guiding the implementation of a number of articles of the Law on Science and Technology, Decree 13/2019/ND-CP on science and technology enterprises...These legal documents stipulate many specific benefits and preferential policies that Science and Technology Enterprises are entitled to, including: incomes of enterprises from production and provision of products based on scientific and technological R&D results are entitled to 04-year corporate tax exemption and 50% reduction of payable tax for the further next 9 years. The raw materials, supplies and components that cannot be produced domestically and must be imported, are exempted from import tax for a period of 5 years from the date of commencement of production as prescribed in Article 16 of the Law on Import and Export Taxes. The scientific and technological services serving and providing technical support for innovation R&D activities, technology transfer are entitled to the incentive of 5% Value Added Tax reduction. Additionally, the science and technology enterprises are entitled to exemption or reduction of land rent and water surface rent rate, and exemption of registration fee for land using or house ownership rights under the provisions of respective laws. The National Fund for Technology Innovation Science and Technology development funds provide credit incentives including grants and loans with preferential interest rates up to 50% of the same rates at commercial banks for science and technology enterprises conducting scientific research, technological development and production and trading of R&D products. These enterprises are given priority, and no service charge when using machinery and equipment at key national laboratories, testing centers, and research institutions. They are also provided with governmental support in the commercialization of scientific and technological research results, registering and establishing intellectual property rights.

Another Resolution No. 36-NQ/TW adopted October 22nd, 2018 by the Central Committee of the Communist Party of Vietnam on the Strategy for sustainable development of Vietnam’s marine economy to 2030, with a vision to 2045 [8] and supported by Resolution No. 26 /NQ-CP dated March 5, 2020 of the Vietnamese Government for implementation plan have defined the goals that Vietnam must be an advanced and sustainable country by the sea, based on breakthrough factors of advanced science and modern technology development and high-quality human resources. These documents have set targets to 2030 and a vision to 2045 to turn Vietnam into a strong maritime nation, meeting basically the
criteria of sustainable development of the prosperous, safe and secure marine economy. The new, advanced, and modern scientific achievements are considered to be the direct factors in promoting the sustainable development of the marine economy, in order to become one of the leading countries in ASEAN with a number of marine scientific and technological fields at an advanced and modern level. Some specific solutions to achieve that goals include: developing a modern high quality and safer shipping fleet in line with minimizing environmental pollution and energy saving, developing high-quality marine human resources, promoting innovation and creativity, taking advantage of scientific achievements, new and advanced technology, attracting experts, and leading scientists, improving the legal instruments on the sea towards sustainable development and ensuring feasibility, synchronous and conformity with international maritime treaties to which Vietnam is a party, promoting the cooperation and support of international and regional partners and organizations to conduct scientific research and apply modern technologies to marine economic sectors.

The Article 7 of the Vietnam Maritime Code 2015, (as amended and supplemented in 2018), stipulates that the government encourages research and transfer of advanced and modern technologies in the maritime domain, including in developing fleets of seagoing ships, seaports, shipbuilding industry through the preferential and incentive policies on taxes and loan interest rates. Vietnam has also developed and applied a system of national technical regulations on ships and inland waterway vehicles. Some basic standards and rules include:

- QCVN 21: 2015/BGTVT National Technical Regulation on the Classification and Construction of Sea - going Steel Ships;
- QCVN 60: 2019/BGTVT National Technical Regulation on Automatic and Remote Control Systems;
- QCVN 62: 2013/BGTVT National Technical Regulation on Navigation Bridge Systems;

These Regulations impose the inspection, classification of ships and technical systems on board. The ship's machinery systems are classified according to the levels of automation with notations MC, M0, M0.A, M0.B, M0.C, M0.D if they satisfy the respective requirements regarding automation systems such as: the remotely controlled system for fuel oil, the remotely controlled mooring system, the autopilot (steering) system, remote controlled liquid cargo transfer pump system, remote controlled ballast water system, motorized opening and closing system, frozen container monitoring system, emergency towing, cargo hose handling equipment, automatic devices for recording main engine parameters, centralized monitoring and control systems for machineries, mechanical pilot hoister, fixed deck washing system and control devices on either side of the bridge etc. It is noted that all of these regulations are technical standards on local automatic or remote-control systems on board. There are no regulations or standards related to autonomous or remotely operated ships as integrated and independently operated object.

Regarding inland waterway transport sector, the Government and the Ministry of Transport have promulgated many policies to make water transport play an increasingly important role. Currently, 9 waterway transport corridors have been formed that connect each other and directly connect to seaports and coastal shipping routes by means of VR-SB-class (river – sea going) ships. Directive No. 37/CT-TTg of the Prime Minister dated September 29, 2020 on promoting the development of inland waterway transport and coastal transport sets out
specific tasks and solutions, in that includes: attracting investment in the development of facilities for building, converting and repairing inland waterway vessels in order to develop a fleet of inland waterway transport vessels with high quality, efficiency in term of operation, environmental protection and energy saving, promote the application of advanced science and technology, the digital platform technology in management, operation of inland waterway and coastal fleet.

