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

Study report on relevant developments, regulations, economic, social and environmental benefits and practical application of autonomous shipping technologies

May 2023
The Analytical report on the relevant developments, regulation, economic, social and environmental benefits and practical application of innovative autonomous shipping technologies was developed in the framework of the project “Improving the safety of navigation and the sustainability of shipping through the introduction of innovative autonomous shipping technologies in the Asia-Pacific region” implemented by ESCAP.
# CONTENTS

I. INTRODUCTION ........................................................................................................................................... 4
II. AUTONOMOUS SHIPPING OVERVIEW ..................................................................................................... 8
III. DEVELOPMENT OF AUTONOMOUS NAVIGATION ............................................................................... 12
IV. DEVELOPMENT OF REGULATIONS ........................................................................................................ 16
   A. International Maritime Organization ................................................................................................. 16
   B. Examples of National Regulations .................................................................................................... 18
V. AUTONOMOUS NAVIGATION IMPACT ANALYSIS IN THE ................................................................. 20
   ASIA-PACIFIC REGION .............................................................................................................................. 20
   A. Regional impact ................................................................................................................................... 20
   B. Social Impact ....................................................................................................................................... 21
   C. Economic Impact ................................................................................................................................. 22
   D. Environmental Impact .......................................................................................................................... 22
VI. TECHNOLOGY DEVELOPMENT ............................................................................................................... 24
   A. China .................................................................................................................................................. 24
   B. Japan .................................................................................................................................................. 27
   C. Republic of Korea ............................................................................................................................... 30
   D. The Russian Federation ..................................................................................................................... 32
   E. Singapore ........................................................................................................................................... 37
   F. The United States of America ........................................................................................................... 38
V. SELECTED ASIA-PACIFIC COUNTRIES REQUIRING THE NEW TECHNOLOGY 40
   A. India .................................................................................................................................................... 40
   B. Indonesia ........................................................................................................................................... 41
   C. Malaysia ............................................................................................................................................ 42
   D. The Philippines .................................................................................................................................. 43
   E. Thailand ............................................................................................................................................. 44
   F. Viet Nam ............................................................................................................................................ 45
VI. STRENGTHENING THE REGION’S CAPABILITIES .............................................................................. 47
VII. CONCLUSIONS ....................................................................................................................................... 49
List of abbreviations ....................................................................................................................................... 51
I. INTRODUCTION

As the engine of global economic growth and the core of the global logistics chain, Asia-Pacific concentrates 62% of international maritime trade. These intensive maritime activities create positive effects such as trade promotion, job opportunities, and development of the shipbuilding industry and many others. At the same time, the current situation in the global shipping sector also leads to economic inefficiencies, marine pollution and safety accidents, especially in Asia which is recording the highest number of accidents worldwide. This has been highlighted in the Commission Study for its 76th session and during the sixth session of the Committee on Transport in November 2020.

New technologies provide significant opportunities for enhancing safety, efficiency and overall sustainability of shipping operations and their deployment has been boosted by the COVID-19 pandemic as a way to increase resilience and provide a practical way forward for dealing with the booming e-commerce and the accompanying demand for swift and reliable shipping services.

Innovative autonomous shipping technologies are currently explored by developed countries around the world, including Asia-Pacific, as they enable better control of the ship’s position and speed, efficient communication with external systems, integrated control of on-board navigation systems, ship management through remote support and control and risk management using advanced ICT and AI technologies, etc. This allows operators to reduce ship operating costs, ensure efficient cargo management, reduce pollutant emissions, prevent maritime accidents and minimize disruptions during the pandemics and similar crises.

Autonomous navigation is a fast-growing area of maritime technology. The world is rapidly developing this high-tech trend, both from technical perspectives and regulatory standpoints. The International Maritime Organization has been actively considering this new trend and encouraging its implementation and further developments.

Efforts are needed to help developing countries in the region to understand wider benefits of innovative autonomous shipping technologies and to solve a wide set of technological and legal aspects linked to their introduction, such as liability areas for marine accidents, insurance issues, cyber hacking, and crew employment. There is also a need to understand and to prepare for the implications of this development for Asia and the Pacific which supplies the bulk of labour force to global shipping. Furthermore, the region suffers from the lack of full understanding of the wide economic, but also social and environmental benefits of innovative autonomous shipping technologies which result in their insufficient prioritization in the strategic transport development plans and mechanisms for regional cooperation. Likewise, insufficient capacity to address legal and technical issues hinders national and regional initiatives in this area and endangers the compliance with the future IMO regulations.

The report aims to collect available data and knowledge on the current status of the use of autonomous shipping technologies and legal regulation at regional and global levels, analyze the social, economic, and environmental impacts of the introduction of autonomous shipping in Asia and the Pacific, and identify ways to promote gender equality and the empowerment of women in the maritime sector.

The project is expected to result in strengthened countries’ capabilities to implement innovative autonomous shipping technologies through exchange of experiences and best practices and enhanced regional cooperation.
The project aims to identify how autonomous navigation can assist to achieve sustainable transport connectivity, logistics, and mobility in the Asia-Pacific region, ways for its implementation in the region, and a transfer of knowledge and experience already gained in the world to the Asia-Pacific region.

The project aims to address these challenges by developing regional knowledge products and supporting national and regional implementation initiatives to facilitate the introduction of innovative autonomous shipping technologies. This will be achieved through raising awareness of the benefits of these technologies, highlighting their efficiency, safety, environmental and other benefits, sharing best practices in addressing the relevant technical and legal aspects in their implementation, as well as identifying opportunities for regional cooperation and possible joint implementation projects.

At the national level, the project will work with selected four countries to enhance their capacity in this area and, where appropriate, develop national implementations plans. In terms of the geographic scope, the project will focus on selected Southeast Asian and South Asian countries, including India, Indonesia, Malaysia, Thailand and Viet Nam, which have particularly strong incentives to introduce these technologies due to the current situation with maritime traffic congestion, maritime accidents and strains caused by the expected growth of maritime trade. These countries have also made some advances in their technical and legal basis for autonomous shipping.

At the regional level, the project will mobilize the existing mechanisms for a regional dialogue on sustainable maritime connectivity to help countries consider a regional approach to implementing autonomous shipping technologies, which, while complying with the future IMO standards, reflects the situation of the region, as a provider of the marine workforce, home to the bulk of shipping activities and a region composed of developing countries facing implementation challenges in complying with global regulations. The project will also seek to identify joint pilot projects bringing together relevant ESCAP member States.

The results of this project should bring cross-cutting benefits to the regional transport connectivity and sustainable transport development, more broadly. Automated shipping technologies offer a range of economic, social and environmental benefits. For example, the selection of the optimal route and system management, leads to more efficient maritime and port services, enhancing countries’ maritime connectivity. It also helps reduce greenhouse gas emissions and significantly contributes to the enhancement of maritime safety.