Overview of the national legal framework shows that the orientations and general policies issued to support research, high-tech application, and automation are generally clear and relatively comprehensive. However, there is still a lack of specific management and technical regulations for R&D and application of innovative, advanced technologies such as autonomous navigation to shipping and shipbuilding industries. For example:

- The high-level legal instruments such as the Vietnam Maritime Code 2015, and the Inland Waterway Traffic Law 2019, currently do not contain provisions specifying the development and application of autonomous navigation and remotely controlled ships. Therefore, the sub-law guiding documents (decrees, circulars...) do not stipulate the same.

- The current national technical regulations do not have detailed management and technical requirement on autonomous and remotely controlled shipping technologies, except for requirement regarding local automatic and remote control systems on board (engine, control, cargo handling...) with the relatively low level of automation. The updating of such requires future experimental research and practices and technology transfer.

2.3 Status of autonomous technology research and development (R&D)

2.3.1 Autonomous technology R&D in different transport sectors

2.3.1.1 Land transportation sector

With the advantages and the supports and preferential policies of the government, autonomous technology has developed rapidly and widely applied in economic sectors of Vietnam recently. In the field of transportation, the most researched and applied automatic control technology is self-driving car, with the ability to sense the surrounding environment and move safely with little or no human intervention. A number of domestic enterprises have made strong digital transformations in production and business, demonstrating Vietnam's readiness to implement self-driving car manufacturing projects in line with future car industry trends, such as eco-friendly electric car that integrates automation and smart connectivity features, helps keeping in the right lane, develops Adaptive Cruise Control (ACC) technology and self-parking capabilities. To produce a self-driving car, the most important thing is the control software, combined with a series of accompanying technologies such as pre-programmed maps, radar, laser sensors, lidar, sonar, GPS, artificial intelligence, camera... Besides, smart technology platforms such as artificial intelligence, big data, cloud effect... are being continuously researched and developed to integrate on modern car systems. These technologies are not new to domestic high-tech enterprises. In recent years, various institutions in Vietnam have begun to pursue the research and development of technologies for self-driving cars. Prominent among them are projects of FPT Group, Hanoi University of Science and Technology, Phenikaa University and VinAI Research Institute (Vin Group).
VinFast – a subsidiary of Vin Group - is the first car company in Vietnam pioneering the application of automation technology to cars. VinFast's cars are equipped with a vehicle operation system based on an intelligent digital technology platform with the application of a global positioning system, ACC (Adaptive Cruise Control - adaptive cruise control system), multi-point collision warning and mitigation. VinAI – another subsidiary of Vin Group - has developed high-precision object recognition technologies based on low-profile hardware (MagNet), multi-camera and multi-object motion tracking (DyGLIP) technologies, monitoring and recognizing driver status, or panoramic view of the vehicle's environment (SVM). VinAI's self-driving system has been assessed as complies with automation level 2+ (the vehicle is partially self-driving with certain automated features through a highly adaptive cruise control system) and is in the process of rising to the next level 3 (vehicle with conditional self-driving capability), according to the Society of Automotive Engineers (SAE) six-level automation scale. Vinfast has successfully researched and developed series of smart cars VF e34, VF31, VF32, VF33 possessing the world's leading advanced technologies such as face recognition technology, multi-language virtual assistant and especially artificial intelligence (AI) technology in vehicle control, allowing self-driving. At the North America and Europe markets. VinFast has launched two series of smart electric cars, VF e35 and VF e36 in 2022. These models meet the safety standards of self-driving cars set by NHTSA (US Highways Traffic Safety Administration) and EURO NCAP (European Vehicle Safety Performance Assessment Program). Models VF e35 and VF e36 are also integrated with automatic driving assistance system (ADAS) and advanced entertainment system (Smart Service) [9].

Recently, Phenikaa Group also has announced to launch its first level 4 intelligent self-driving car, which is mainly designed to operate in resorts or golf courses. Although it is not an actual vehicle on the road and only has a limited size and speed, the product is also equipped with many advanced features such as automatic lane change, pedestrian and road sign recognition, traffic motion of surrounding objects analysis, and without the need for steering wheel or brake pedal. The model was researched and developed by Phenikaa X - a technology subsidiary company under Phenikaa Group, established in 2020 with the goal of becoming a leading technology company in the field of self-driving cars and industrial robots in Vietnam. According to Phenikaa Group, this is the first "Made-in-Vietnam" smart self-driving car model in Vietnam with self-driving car technology at level 4 based on the 5-level scale of SAE. The project is developed and applied by a team of scientists and experts of the Group according to international standards. Phenikaa's self-driving car has outstanding intelligent features, using artificial intelligence technology and most advanced technologies in the world such as 2D/3D maps, Lidar sensors, SLAM, machine learning, deep learning... The model is currently operated within the campus of Phenikaa University. In addition to the introduction of self-driving cars, Phenikaa also introduced a technology solution for intelligent traffic made by its subsidiary company named Phenikaa MAAS [10].