To this end, the project will identify challenges and opportunities created by autonomous shipping technologies, highlighting the obstacles of legal and technical nature, but also wider benefits of these technologies. Based on this analytical work, national workshops will be held in selected countries to develop national implementation plans. At the regional level, the project will organize expert meetings and consultations to develop a regional approach to the adoption of innovative autonomous transport technologies in Asia and the Pacific and seek to identify opportunities for joint pilot projects among ESCAP member States.

The implementation of this project will contribute to achieving several goals and indicators of the recently adopted Regional Action Programme on Sustainable Transport Development (2022-2026):
**Area 2: Maritime and interregional transport connectivity.** Indicator of achievement: Increased capacity of relevant stakeholders to implement global regulations and instruments to enhance the environmental sustainability and resilience of maritime transport.

**Area 3 Digitalization of transport.** Indicator of achievement: Increased capacity of members and associate members to implement smart port reforms and support the digitalization of port and maritime transport.

**Area 4: Low carbon mobility and logistics.** Indicator of achievement: Increased capacity of relevant stakeholders to implement global regulations and instruments to enhance the environmental sustainability and resilience of maritime transport.

The transport sector, especially freight sector, has long been a male-dominated area where women have limited access to employment and opportunities created by new technologies. The transformation of the shipping sector through digitalization and automation will impact the ongoing process of mainstreaming gender issues into the maritime development policies. The development of technical and legal solutions for autonomous shipping is reshaping maritime profession (for example, by transforming many tasks into office-based rather than ship-based tasks), potentially creating more opportunities for women. Accordingly, the project will address the gender implications of introducing autonomous shipping at the national and regional levels and discuss the necessary actions for greater women’s empowerment.

Sustainable transport development has been set as an important policy objective in the Regional Action Programme for Sustainable Transport Development in Asia and the Pacific (2022–2026). “Maritime and interregional transport connectivity”; “Digitalization of transport”; and “Low carbon mobility and logistics” have been selected as three of seven thematic areas of work.

ESCAP's intervention will strengthen member States' capacity to support the digitalization, low emission and efficient shipping services in line with the new Regional Action Programme, ultimately contributing to the achievement of several Sustainable Development Goals.

The autonomous shipping-related technologies and legal regulations analysed in this project can directly or indirectly contribute to the achievement of new RAP goals (efficient and resilient transport and logistics networks) and specific indicators such as safe navigation, green shipping, digital transformation, and greenhouse gas reduction. The results of this work will be mainstreamed into the regional dialogue on sustainable maritime connectivity as mandated by Commission Resolution 76/1 and as envisaged in the RAP thematic area on Inter-regional and Maritime Connectivity.

The planned outcome of the project will be achieved through the enhancement of the stakeholders’ understanding the benefits of innovative autonomous shipping technologies with due consideration of the specific needs and challenges of the national and regional level, including technological and legal aspects, and their capacities to develop national plans for effective implementation of the technologies as well as engaging in regional collaboration initiatives. To this end, the project will employ a mix of interventions comprising knowledge product development, exchanges of knowledge, experience and best practices, offering of advisory services to selected countries and supporting regional dialogues. The activities are summarized as follows:

1. Preparation of the knowledge products on the wider benefits of innovative autonomous shipping technologies with due consideration of the specific needs and challenges of the region and assessment of technological and legal aspects in the selected four countries. The analytical report will include an overview of the development and practical application of innovative autonomous shipping technologies in the region and the world, its impact on safety of navigation, the environmental sustainability of the logistics of sea and river
transport and transforming of working conditions for workers in the waterborne transport
industries.

2. Supporting selected target countries in developing national plans for the implementation
of autonomous shipping technologies in line with the specific needs of each country. The
national plans will include proposals for gender equality and women's empowerment in the
maritime sector.

3. Organization of meetings and conference to review the analytical report, develop policy
recommendations for the introduction of autonomous navigation in the region, discuss
technical and legal solutions, and explore a cooperative system among member countries
for the practical implementation of autonomous shipping technologies.

Supporting a regional dialogue, including during the Regional High-level Dialogue on Sustainable
Transport Connectivity, to discuss policy recommendations on advancing innovative autonomous
shipping technologies in the region and identify pilot projects for regional cooperation. The report
will be helpful for policymakers, port authorities, shipping lines, shipowners, shipyards, and equip-
ment manufacturers.
II. AUTONOMOUS SHIPPING OVERVIEW

Maritime transport is one of the fundamental industries of the global economy, ensuring its very existence. Almost the entire volume—over 90%—of world trade is provided by maritime transport. Transformations in the maritime industry have a significant impact on the entire global economy and even on the global political landscape: it is enough to recall historical examples of previous technological transformations.

In the 15th and 16th centuries, the introduction of multi-masted sailing fleets and navigation instruments gave rise to the Age of Great Geographic Discoveries, which became, in fact, the era of economic and political dominance of the European region throughout the world. The advanced implementation of these technologies turned England, Spain, and Portugal into superpowers, whose languages are now spoken by the majority of the world’s population.

The appearance of ships with mechanical engines in the 19th and 20th centuries allowed for a significant increase in ship size while reducing the required crew on board, as well as expanding shipping routes. This radically reduced the cost of maritime transportation and became the basis for the modern global economy. Previously, it was unthinkable to consider purchasing any goods, not just luxury items, that could be more profitable on another continent than producing them nearby. And among the first countries to introduce these technologies were the future leaders of the global economy: the United States of America, Japan, and Germany.

Today, the volume of transportation by sea has reached record levels, and the potential consequences of incidents at sea have reached equally record levels. As with other modes of transportation, the human factor is the main cause of such incidents; around 80% of incidents at sea occur due to subjective human errors.

![Figure 1: Safety & Shipping 1912-2012 From Titanic to Costa Concordia, Allianz Global Corporate & Speciality](https://www.agcs.allianz.com/news-and-insights/reports/claims-in-focus.html)

The annual losses of maritime carriers from accidents and other incidents related to human errors exceed billions of dollars, but even this figure is not as significant as the hundreds of lives of sailors...
and fishermen that are claimed by sea disasters every year. Thanks to the stringent and comprehensive measures taken by the International Maritime Organization (IMO) and national maritime administrations, the number of human casualties at sea has been reduced by an order of magnitude in recent decades, but these professions still remain some of the most dangerous for life.

The risk to life and harsh working conditions, especially exacerbated during the coronavirus pandemic, have led to another challenge that the maritime industry has faced in the 21st century: the growing shortage of qualified seafarers, primarily the officers, on whom the safety of navigation depends. Today, this shortage is estimated at over 5%, and by the year of 2025, it will reach up to 20% of the required number of maritime officers. In these conditions, the implementation of autonomous navigation becomes almost the only long-term opportunity for shipowners and the industry as a whole to ensure the safety of navigation.

Autonomous navigation is the ability of a vessel to operate and navigate on its own, without the need for human intervention. It is done by the means of advanced technologies such as artificial intelligence, machine learning, and robotics, which allow the vessel to perceive and interpret its surroundings, make decisions, and take actions accordingly.