1.3.1.2 Air transportation sector

Another example is that, In 2017 at Ho Chi Minh City Hi-Tech Park, FPT Group launched its first self-driving car after more than a year of development. In the process, FPT tested two different car models. One model is a small electric self-driving car that runs in golf courses and urban areas. The second model is a self-driving version for normal cars after converting the features of a commercial existing vehicle. The Group also established a division dedicated to developing FPT Global Automotive with the goal of developing automation...
level 5 vehicles (vehicles capable of fully self-driving cars, and also launched its own self-driving car platform). However, in developing self-driving cars, the hardware makers must closely collaborate with the software sides. Currently, FPT's self-driving car technology can help users book a car remotely through a smartphone application developed by FPT Software. To book a car, users only need to select the starting and ending points on the application, the system automatically calculates the optimal route to coordinate the car to pick up passengers in the order of calling time. In fact, according to evaluation, FPT's self-driving cars have only reached level 3 by the Society of Automotive Engineers (SAE), and still have to implement many additional solutions to match the traffic requirement in the real world [11].

In the field of unmanned aerial vehicles (UAV), many research projects and practical applications are also implemented. Examples can be mentioned as the project of an unmanned aircraft for cartography, a product manufactured by scientists from the Institute of Science and Cartography. This is the result of the project "Researching and manufacturing a swarm UAV system" and building a flight control software to take pictures, implement automated LiDAR ((Light Detection And Ranging) scanning work, and to maximize the ability to collect geospatial data. In actual testing, the institute's scientists have deployed LiDAR scanning flights using UAVs to create topographic maps in Ha Tinh and Quang Binh provinces. Accordingly, with 4 UAVs flying at altitude 20km over an area of 4,000 ha, scientists only had to do it in 1 day with 5 hours of flight time to capture and scan LiDAR simultaneously. In particular, this UAV system only needs 1 operator, all data will be automatically sent to the processing system in real time [12]. Another example is the drone project “Than Nong” (Demeter VS 20), which is recently piloted for agricultural application purposes such as spraying pesticides, spreading fertilizers or sowing seeds.... The project has been awarded the first prize at VietSolutions 2020 event and has been put into practical implementation with many benefits [13].

1.3.1.3 Waterborne transportation sector

In the field of waterborne vehicles, in Vietnam, the research and manufacture of remote-controlled navigating equipment are still limited, with small size and scale. At the end of 2022, The F.I.R.S.T research teams from the National Economics University and Hanoi University of Technology launched an unmanned vessel to help measure depth, take water samples and collect garbage in rivers and lakes with estimated cost about $5,000. The vessel is made of composite, weighs 8 kg, has dimensions of 1.15 x 0.7 x 0.5 m, corresponding to length, width and height. The vehicle design has a two-hull form, in order to increase stability when facing unfavorable conditions such as waves and wind. The front part of the vehicle equipped with a camera, three sensors to detect obstacles around. To connect to the control application on the computer, the vehicle is equipped with GPS and wifi communication module. Through the control application, the user can choose the mode to navigate automatically in a straight line or by zig zac. The three main functions of the vehicle are depth measurement, water sampling and garbage collection. As tested, the vehicle has total operating time about 3 hours within the range 1 km and can measure a maximum depth of 50 m, with an error of 20 cm. The research team evaluates the product to be useful to agencies, environmental companies, and civil private purposes [14].

The Ho Chi Minh City University of Technology also researched a number of topics such as design of a dynamic positioning for unmanned surface vehicles using GPS/INS (VIAM-NAVI-M) and developed some unmanned equipment models. Model VIAM-USV1000 uses Lithium
battery and can move to the waypoints designated by the operator and be remotely monitored on the computer. The USV constructed based on that model can be operated continuously for 5 hours with a maximum speed of 10km/h. The outstanding feature of the USV is the ability to perform automatic monitoring at river areas, transmitting the collected data for processing and displaying on website in the real time mode. The USV with the size of 1.2 meters x 0.8 meters, weighs 70kg, can develop a speed up to 4 knots. The USV can be applied in the field of environmental research and monitoring, transporting small diving equipment, water patrolling, rescue and security activities. Besides USV, some other research projects are also being conducted by the same team, namely: Remotely operated vehicle (ROV) model VIAM-ROV500 and model VIAM-ROV900 with sizes of 0.9 meters x 0.4 meters x 0.4 meters, weight 70kg, depth of movement 100 meters under surface, speed range from 0 to 2 knots, designed for demining, security patrol, rescue, oil and gas exploration, underwater archeology, shipwreck searching; An autonomous underwater vehicle (AUV) with the sizes of 2 meters (length), 0.25 meters (diameter), weight 80kg, depth of movement 100 meters under surface, moving speed 5 knots, designed for surveying geological surfaces, gathering information on mineral deposits, clearing mines, and other military purposes [15].

The Vietnam Institute of Geodesy and Cartography has designed and built an unmanned remotely controlled water surface vehicle to conduct surveillance of the seabed and collect the natural resource and environmental data. The project was carried out within 30 months from January 2018 to June 2020. The vehicle can measure data in water depth from 1 to 1,000 meters and automatically send data back via radio signals and GPRS waves. The vehicle is constructed of composite plastic and equipped with data recording software, online camera, GPS, antenna and an echo sounding device. With the current design, the vehicle has a load capacity of 60kg and is fitted with two batteries, so it can be operated continuously for 8-10 hours [16].

2.3.2 Research of autonomous technologies in shipping

Unlike UAV, Self-driving car, autonomous shipping is something different as it touches the really big vehicles, complicated systems and still goes behind. In fact, in the field of maritime and shipping, there are a few of research topics on automation technology. As examples, they can be named:

- Project Code DT 194025 “Research, Design, Production of Autopilot System applying Adaptive Control Methods”, implemented by Vietnam Maritime University (VIMARU) and approved by Ministry of Transport in 2019. The project objective is to be proactive in researching, designing and manufacturing an autopilot system that applies adaptive control methods for ships with the desire to master technology, reduce costs, develop advanced technology serving the shipbuilding industry, which is an important and key element for the sustainable development of Vietnam's marine economy. The project has researched, designed, and successfully manufactured a ship's autopilot system that applies adaptive control methods for cargo ships with a DWT of 22,000 or less, improving the quality of ship navigation control, optimizing energy use. The application of adaptive control method to the autopilot system based on the standard model designed according to the optimal algorithm makes the control system adapt to the change of objects and environmental disturbances and achieve the energy optimization of the rudder.
addition, the use of the Kalman observer unit in the control system contributes to reducing the cost and complexity of measuring object state variables and is also a tool to minimize the influence of environmental disturbances on the quality of control. The autopilot system is designed and manufactured by the author's group according to the digital steering system technology widely applied on current ships, in which the controller is programmed and installed in the CPU including the PLC device and computer, linked with HMI display, peripheral elements and alarm panel, fully respond to current driving modes. This technology makes the interaction between the operator and the system more convenient and easier, and the application of an adaptive algorithm to the controller is a new point in improving control quality compared to other systems using the current classic PID algorithm. The successful manufacture of the digital steering system allows to be proactive in software and hardware manufacturing technology, towards mastering the technology of manufacturing autopilot systems and reducing product costs for the domestic shipbuilding industry [17].

- Project code AT22303 “Research, design and manufacture of smart traffic control system for ships on the basis of application of artificial intelligence in processing big data from RADAR/AIS to enhance maritime safety”, implemented by Vietnam Maritime University (VIMARU) and approved by Ministry of Transport in 2022. The objective of the project is research and application of artificial intelligence technology - an achievement of the 4th industrial revolution in the maritime transportation field to enhance maritime traffic safety. The smart traffic control system for ships is designed and manufactured based on the application of artificial intelligence technology in processing big data from the ship’s RADAR/AIS devices in real time to bring forecasting, early warning of risk of collisions and support making optimal decisions for crew members in changing direction, speed of ship or both to avoid the situation. The ship’s smart traffic control system was built and tested to fully meet the technical standards, such as: the parameters $C_{p_{\text{amin}}}$ and $T_{C_{\text{Amin}}}$ are in accordance with COLREG 72, high accuracy and reliability with learning error up to 0.05%, number of learning samples is over 4,000, and processing latency 900ms. The technical standards of the system have been independently verified by Center for Standards - Measurement – Quality 1 (QUATEST 1) and the Department of Naval Engineering [18].