Autonomous navigation can be used for a variety of purposes, such as cargo and passenger transportation, surveillance, and search and rescue operations. The technology has the potential to improve safety and efficiency in maritime transport by reducing the risk of human error, increasing the accuracy of navigation, and optimizing routes to save time and fuel costs.

Autonomous navigation technology in maritime transport offers a wide range of potential benefits, including increased safety, efficiency, and sustainability. Here are some of the key advantages:

Improved safety: Autonomous navigation systems can significantly reduce the risk of accidents and incidents at sea. By eliminating the need for human operators, who may be subject to fatigue, distraction, or other human errors, autonomous vessels can navigate more consistently and with greater accuracy. Additionally, these systems can detect potential hazards and take proactive measures to avoid them, such as adjusting course or speed.

Increased efficiency: Autonomous navigation can optimize shipping routes and speeds to reduce fuel consumption, save time, and minimize costs. By analyzing data on weather patterns, sea conditions, traffic, and other factors, these systems can make real-time adjustments to routes and speeds to avoid delays and improve overall performance.

Cost savings: With greater efficiency and reduced human labor costs, autonomous navigation can potentially save significant amounts of money for shipping companies. By optimizing routes and minimizing fuel consumption, companies can reduce their operating expenses while increasing their competitiveness in the market.

Reduced environmental impact: Autonomous navigation systems can contribute to a more sustainable shipping industry by reducing greenhouse gas emissions and other environmental impacts. By optimizing routes and speeds to minimize fuel consumption, vessels can reduce their carbon footprint and contribute to global efforts to combat climate change.

---


Improved data collection and analysis: Autonomous navigation systems can collect and analyze vast amounts of data on weather, sea conditions, and other factors, which can be used to improve forecasting and decision-making. These data can also be shared with other stakeholders in the industry, such as port authorities and shipping companies, to improve overall performance and efficiency.

Enhanced situational awareness: Autonomous navigation systems can provide real-time information on vessel location, speed, and other factors, which can help operators make informed decisions and avoid potential hazards. This information can also be shared with other vessels to improve overall safety and coordination.

The implementation of autonomous navigation has the potential to contribute significantly to low-carbon mobility and logistics. Here are some ways in which autonomous navigation can help reduce carbon emissions by reducing fuel consumption and emissions associated with vessel operations:

Optimized routing: Autonomous navigation systems can optimize vessel routes to reduce fuel consumption and emissions. By using real-time data on weather conditions, sea state, and traffic, autonomous ships can select the most fuel-efficient route, avoiding areas with high waves or strong currents.

Energy-efficient operation: Autonomous navigation systems can optimize vessel speed and power to reduce fuel consumption and emissions. By adjusting vessel speed and power to match the optimal route, autonomous ships can minimize fuel consumption while maintaining safe and efficient operations.

Reduced idle time: Autonomous navigation systems can reduce idle time at ports by optimizing vessel schedules and reducing waiting times. This can reduce fuel consumption and emissions associated with port operations.

Predictive maintenance: Autonomous navigation systems can monitor vessel performance in real-time and predict maintenance needs before they become critical. This can help reduce downtime and improve vessel efficiency, reducing the need for vessel replacements that contribute to carbon emissions.

Improved cargo handling: Autonomous navigation systems can optimize cargo handling processes, reducing idle time and emissions associated with loading and unloading operations. By using real-time data on cargo demand and vessel capacity, autonomous ships can ensure that cargo is loaded and unloaded efficiently, reducing waiting times and improving vessel utilization.

The benefits of autonomous navigation technology for gender equality and women's empowerment are not immediately obvious, but there are several ways in which this technology could contribute to more equitable and inclusive outcomes. These indirect impacts include:

Increased access to job opportunities: Autonomous navigation systems have the potential to reduce the physical demands and safety risks associated with certain types of maritime jobs, such as deckhands and pilots. This could open up these jobs to a wider range of candidates, including women who may have been excluded from these roles due to physical or safety concerns.

Reduced gender bias: Autonomous navigation technology can help to reduce bias and discrimination in the workplace by relying on objective, data-driven decision-making rather than subjective

---

3 Gender_Equality_Survey_report_in_Maritime_AP, ESCAP, February 2023
assessments of performance or suitability. This can help to create a more level playing field for women and other underrepresented groups. Being an innovation, the technology from the very beginning may implement proper work climate and provide gender diversity. Within a new technology implementation, policies of non-discrimination nature are much easier to follow.

Greater flexibility: With autonomous navigation systems, shipping companies may be able to offer more flexible work arrangements, such as remote or part-time work, which could benefit women who may have caregiving responsibilities or other constraints that make traditional work arrangements difficult.

Improved safety: As noted earlier, autonomous navigation systems can improve safety at sea by reducing the risk of accidents and incidents. This can benefit all workers, including women who may be particularly vulnerable to harassment, assault, or other forms of violence in male-dominated work environments.

Increased representation: The development and implementation of autonomous navigation technology can be an opportunity to increase the representation of women and other underrepresented groups in maritime industries. By involving diverse perspectives and experiences in the design and implementation of these systems, it may be possible to create technology that is more inclusive and equitable.

Overall, the benefits of autonomous navigation in maritime transport are significant and have the potential to transform the industry. However, there are still challenges to be addressed, such as regulatory and safety considerations, as well as technical issues. Some of the key challenges and opportunities created by autonomous shipping technologies:

Legal framework: One of the biggest challenges facing the adoption of autonomous shipping technologies is the lack of a clear legal framework. There is currently no international regulatory framework that addresses the legal and liability issues associated with autonomous ships. This creates uncertainty for stakeholders and can delay the adoption of these technologies.

Liability: The adoption of autonomous shipping technologies raises complex liability issues. Who is responsible for accidents or damage caused by an autonomous vessel? How will insurance policies be affected? These are just some of the questions that need to be addressed.

Technical complexity: Autonomous shipping technologies are complex and require advanced sensors, software, and algorithms to operate effectively. Ensuring the reliability and safety of these systems is a significant technical challenge that requires extensive testing and validation.

Technical interoperability: Ensuring the interoperability of different autonomous shipping systems is a significant technical challenge that requires standardization of communication protocols and interfaces.

Cybersecurity and data privacy: As with any digital technology, autonomous shipping systems are vulnerable to cyberattacks. This presents a significant risk to the safety and security of autonomous ships, as well as the goods they transport. Ensuring the cybersecurity of autonomous ships will require robust security measures, such as encryption and firewalls. Autonomous shipping technologies rely on data, which raises concerns about data privacy and security. Ensuring the privacy and security of data generated by autonomous ships will require robust data protection measures.

Public perception: The adoption of autonomous shipping technologies is likely to face resistance from some stakeholders, including seafarers, labor unions, and coastal communities. Ensuring public acceptance of these technologies will require effective communication and engagement strategies. The attractiveness of the new technology prompts active overcoming of these barriers both at the global and national level.
III. DEVELOPMENT OF AUTONOMOUS NAVIGATION

Shipowners' expectations for the new technology are very high: this is probably the only case in many years when shipowners will not have to pay for increased safety through increased costs, but rather can reduce their operational expenses. According to a survey by the Norwegian Shipowners' Association, 5% of shipowners expect autonomous ships to appear in their fleet by 2025, and 50% expect this to happen by 2050. The Japanese Nippon Foundation plans for 10% of Japanese ships to become autonomous by 2030 and up to 50% by 2040.

The idea of autonomous navigation appeared half a century ago, in the 20th century. At that time, it was supported by the successes of the third industrial revolution - radio electronics, computer technology, and space systems - in maritime transport. The maritime industry eagerly consumed technologies capable of replacing unreliable human eyes and hands: it was here that radar stations were among the first to be used as technical vision, autopilots for course holding, satellite positioning systems, automatic identification systems, and others. In the 1980s, Japan, which was simultaneously the world's leading maritime and shipbuilding country, as well as the leading producer of microelectronics and robotics, even initiated a program to create autonomous ships.

However, it turned out to be impossible to transfer the main function of a human on board, to evaluate the situation and make adequate decisions to a machine, because the information technologies of that time could not offer what appeared only in the 21st century - artificial intelligence. Remote control was also unavailable due to the underdeveloped maritime telecommunications, which still remain one of the industry's weak points today.

In the early 2010s, the successes associated with the introduction of artificial intelligence and machine learning for unmanned technologies in other types of transport, and the rapid growth of maritime satellite telecommunications, as well as the shortage of personnel, which European countries and Japan were the first to face, served as prerequisites for the beginning of active practical developments in the field of autonomous navigation.

In 2012, with the support of the European Union (EU), the first large-scale research project on autonomous navigation - Maritime Unmanned Navigation through Intelligence in Networks (MUNIN) was initiated with the involvement of organizations from Germany, Norway, Sweden, Iceland, and Ireland. Within the framework of MUNIN, a theoretical concept of an autonomous ship controlled by onboard automation under the supervision of a shore-based center was developed. As an example, a Handymax-class bulk carrier was used, and its autonomous voyage was simulated in theory and on a navigation simulator. The project was completed in 2016 and became a milestone in the development of autonomous navigation, forming the main architectural, functional, and technological approaches. So far, the project has identified several potential benefits of autonomous navigation, including reduced speed and improved safety. The project is being conducted with the assistance of a number of leading universities and research institutes, such as Aptomar AS, Chalmers technical University, Fraunhofer Center for Maritime Logistics, Hochschule Wismar, MarineSoft, Marintek, University College Cork and has made good progress towards its goal of developing a practical and viable concept for autonomous maritime transportation.

In 2016, Kongsberg, with the support of the Norwegian government, created the world's first test zone for autonomous ships in Trondheim, Norway, and another one in Horten in 2017. In 2017, Rolls-Royce, in collaboration with the Technical Research Center of Finland (VTT), opened a test zone and research center for autonomous ships in Turku, where in 2018, tests of the remotely operated ferry Falco were conducted. This was part of the Advanced Autonomous Waterborne Applications (AAWA) international project funded by the Finnish Funding Agency for Innovation (TEKES) and implemented by a consortium that included Rolls-Royce, Deltamarin, Inmarsat, DNV, Intel, and VTT. In the same year, Rolls-Royce, with the support of the Danish Maritime Administration, conducted tests of the remotely operated tug Svitzer Hermod in the port of Copenhagen in collaboration with Svitzer. Wartsila also tested the remote control of an 80-meter Highland Chieftain ship via satellite, which was the first time outside the line of sight. In 2018, ABB also conducted remote control tests in real conditions on the 34-meter ferry Suomenlinna II in Finland. In October 2019, ABB signed a contract with Keppel Offshore & Marine for the experimental operation of an autonomous tugboat in the port of Singapore with the support of the Singaporean government and the American Bureau of Shipping (ABS). And in March 2020, Wartsila began a joint project with the Port and Maritime Administrations of Singapore to equip an autonomous tugboat, which is funded by the Maritime Administration and the government MINT Fund.

These experiments have demonstrated the viability of remote ship control, which, however, does not solve the key problem of the human factor, but reduces it by transferring the decision-making person from the ship to more comfortable conditions.

In December 2017, Kongsberg announced its flagship project in the field of autonomous navigation - Yara Birkeland, an 80-meter electric container ship that was to become the first ship with

---


automatic control. As part of the project, the ship should be equipped with additional sensors, route and dynamic positioning systems, automatic mooring systems, automatic deviation systems, remote control systems, including remote monitoring systems and Kongsberg's engine management and production technology, K-Power electrical equipment management system, autonomous electric cranes, as well as connected to fleet management and collaboration systems K-Fleet and K-IMS, in addition to the mandatory conventional means. The cost of the project is 400 million Norwegian kroner (47 million US dollars), a third of which is financed by a grant from the Norwegian government.

At the first stage of Yara Birkeland operation, the control systems should be tested under the crew's supervision, then undergo experimental operation in remote mode with the crew on board, and then in autonomous mode with subsequent reduction of the crew on board. The planned start of the tests was shifted from 2018 to 2022.

One more project – the Autonomous Shipping Initiative for European Waters (Autoship project) is initiated by the European Commission and is been implementing by the group of companies belonging to different countries, that is, Ciaotech PNO Group (Italy), Kongsberg Maritime AS (Norway), Kongsberg Digital AS (Norway), Kongsberg Norcontrol AS (Norway), Sintef Ocean AS (Norway), University of Strathclyde (Scotland), Eidsvaag AS (Norway), ZULU Associates (Belgium), Bureau Veritas (France), De Vlaamse Waterweg NV (Belgium). The project is financed within the framework of Horizon-2020 program. The project is under the leadership of Norway with seabed areas arranged in Belgium. The purpose of the project is to test uncrewed vessels and explore the associated problems (legal, technical, human-related, safety-related, ecological, economical) and work out future recommendations. The project plans to build and operate 2 different autonomous vessels for short sea shipping and inland waterways. It is expected that commercial operation could start by the end of 2023.

In France, a concept of Remotely Operated Service at Sea (ROSS) where an unmanned vessel can be piloted from a remote control centre (RCC) was developing. The aims were to operate the vessel from a platform or floating production and storage unit (FPSU), on which a technician is present full-time to maintain the equipment and validate technically and legally the possibility of remote operation of a ship from a very great distance, from one part of the world to another, by a merchant marine officer. Within ROSS concept, applicable rules, required regulations, possible gaps were developed and verified. The proper risk analysis was done by Bureau Veritas.

Autonomous navigation is an increasingly sought-after feature in today’s shipping that promises a safer, more effective and eco-friendly experience. To achieve it, a range of complex technologies are needed – from advanced sensors to sophisticated algorithms – all of which need to be combined and perfectly tuned.

Core basis of the autonomous navigation is a combination of two things: sensing capabilities, such as cameras, laser scanners, ultrasound and sonar; and intelligent algorithms that can process the data collected by these sensors promptly and accurately, and manage the ship depending on the data-driven outcomes. All elements need to work synchronously yet independently.

High level of environmental understanding is required both for ship internal infrastructure, including mechanisms and devices to make decisions that ensure safety of the ship and surroundings.