- The project “Ship Autopilot System Design and Testing on Santana Ship Model Based on Neural-Fuzzy Method” implemented by the University of Transport of Ho Chi Minh City. The Project result is design of Ship autopilot system based on the output feedback neural-fuzzy (ANFIS) controller in 3-axis coordinate system which controls a heading of the ship under the effect of the waves, wind and water currents. The inputs of system include the feedback heading of the ship, angle of the waves, wind and water currents, and then the outputs area rudder angle and the heading. In order to increase the adaptability of the system under the effect of the environment, ANFIS controller is designed using of neural-fuzzy with the Takagi – Sugeno method that approximate the input signals and linearized the output signal. The simulation results via Matlab software and the experimental results on Santana ship model showed the effectiveness and advantages of the proposed method [19].
It should be noted that, in general, automation technology is highly interested and prioritized for development in Vietnam. There are many researches and wide application of automatic control technology in different fields of economy. However, these research directions and applications are still relatively limited in the transport sector, especially in the maritime field. As exampled above, there have been some SUV studies, but the scale is still small, just at the experimental stage and applied mainly to hydrological, environment monitoring etc., but not for transportation purposes. In the maritime industry, recently there have been research projects on automation of ship control systems, but these studies are also focusing on specific ship component systems onboard such as auto pilot system. There is no overall integrated research and development project on autonomous shipping technologies in the proper meaning yet. There are a number of reasons that may be listed. Firstly, shipping technology is a new field of research with very limited partners, high risks - especially the risk of pioneering research with long-term investment and difficulty in accessing financial and public resources. Secondly, the enterprises and institutes have recently set the objectives of prioritizing the recovery and development of businesses at first and foremost level after the covid 19 pandemic time, so new technology investment may be in wait list. Thirdly, the access to information and awareness about the benefits, current development status and future trend, as well as the opportunities for cooperation in autonomous shipping technologies is still limited and has not been appropriately interested by the stakeholders.

2.4 Opportunities and challenges for autonomous shipping technologies

2.4.1 Opportunities

Vietnam has great advantages and potential to develop a fleet of ships with green, modern and sustainable technology applications such as autonomous navigation. Some of the reasons may be mentioned as follow:

a) Vietnam has a strategic geographical position with a long coastline and is close to important international shipping routes from north to south and from east to west and can become an important gateway connecting goods between ASEAN and China to America, Europe, Japan, Korea and Australia.

b) Vietnam maintains a stable political environment, strong economic grow rate in recent years and in the coming time. Vietnam has become a safe destination for foreign investors, so the volume of goods through Vietnam’s seaport system will continue to increase in the coming years, creating great opportunities for the Vietnamese fleet. Especially after the Covid-19 pandemic, Vietnam has got more important roles in shifting the global supply chain.

c) Vietnam is an active member of many international organizations, including the International Maritime Organization (IMO), the International Labor Organization (ILO). For international maritime activities, Vietnam has basically joined all conventions related to assurance of maritime safety and security, maritime labor and marine environment protection. The national legal system related to the maritime domain is relatively comprehensive, which is an important basis for promoting the development of maritime activities including shipping with advanced technologies. The country’s economy has the highly opened level of integration with the global economy, by participating in many
bilateral and free trade agreements and treaties. Vietnam has signed 28 bilateral maritime agreements with other countries. This creates a lot of advantages for the Vietnamese fleet when operating in the waters of the signatory country. Vietnam is a member of ASEAN and is aiming to build a common ASEAN economic community (aiming to create a single common market and unified production base, including the free movement of goods, services, investment, capital, and skilled labor, thereby improving competitiveness, and promoting common prosperity for the whole region, creating attractiveness for investment and business from outside). Vietnam has been a member of the World Trade Organization (WTO) since 2007. In recent years, Vietnam has joined many free trade agreements, especially new generation free trade agreements such as the free trade agreement. Comprehensive and Progressive Agreement for Trans-Pacific Partnership (CPTPP) (effective from January 14, 2019), Free Trade Agreement between Vietnam and the European Union (EVFTA) (effective from January 1, 2019). The Regional Comprehensive Economic Partnership (RCEP) Agreement between ASEAN (including Vietnam) and 05 partners, namely China, Korea, Japan, Australia and New Zealand came into force from January 1, 2022.

d) The government always gives priority to the development of modern and digital technologies for all sectors of the economy, including shipping. Vietnam actively processes the revisions and updates of the current maritime regulations to create clear legal corridor for shipping activities to be developed. Moreover, the Government’s focus in maritime transport policy is increasing through a series of master plans such as: Master plan on development of Vietnam's shipbuilding industry until 2020, orientation to 2030 (by Decision No. 2290/QD-TTg dated November 27, 2013 of the Prime Minister), Master plan on development of Vietnam's shipping until 2020, with orientation to 2030 (Decision No. 1601/QD-TTg dated 15/10/2009 of the Prime Minister), Master plan on development of Vietnam’s shipping fleet to 2030 (Decision No. 1254/QĐ-BGTVT dated 28/09/2022 of the Minister of Transport), and a series of positive changes in simplification of administrative procedures such as electronic customs, online tax declaration procedures etc. have created favorable conditions for shipping enterprises and contribute to the development of the maritime transport industry with the priority of applying the advanced technologies.

e) Vietnam’s demand for goods transported by sea is forecasted to have a total volume of about 906.8 million tons by 2030 (according to the Master plan on development of Vietnam's seaport system in the period of 2021-2030, vision to 2050). With this forecast, the market for sea transport is very large, opening an opportunity for greater demand of Vietnam’s shipping fleet in the coming years.