The development of technologies described above has been impressive over the past few years. From high resolution mapping techniques to self-learning AI algorithms capable of optimizing their own behavior, progress has been made in leaps and bounds in several countries. And it looks set only to accelerate in the future, with ever more reliable hardware being developed alongside enhanced processing power.
The technologies required for autonomous navigation are developing rapidly, but there are still many challenges to be overcome before these technologies can be widely used. Currently, the most advanced autonomous navigation systems are able to handle simple tasks such as following a route with obstacles avoiding, maneuvering in tight water areas, dealing with traffic. The set of technologies which are already available and are in use right now is provided in the Technology Development section of the current document. The world’s major developments of the autonomous navigation were made in the Asia-Pacific as it is described in more details further. But before we have to describe one more vital factor of the new technology development – regulation implementation.
IV. DEVELOPMENT OF REGULATIONS

The development of autonomous navigation technologies may revolutionize the way of cargo handling all over the world, including small and big countries. It’s a global trend able to change in the future a lot of fields of shipping industry and nearby productions. Implementation of the technologies may modernize a lot of things and processes, like infrastructure in ports, shipping management, cargo transportation, and others. Having in mind the international nature of the shipping, the need for common rules, understandable procedures, and clear definitions become obvious.

One of the biggest challenges in establishing such a framework is the lack of consensus on what constitutes safe and responsible use of autonomous navigation systems. Several countries have different laws and regulations governing the use of these systems, while many countries have mostly nothing. These differences can lead to confusion and inconsistencies in the implementation and proper use of the technologies in question.

Another challenge is ensuring that the legal framework keeps pace with technological advancements. Legal frameworks should allow innovations and remain relevant and effective.

Nowadays, there is a growing recognition among policymakers and industry leaders that a legal framework for autonomous navigation is essential. This framework would provide clarity on issues such as liability, data privacy, cybersecurity, and others which are critical for ensuring safe and responsible use of autonomous navigation systems.

To establish international standards for autonomous navigation, policymakers must work together to develop a comprehensive legal framework that takes into account the unique needs and concerns of different regions and industries. This will require collaboration between governments, industry leaders, and other stakeholders to ensure that all perspectives are represented.

A. International Maritime Organization

The International Maritime Organization (hereinafter referred as the IMO) is an intergovernmental organization, a dedicated UN specialized agency with responsibility for the safety and security of shipping and the prevention of marine and atmospheric pollution by ships.

As a specialized agency of the United Nations, IMO is the global standard-setting authority for the safety, security and environmental performance of international shipping. Its main role is to create a regulatory framework for the shipping industry that is fair and effective, universally adopted and implemented. Currently, 175 states are IMO members, and 3 more states are associated members. Intergovernmental organizations and nongovernmental institutions representing marine, legal, industrial, and ecological services participate in IMO activities as observers and consultants accordingly.

The Organization consists of an Assembly, a Council and five main Committees: the Maritime Safety Committee (MSC); the Marine Environment Protection Committee (MEPC); the Legal Committee (LEG); the Technical Cooperation Committee (TC) and the Facilitation Committee (FAL) and a number of Sub-Committees support the work of the main technical committees.

At the 98th session of the International Maritime Organization's (IMO) Maritime Safety Committee (MSC) held in 2017, it was decided to conduct a Regulatory Scoping Exercise (RSE) regarding autonomous shipping. The first definition of Maritime Autonomous Surface Ships (MASS) was formulated, which refers to a vessel that can operate to some degree without a human onboard.
Legal Committee and Facilitation Committee of IMO were also involved in RSE of the instruments under their guidance respectively.

Further development of the concept of autonomous shipping was achieved at the 101st session of the IMO Maritime Safety Committee in June 2019, when the Interim Guidelines for MASS trials were adopted and approved, which all states should follow.

The RSE has verified that the existing IMO instruments have historically been developed on the basis that the ship would have at least a minimum level of manning on board to carry out the various tasks required to ensure safe, secure, and environmentally sound ship operations.

The ever-increasing use of automation in the operation of ships, along with the anticipated increase in the use of remote control and autonomous operation of key functions, will require a different approach and therefore some adjustment of the accepted norms regarding on board manual intervention and control as contained within SOLAS and other IMO instruments.

In facing these challenges, it is recognized that some aspects associated with MASS may not be adequately or fully addressed in SOLAS or other IMO instruments and that additional guidance may be required on the design and operation of MASS to achieve a level of safety that is at least equivalent to that expected of a conventional ship.

Overall, the RSE of the IMO committees identified "common potential gaps and/or issues" regarding the regulation of MASS. These include the roles and terms "captain," "crew," or "responsible person," requirements for the remote control station/center of MASS, the status of the "remote operator," and definitions and certificates.

At the 103rd session of the IMO Maritime Safety Committee (MSC) in May 2021, the results of the MSC’s Regulatory Scoping Exercise (RSE) were presented. Thus, upon the results of the RSE, the Committees involved considered several options to deal with MASS in the future and decided the goal-based MASS Code would be the most appropriate option. This Code would address the functions needed to obtain safe and reliable operations of MASS insofar as they are not adequately or fully addressed in other applied IMO instruments, such as SOLAS, while ensuring that required safety levels are maintained or enhanced through the implementation of remote control, or autonomous operation, of key functions.

This Code is intended as a supplement to other IMO instruments, such as SOLAS, and provides a regulatory framework for the performance of remote control and autonomous operation of key functions, as applicable.

The safety principles and objectives of this Code reflect changes in the operational risks (increases or reductions) which may result from the introduction of remote control and autonomous operation of key functions and address their management and reduction through mitigation measures and controls.

This Code has been developed based on the Generic guidelines for developing IMO Goal-based Standards (MSC.1/Circ.1394/Rev.2) and the Principles to be considered when drafting IMO instruments (resolution A.1103(29)).

The provisions of this Code should be implemented for individual remotely controlled or autonomous functions even where persons are on board to handle other functions.

This Code takes into account that certain operational functions may be controlled from a location, or locations, remote from the MASS and addresses necessary aspects of such remote operations centres.
The Joint Working Group of Legal Committee, Facilitation Committee and Maritime Safety Committee was established to monitor the developments of goal-based MASS Code.

To develop the draft MASS Code, MSC established a Correspondence Working Group composing of all interested IMO member states and observers. The MSC MASS CG has identified several areas that need to be addressed in order to ensure safe navigation with a-Navigation. These include: navigation safety, cyber security, environmental protection, and human-machine interaction. The group is also exploring ways to ensure that a-Navigation technology is used responsibly and ethically.

The brief contents of future MASS Code are drafted and approved in general, the detailed text of the code is in progress. Currently the MSC MASS CG established several sub-groups for dealing with the following areas: navigation, remote operations, communications, and operation control. All the subgroups are operating via correspondence.

The non-mandatory MASS Code is expected to be ready by 2025. By now, there is only one official internationally approved document is issued by IMO, that is, Interim guidelines for MASS trials (MSC.1/Circ.1604). But several countries have already implemented its own national legislations and R&D to initiate MASS deployment.

B. Examples of National Regulations

The Russian Federation

In the Russian Federation, the first initiative to incorporate the autonomous navigation into the national legislation was initiated in 2019. A huge circle of the involved governmental and non-governmental institutions, commercial companies, as well as Federal Agency on Maritime and River Transport, Ministry of Economic Development and Trade together with Ministry of Transport were tasked to consider the innovations and the required amendments. The total global topic on autonomous shipping was included into the MARINET Roadmap of the National Technology Initiative.

On the 5th of December, 2020, the Government of the Russian Federation announced a wide range experiment on trials of autonomous vessels and issued a Regulation No.2031 “On Experiment on Trial Operations of Autonomous Ships Flying the State Flag of the Russian Federation”.

The following main tasks were identified:

1. Probation of autonomous navigation systems
2. Testing of remote control over vessels sailing in the various navigation areas
3. Efficiency determination of autonomous navigation systems
4. Workout of engineering solutions for autonomous shipping
5. Verification that the autonomous navigation is possible in the assigned areas.

Within the experiment, the Federal Agency on Maritime and River Transport developed and officially published Recommendations on the application of Convention on the International Regulations for Preventing Collisions at Sea (COLREG, 1972) by autonomous ships within the trial operations of autonomous ships flying the State flag of the Russian Federation.

Currently, the Russian government is discussing the Federal Law regulating autonomous navigation in Russian ports. The draft law has already developed and is under the consideration of the Parliament. The law is assumed to modify the following laws and regulations:
- Merchant Shipping Code
- Inland Waterways Transport Code
- Sea Ports Act
- General Rules of Navigation in Sea Ports
- Compulsory Regulations in Sea Ports
- Minimum Manning Requirements for seagoing vessels
- Regulation of certification of seafarers

The law itself, when adopted, would cover definition of autonomous ship, crew and shore personnel, notion of master, the circle of responsibilities, the role of the shipowner, as well as defined water zones and port rules.

Upon the development of the project, the Russian Federation informed the MSC of the IMO about the development of the regulatory instruments.

The United Kingdom

The United Kingdom has already introduced its own legislation with regards to autonomous shipping. UK has launched and continued to support an international working group on autonomous shipping – Maritime Autonomous Systems Regulatory Working Group. The group involves a wide range of experts from maritime industry, education and research centers, and representatives of UK maritime administration and government. The group meets once a year, it considers various topics relating to autonomous shipping and providers wider views to the industry.

Major classification societies, such as American Bureau of Shipping, Bureau Veritas, Det Norske Veritas, China Classification Society, Class NK, Lloyd Register, Russian Maritime Register of Shipping are also involved in the development. Many of these classification societies have already conducted their own researches and published risk assessment of usage of autonomous technologies. They also issued regulatory documentations on maritime autonomous ship classification and operations.
V. AUTONOMOUS NAVIGATION IMPACT ANALYSIS IN THE ASIA-PACIFIC REGION

A. Regional impact

The Asia-Pacific is the world’s fastest-growing economic region. It is home to more than half of the global population and a third of the global GDP. The region is expected to continue its growth trajectory over the next decade, with an average annual growth rate of 5.1%, according to the latest forecast by International Monetary Fund (IMF). This growth will be driven by rising middle-class populations in countries such as India, Indonesia and China, as well as rapid urbanization in countries such as Vietnam and Bangladesh.

According to the UNCTAD’s Review of Maritime Transport 2022, the regional countries are one of the top 25 maritime nations in the world (by fleet size ranking): China, Japan, Singapore, Indonesia, the Republic of Korea, the Russian Federation, the United States, and Malaysia.

Autonomous navigation technology has the potential to significantly improve transport connectivity, logistics, and mobility in the Asia-Pacific region, which is home to some of the world’s busiest shipping routes and ports. Here are some ways in which this technology could contribute:

1. Improved supply chain efficiency: Autonomous navigation systems can optimize shipping routes and speeds to reduce transit times, lower costs, and improve reliability. This can benefit the entire supply chain, from manufacturers and exporters to retailers and consumers. By reducing bottlenecks and delays, autonomous navigation can also help to unlock the full potential of the region’s trade corridors.

2. Enhanced port operations: Autonomous navigation technology can be integrated with other digital technologies, such as smart sensors and data analytics, to improve port operations and reduce congestion. For example, automated container handling systems can speed up loading and unloading times, while real-time data on shipping schedules and cargo volumes can help port operators to plan and allocate resources more efficiently.

3. Improved last-mile logistics: Autonomous delivery vehicles, such as drones and ground-based robots, can improve last-mile logistics by delivering goods more quickly and efficiently. This can be especially important in the Asia-Pacific region, where many urban areas are densely populated and congested.

4. Increased mobility options: Autonomous navigation technology can expand mobility options in the region, particularly in areas where traditional transportation infrastructure is limited or inadequate. For example, autonomous boats and ferries can provide low-cost transportation in coastal and riverine areas, while autonomous buses and shuttles can improve public transportation in urban areas.

5. Reduced environmental impact: The Asia-Pacific region is home to some of the world’s most heavily polluted cities, and transportation is a major contributor to air and water pollution. Autonomous navigation technology can reduce the environmental impact of transportation by optimizing routes and speeds to minimize fuel consumption and emissions. Additionally, autonomous vessels can be powered by clean energy sources, such as solar or wind power, further reducing their carbon footprint.

6. Improved cross-border connectivity: The Asia-Pacific region is home to many countries
with diverse languages, cultures, and regulatory frameworks, which can create barriers to cross-border trade and transportation. Autonomous navigation technology can help to overcome these barriers by providing standardized, data-driven solutions that can be adapted to different contexts and languages.

Overall, the benefits of autonomous navigation in maritime transport are significant and have the potential to transform the maritime industry and the global economy, including the Asian-Pacific region’s role and development. While the technology is still in its early stages, it is important to understand these potential impacts in order to prepare for the future of maritime transportation.

**B. Social Impact**

The implementation of autonomous navigation in the Asia-Pacific region is expected to have significant social impacts, both positive and negative. One of the main benefits of this technology is increased safety, as autonomous vessels can reduce the risk of accidents and improve response times in emergency situations. This can help to protect the lives and well-being of workers in the shipping industry. According to a report by the International Transport Forum, the implementation of autonomous navigation could reduce the number of accidents and fatalities in the shipping industry by up to 75%. With the implementation of autonomous navigation technologies, it is possible that these numbers could be significantly reduced.

However, the main concern regarding the implementation of autonomous navigation is the potential loss of jobs in the shipping industry. The introduction of autonomous navigation could also lead to job losses in the shipping industry. According to a report by the World Economic Forum, the introduction of autonomous shipping technologies could lead to the displacement of a significant share of the current workforce in the industry. According to a study by the International Transport Forum, the automation of the shipping industry could lead to a reduction in the number of jobs by up to 50% in some countries. This could have a significant impact on the local communities that depend on the shipping industry for their livelihoods. For example, in the Philippines, the shipping industry is a significant employer, providing jobs to around 400,000 people. The introduction of autonomous navigation technologies could lead to the displacement of many of these workers, which could have a significant impact on the local economy and the livelihoods of these individuals and their families.