f) Vietnam has the maritime and technological education system, which provides sufficient skilled human resources for the management and operation needs of shipping industry, including R&D of maritime innovative autonomous navigation technology. Vietnam also has a pool of experts in digital technology and artificial intelligence, including those working for transnational corporations such as Google, Facebook, Microsoft, Amazon, and different leading universities and research institutes around the world. In addition, Vietnam also has a young and abundant information technology human resource with about 430,000 software engineers, most of them (55%) in the age group of 20-29.

h) The operation and management of the sea going fleet of Vietnam is being upgraded gradually through application of information technology, software, data science achievement in line with the trend of forming the logistics industry in the context of the science and technology revolution version 4.0.
j) Vietnam has many pioneering IT enterprises, which are currently investing in R&D projects in automation, robotics, smart transport and production. The collaboration between software and shipping industries is the propulsion for promoting the autonomous navigation R&D projects.

k) The traffic conditions and transport culture in Vietnam are very diverse and complicated, which can be an ideal environment for developing and testing control algorithms for better lability and wider applicability.

2.4.2 Challenges in application of autonomous shipping technologies

Besides the advantages and opportunities, the consideration and application of advanced autonomous navigation technologies in Vietnam are facing with a number of general and specific challenges. The non exhausted list of the challenges can be noted as follow:

a) The fleet: Statistics show that at this moment Vietnam’s sea going fleet contains mainly of small vessels with not-good-enough technical condition, non-state-of-the art equipment, that is causing low operation efficiency, low competitiveness and not environmentally friendly. This is a challenge to convert or apply innovative technologies (such as autonomous shipping) in building a fleet to meet the Vietnam’s commitment to achieve net-zero emissions by 2050 as stated at the COP 26.

b) The Investors: The role and scale of state-owned shipping companies have all been narrowed down after the crisis in 2008-2010 years. Many companies have been equitized or dissolved. Most of Vietnam's shipping companies are private with limited size and financial potential. There are a number of companies which own or manage only 1 or 2 ships with deadweight from 1,000 to 5,000 tons. These companies have very limited experience, human and financial resources in shipbuilding and operation, so they do not focus on investing in new and automated technologies.

c) Business culture: Investment-as-movement, short-term thinking and seasonality still dominate the trend of investment in ship building and operation by small and medium enterprises. Many Vietnamese ship owners buy ships when the market is good and sell them when the market shows some downward indicators, that makes the development of the fleet unsustainable. This can be a barrier for bringing in advanced technologies, which normally at the first stage accompanies high risk, high capital and long-term investment.

d) Financial resources: A decade back in Vietnam, the capital sources for shipping development came mainly from bank loans or foreign official development aids (ODA) and guaranteed by government. The 2008-2010 crisis with the shipping industry has greatly affected the investment capital for shipbuilding and modernization of the fleet. Almost all sources of credit or guarantee for building and buying ships with more modern technology have been cut off. Shipping and shipbuilding became high risk economy sectors, the procedure for them to access the bank credit afterward became stricter, and the bank loans provided with higher interest rates. All of that creates a financial burden for business and for investment in high-tech issues. Moreover, after the covid 19 pandemic, companies focused their resources on restoring and developing their existing fleets, so these years, they do not pay adequate attention to autonomous shipping technologies. In order to resume the mode, it is necessary to receive support
from the government in terms of specific preferential policies, from international support in technology, resources and experience, as well as to enhance awareness of the innovative navigation technology among the maritime industry communities.

e) Legal framework: The pace of new technology development today often moves faster than the regulatory framework around it. Maritime laws and regulations fail to fill the gaps and thus become barriers to the introduction of advanced technology. In terms of policy, the government is very supportive of maritime innovation projects. But in reality, the Vietnamese legal system has not yet developed any specific regulation for autonomous shipping, including technical regulations for research, testing, manufacturing, construction and operation, safety, liability in the event of an accident.

f) Investment risk: From an economic point of view, the initial investment costs for autonomous shipping technologies can be expensive. Therefore, the basic R&D needs proper attention and investment. However, this is a new area of investment, and many risks cannot be fully identified, including skepticism about practical and successful application thereof. That will be a barrier to being able to convince investment capital for the project as well as for mitigating the risks encountered. Vietnam maritime sector has not been proactive and agile in seizing opportunities to properly invest in this new technology.

g) Technical standards and compatibility: Vietnam have not yet drafted technical rules or standards for autonomous ship, system and equipment thereof. As a new and experimental field, many stakeholders (including hardware, software researchers and makers) are working to develop technology according to their own potential and knowledge. Lack of common standardization may lead to the introduction of different technical specifications and algorithms that are not compatible. The IMO project on goal-based standard for MASS, which is currently under drafting process, may support to unify the trends.