On the other hand, the use of autonomous navigation technologies could also provide new opportunities for workers in the shipping industry. With the increased efficiency and reduced costs associated with this technology, it is possible that new jobs could be created in areas such as vessel monitoring, maintenance, and control. Furthermore, the use of autonomous vessels could potentially lead to a reduction in the number of crew members required on each vessel, freeing up resources to invest in training and development programs for workers in the industry.

From the entire economy view, the implementation of autonomous navigation could also have positive social impacts. For example, reducing operating costs could lead to a reduction in the price of goods, which could benefit consumers. Additionally, the use of autonomous vessels could lead to a reduction in the number of accidents and fatalities in the shipping industry.

Furthermore, the implementation of autonomous navigation could also lead to increased trade and economic growth in the region. According to the Asian Development Bank, trade in the Asia-Pacific region is expected to grow by 6.3% in 2021, driven by strong demand from China and
other emerging economies. By improving efficiency and reducing the cost of shipping, autonomous navigation could facilitate this trade and contribute to the economic development of the region.

Also, the introduction of autonomous shipping could also bring new opportunities for innovation and collaboration, particularly in the development of new skills and technologies that can improve the efficiency and sustainability of the industry.

C. Economic Impact

Autonomous shipping could have a significant impact on the economics of the maritime industry, particularly in terms of cost savings and efficiency gains. By removing the need for onboard crew and reducing the risk of accidents, autonomous shipping could significantly reduce operating costs and increase productivity. Additionally, the use of autonomous vessels could also reduce the risk of disruptions to supply chains, such as delays caused by weather or labor disputes. However, the introduction of autonomous shipping could also create new challenges for the industry, particularly in terms of regulatory compliance, liability, and insurance. These issues could increase costs and create new risks for stakeholders in the industry.

One of the potential benefits of autonomous navigation is the increased efficiency and reduced costs associated with this technology. With the use of autonomous vessels, it is possible to reduce the operating costs of the shipping industry, including fuel and labor costs. In 2019, the global shipping industry spent an estimated $140 billion on fuel alone. By reducing fuel consumption, autonomous vessels could significantly reduce operating costs and improve profitability for shipping companies.

According to a report by the International Transport Forum, the automation of the shipping industry could reduce operating costs by up to 22%, driven by a reduction in crew costs and improved vessel utilization. This reduction in operating costs could lead to a reduction in the price of goods, which could benefit consumers and potentially stimulate demand.

Moreover, the use of autonomous vessels could also lead to a reduction in transportation times and an increase in the frequency of shipping. This could help reduce supply chain disruptions and lead to increased trade volumes. According to a report by the United Nations Conference on Trade and Development, the implementation of autonomous navigation could help reduce the time it takes for goods to move between Asia and Europe by up to 30%.

Furthermore, the implementation of autonomous navigation could also lead to increased competitiveness in the region's shipping industry. By reducing operating costs and increasing efficiency, autonomous navigation could help shipping companies in the Asia-Pacific region to better compete with companies from other regions, such as Europe and North America. This increased competitiveness could lead to increased market share and revenue for these companies, which could contribute to the economic growth of the region.

D. Environmental Impact

Autonomous shipping could have a significant impact on the environment, particularly in terms of reducing greenhouse gas emissions and improving the sustainability of the maritime industry. One of the most significant benefits is the potential reduction in greenhouse gas emissions. According
to a report by the International Transport Forum, autonomous ships could reduce greenhouse gas emissions by up to 12% due to more efficient routing and reduced speeds. This reduction could have a significant impact on global emissions, as the shipping industry is responsible for approximately 3% of global emissions.

In addition to reduced emissions, the implementation of autonomous navigation could also lead to increased use of renewable energy sources. Autonomous vessels can integrate renewable energy sources such as solar or wind power more easily than traditional vessels, which require additional space and infrastructure to support renewable energy systems. According to a study by DNV GL, the increased use of renewables in the maritime sector could lead to a 100% reduction in greenhouse gas emissions by 2050. This reduction would be critical in helping to mitigate the impact of climate change.

Moreover, the implementation of autonomous navigation could help reduce the risk of oil spills and other environmental disasters caused by human error.
VI. TECHNOLOGY DEVELOPMENT

The Asia-Pacific region plays a major role in the development of the autonomous navigation: here the world’s main technology developments and practical implementation are concentrated, as it is described in this report.

At the same time, there is a significant disproportion in the development and even access to the new technology between different countries of the region. We see one group of developed countries leading in autonomous navigation implementation in the world and another group without access to this technology.

The first group – China, Japan, the Republic of Korea (ROK), the Russian Federation, Singapore, and the USA – has a strong position in autonomous navigation development. Conducted various trials of MASS and came to the level of implementation of autonomous navigation in commercial operation. Currently, the Russian Federation is the only country in the world, where MASS us is allowed in commercial operation, as a national experiment following up the world’s largest trial project of autonomous navigation in real conditions. Japan, China and ROK are also very close to this stage based on a number of extensive trials of autonomous navigation in real conditions.

A. China

China is one of the world's largest maritime nations, with a long history of seafaring and trade. Its maritime industry plays a crucial role in supporting the country's economy and global trade, with the shipping industry being one of the most important sectors. According to the data from the China Maritime Safety Administration, the total number of vessels in the Chinese merchant fleet was 6,586 as of the end of 2020. This includes various types of vessels such as bulk carriers, container ships, tankers, and general cargo ships. In terms of vessel ownership, Chinese companies owned 3,518 vessels, accounting for more than half of the total fleet. Foreign-owned vessels that fly the Chinese flag accounted for 2,579, while the remaining 489 vessels were jointly owned by Chinese and foreign companies. According to data from the United Nations Conference on Trade and Development, as of January 2020, China had a total of 5,442 registered vessels, with a combined gross tonnage of 243.4 million.

China has a powerful shipbuilding industry, accounting together with shipping for a significant share of the country's GDP. The sector has been growing steadily over the years, driven by the country's rapid economic development and expanding trade volumes. According to data from the China Association of National Shipbuilding Industry, the country's shipbuilding output in 2020 reached 38.6 million deadweight tons (DWT), accounting for around 42% of the world's total and making it the world's largest shipbuilder for the 17th consecutive year.

In addition to shipbuilding, China is also home to some of the world's largest ports. According to the World Shipping Council, China has seven of the world's top 10 container ports by volume, including the ports of Shanghai, Shenzhen, and Ningbo-Zhoushan. These ports handle a significant share of the country's trade with the rest of the world.