h) Public awareness and perception: Awareness of autonomous navigation technologies and their benefits are still very limited among Vietnam’s maritime community to get the major consensus. Autonomous shipping technology is developing, but of course not yet fully mature. The concept dominates that in many situations humans are better at identifying and responding to hazards than robots do. Just for example, when interacting with people on the other non-autonomous vessels, the autonomous ship needs to learn to make sense of the actions or gestion of them in order to react appropriately. When facing an obvious accident, how the autonomous ship could prioritize the safety of the crew. Another social perception issue is that Vietnam has a large workforce and job creation for them is one of the Government's priorities. The application of advanced technology such as autonomous navigation also requires solving the problem of redundant labor in the maritime sector.

i) Hardware manufacturing capability limitation: At a high degree of automation when applying autonomous shipping technologies, the hardware system must further solve the problems of accuracy and speed in processing large amounts of data from sensors. Vietnam still has a limited capability in manufacturing such computer system and sensors. Many systems, equipment and components must be imported.

j) Operation conditions and environment: unfavorable operation environment at sea and bad weather of course are always the challenges for R&D, design and manufacturing
autonomous ship, taking into account the correctness and reliability of the systems and sensors. Autonomous shipping requires a highly disciplined traffic environment. However, the traffic conditions, the culture of waterway transport and traffic rule compliance in Vietnam have not yet reached the ideal level, and even give a huge barrier for them. Even the ship with level 2 of automation and remote control can still be quite difficult to be operated.

k) Risk consideration regarding safety, security, cyber-attacks: No matter how modern, machines still have errors. In many ways, hardware devices such as sensors are used more effectively than human senses. However, sensors have their faults, which can be misaligned or damaged by the impact of the environment, especially the marine environment. From a software perspective, artificial Intelligence versus human intelligence and emotions, vessel crew rely on subtle cues and non-verbal communication such as eye contact or facial expression reading and body language for instant judgment and behavior prediction, so the big challenge is whether software engineering with artificial intelligence can do that to ensure correct and safe decision making. It is necessary to carefully study the safety impacts of autonomous shipping technologies and requires a lot of data and time. With autonomous shipping technology at levels 1 and 2, when there is still human intervention to make decisions, software technology is an advantage. However, at a high degree of automation and applying AI, from a technical perspective, it is very difficult to "teach" the vessel if the data set is incomplete. In theory, a "complete" dataset of all traffic situations to teach a system is infinite in size. Even on the same route, every day the vessel will encounter different weather conditions, objects and traffic situations. In the long run, getting a representative training dataset and a deep learning system good enough to leverage them will always be a major challenge. Intelligent systems will not stop learning as they receive more and more information. There can also be a risk that the computer could actually learn wrong so to make sure that the new learning behavior is as safe as the past or better is a challenge. In addition, the difference in combining data from different types of devices and sensors on ships may also lead to errors in the identification of objects participating in waterway traffic, increasing the risk of unsafety. Security and Cyber security are also well-known risks, that need to be appropriately dealt with.

l) Training and cooperation: Autonomous shipping technology requires investment in training with higher operational skill requirements. The fact is that the team of domestic experts is still thin and lacks close cooperation. Vietnam has young and competent pool of software and data engineers, but they are not trained in marine technology. On the other side, maritime experts have limited knowledge and skill in data and software engineering. There is a lack of national training programs and expertise forum to strengthen links and exchanges between the sector research groups on autonomous navigation topics, as well as between the domestic and foreign experts. In developing autonomous technologies, the hardware stakeholders must always go together with the software side.
3 Recommendations

Autonomous shipping technologies have undeniable advantages and will become the predominant trend in shipping in the near future. The research, development, and application of such are in line with the Marine Strategy of Vietnam toward 2030, with the vision of 2045, to build and maintain a modern and sustainable sea going fleet with high-tech, green, and efficient technologies. Besides, the challenges of autonomous shipping technologies, as analyzed in previous chapter of this report, are still significant and require proportional and systematic solutions to overcome. As in case of Vietnam, the movement of this tendency is currently just at the starting point and posing very limited progress. In order to speed up the process, a road map is recommended to be created and implemented, with Vietnam Maritime Administration (Vinamarine) as a focal coordinating point, taking into account the following:

For Vietnam:

- Communication and public perception engagement: It is necessary to create and implement a communication campaign or program on autonomous shipping technologies (via public media topics, forums, exhibitions, workshops, press releases...), the progress and the advantages thereof and how they could contribute to the fulfilment of the Marine Strategy of Vietnam toward 2030, with the vision of 2045. The activities will draw the attention of all stakeholders, including governmental bodies, economic entities, research institutes in the maritime field to that new trend of development, hence support to generate the public resources and consensus perception based on the awareness of the benefits and risks associated with autonomous shipping.

- Policy and regulatory frameworks: High level Policy and Strategy of the Government are supportive to the application of new and modern technologies. However, the maritime regulations need to be revised in a more specific way so that the autonomous navigation technologies can be properly encouraged and developed. The Vietnam Maritime Code 2015 which is being revised for planned amendment in 2025, should be updated with specific clauses regarding autonomous shipping. The under law guiding regulations such as decrees, circulars, national technical rules for construction and classification of ship then should be revised accordingly to create a favorable and incentive environment in the process of research, adoption, investment and implementation, which cover clear standards for infrastructure, operation areas and routes, communication, safety, security, autonomous vessel design, operation and maintenance, data privacy, legal and liability etc. The regulations should be continuously updated based on the gradual maturity of the R&D and experimental results, as well as the updates of international instruments. A roadmap for the application of different levels of autonomous navigation may need be created inline with the resource and infrastructure conditions available.

- Research and development: There should be a prioritized program with appropriate funding sources (governmental, public, private or internationally supporting budgets) for specific research and development projects relating to autonomous shipping technologies, that could be realized in the form of service order or contract to the research institutes or capable economic entities. This would be better to include partnerships between maritime industry and economy (such as VIMC, SBIC, Thaco Group, Vin Group...) and academia (Vietnam Maritime University, University
Transport of HCMC, University of Science and Technology...) to develop and test new technologies in a real-world environment and ones may be the future beneficiary operators. The collaborations between the domestic entities with potential experience and knowledge in the fields of automation, digital technology, such as Viettel, Phenikaa, VNPT, FPT are encouraged to deploy new algorithms and sensors, data science, machine learning and AI application.

- Infrastructure: Plans and resources allocation should be considered for investment in infrastructure needed to support and ensure that autonomous navigation technologies can be operated efficiently, reliably and securely. The investment in infrastructure may cover: construction and maintenance base for autonomous ship and equipment, shore based control center, autonomous ports and routes with supporting safety of navigation facilities, emergency response and rescue, high-speed communication networks, data centers etc.

- Human resource preparation and capacity building: Current training programs in the maritime institutions and colleges need to be updated accordingly with formal training on autonomous navigation technologies in preparation and development of skilled workforce for researching, constructing, operating and maintaining autonomous ships and infrastructure. Vietnam has a young and potential pool of IT and data engineers, that could timely contribute to the process if additional training can be provided. Collaboration and knowledge sharing programs from the leading countries in this field is another option.

- Collaboration and knowledge-sharing: Collaboration and knowledge-sharing is essential for advancing new technologies such as autonomous navigation. The Government, MoT and Vinamarine should organize a floor for connecting and experience sharing between the domestic stakeholders on the topic of autonomous navigation to facilitate the collaboration. This can be a network forum, fan page, portal and any other appropriate form and moderated by Vinamarine. The Government, MoT and Vinamarine should also support in allocating and connecting the international partners with the domestic stakeholders for the same objectives. The international supports and cooperations in autonomous shipping technologies, including research and development, funding, co-funding, training, experience sharing, technology transfer based on the win-win principle, benefit harmonizing, risk sharing should be prioritized.

- Timeline (the phases): The implementation of autonomous shipping technologies in Vietnam is suggested to be split into 3 phases.
  - The 1st phase starting from 2023 to 2025 is the preparation phase. This phase is for carrying out the necessary preparation steps such as developing plans, objectives, projects, awareness and communication, preparing the temporary legal framework, finding resources, connecting partners, setting up environment and infrastructure etc. for autonomous shipping technologies research and development.
  - Phase 2 runs from 2026 to 2030. This phase is for implementing research and development projects on autonomous shipping technologies, as well as for continuing to seek and expand opportunities for collaboration, technology transferring, revising legal and technical regulations based on research results,
planning and infrastructure investment for appropriate levels automation selected, including the preparation of port areas and routes for future operation of autonomous ships.

- Phase 3 starts after 2030 onward. This phase starts to put into commercial operation any pilot autonomous navigation project at different levels of automation and thereby to adjust, plan and prepare for the replication of this technology in the country maritime sector.

**For ESCAP and international organisations:** the international partners, donors, stakeholders from leading countries like the Russian Federation, Japan, China, and the Republic of Korea are warmly welcome and suggested to support Vietnam in promoting the autonomous shipping technologies, such as enhancement of collaboration in communication and awareness training, capacity building, experience sharing, research and development activities, technology and equipment transferring-supplying, allocation and/or provision of funding resources. The best way to implement could be a proposal for collaboration in specific pilot project with the participation of Vietnamese stakeholders via focal point Vinamarine.
Appendix – List of references

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2. MSC 107-5-2 - Report on implementation of autonomous ships flying the State Flag of the Russian Federation
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8. Resolution No. 36-NQ/TW adopted October 22nd, 2018 by the Central Committee of the Communist Party of Vietnam on the Strategy for sustainable development of Vietnam’s marine economy to 2030, with a vision to 2045
17. Project Code DT194025 “Research , Design, Production of Autopilot System applying Adaptive Control Methods”, implemented by Vietnam Maritime University (VIMARU) and approved by Ministry of Transport in 2019
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