The shipping industry in China is dominated by state-owned enterprises, including China COSCO Shipping Corporation Limited, China Merchants Group, and China Shipping Group Company. These companies own and operate a large portion of the country's commercial fleet, which includes a mix of container ships, bulk carriers, tankers, and other vessels.
China's maritime industry has been a key driver of the country's economic growth and development, contributing significantly to job creation, foreign trade, and industrial development. However, the sector also faces a number of challenges, including overcapacity, low profitability, and environmental concerns. To address these challenges, the government has implemented a range of policies aimed at promoting sustainable development in the maritime sector, including the promotion of energy-efficient ships, the development of clean energy sources, and the improvement of maritime infrastructure.

The government's support and promotion of the maritime industry is one of the key factors contributing to the competitiveness of China's merchant fleet. China has implemented policies to develop its shipbuilding industry, including subsidies and tax incentives to shipbuilders, which has led to a significant increase in the production of ships over the past decade.

In addition to shipbuilding, China's shipping industry has also benefited from its strategic location as a major trading nation. The country's rapidly growing economy has driven demand for raw materials and goods, which has led to a significant increase in its imports and exports. As a result, China's shipping industry has become one of the world's busiest, with its ports handling more than a third of global shipping container traffic.

Furthermore, China's shipping companies have been expanding their operations globally, acquiring shipping assets and forming strategic partnerships with foreign companies. For example, China COSCO Shipping Corporation Limited, the country's largest shipping company, has been actively acquiring overseas ports and terminals, including the acquisition of the Greek port of Piraeus in 2016. The company's fleet consists of more than 1,300 vessels, including container ships, bulk carriers, and oil tankers, with a total carrying capacity of over 105 million deadweight tonnes.

Despite China's significant role in the shipping industry, there are still some weaknesses that the country's merchant fleet and shipowners face in the global market. One of the primary challenges is overcapacity, with many Chinese shipyards producing vessels that exceed global demand. This has led to a surplus of vessels, which can drive down prices and reduce profitability for Chinese shipowners. Another issue is the perception of Chinese ships as low-quality, due to reports of safety and environmental violations. In recent years, there have been several incidents of Chinese vessels being detained or barred from ports due to safety concerns. Additionally, China's environmental record has been a subject of scrutiny, with concerns over pollution and greenhouse gas emissions.

China's merchant fleet has also been adopting new technologies and innovations to improve its competitiveness. For example, the country has been investing in autonomous shipping technologies, with a number of companies developing autonomous ships for use in its domestic waters. In addition, China has been promoting the use of liquefied natural gas (LNG) as a cleaner and more efficient fuel source for its shipping industry, with more than 300 LNG-fueled ships in operation as of 2020.

Technical developments in China are wide and involve many various entities, including commercial companies, universities, and regulatory bodies. Thus, the developments of digitalization, connection, and automation of ship management processes are conducted by the Wuhan University of Technology in cooperation with Harbin Engineering University, Shanghai Ship and Shipping Research Institute, Beijing Highlander Digital Technology, Shanghai Merchant Ship Design and Research Institute, XhenDui Industry Artificial Intelligence, Tianjin Navigation Instruments Research Institute, and others. Under the control of the China Classification Society, Chinese engineers are working on such intelligent systems as navigation, machinery maintenance, energy efficiency management, cargo management, integration platform, and remote control stations.
In China, there are several test and verification platforms used for autonomous ship trials – in Zhuhai, Zhanjiang, Qingdao, Rizhao, Dalian, and other places. Simulation platforms are widely used to test the equipment and developed technical solutions.

In China, autonomous ships are now considered part of the country's national "Smart Ship" program. In 2003, the Innovation Center for Intelligent Control and Applied Technologies for Marine Equipment was established in China, with support from which construction of the first "smart ships" began in 2016. In 2018, the China State Shipbuilding Corporation, together with the China Classification Society, announced plans to create autonomous ships, which were supported by the Chinese government. The main focus of development lies in the area of technical management, which is based on China's rapidly growing capabilities in engine manufacturing and marine equipment production.

In 2019, the corporation reported an experimental voyage of a bulk carrier whose technical equipment was controlled remotely, and in December 2019, the first autonomous ship test was conducted in China - the 13-meter JinDouYun-0. In the fall of 2021, the electric container ship Zhi Fei (117 m, 300 TEU) was launched, which is expected to be equipped with autonomous navigation systems.

![Picture 3. JinDouYun-0](image1)
Source: China’s first autonomous cargo ship completes trial voyage, Jason Jiang; December 16, 2019, splash247

![Picture 4. Zhi Fei](image2)

JinDouYun-0 (with 12.8 m length, 3.8 m beam, 1 m draught, 8 knots speed) is equipped with propulsion system with digital controls, she made her first trial voyage with cargo from Zhuhai’s Dong Ao Island to Hong Kong-Zhuhai-Macao Bridge. The vessel can navigate autonomously, under remote control, tracked autonomous navigation and avoid collisions. Remote control navigation is used for entrance/departure to/from the place of cargo operations and in case of heavy navigation conditions. Being in this mode, the ship is controlled remotely from the shore. To meet...

---


the requirements for communications and relevant coverage area established by China MSA, the control station was equipped with specifically designed network antenna. This antenna provided additional area coverage and base communication net for trials.

One of the most prominent examples of Chinese autonomous navigation technology is the Zhi Fei, a 300TEU container vessel that is fitted with indigenous systems for independent route planning and collision avoidance. Communications between the vessel and shore stations are conducted via 5G, satellite, and other multi-network, multi-mode systems. If the program is successful, the project team will incorporate similar autonomous technologies on future container vessel newbuilds with larger capacities, typically between 500 and 800 TEUs. The Zhi Fei has three driving modes: manual driving, remote control, and autonomous navigation. It can realize the functions of route independent planning, intelligent collision avoidance, automatic berthing and disembarking, and remote control driving. These features make it an excellent example of the current state of Chinese autonomous navigation technology.

Here there is a tendency for green shipping as well, the developments are aiming for combination of electric ships equipped with autonomous navigation. The technologies supplement each other to make the world cleaner, greener, and safer.

**B. Japan**

Japan has a long and rich maritime history dating back to ancient times. Today, the country's maritime industry plays a significant role in the global shipping market. Japan is home to some of the world's largest shipbuilding companies, such as Mitsubishi Heavy Industries, Imabari Shipbuilding, and Kawasaki Heavy Industries. Additionally, the country has a large fleet of ships, including cargo ships, tankers, and container ships.

According to the Japan Shipowners' Association, as of the end of March 2021, Japan had a total of 4,383 registered vessels, with a gross tonnage of 170.7 million. This fleet is comprised of various types of vessels, including 1,354 bulk carriers, 949 oil tankers, 929 container ships, and 627 chemical tankers. In terms of capacity, the Japanese fleet ranks fourth in the world after Panama, Liberia, and the Marshall Islands, according to data from the International Maritime Organization.

The shipping industry plays a critical role in Japan's economy, with the country heavily reliant on exports. The Japan Maritime Center reports that the maritime industry contributes around JPY 16.6 trillion (approximately USD 150 billion) to the country's economy annually, which is equivalent to around 3% of Japan's GDP. In addition, the industry employs around 650,000 people in various roles, including seafarers, shipbuilders, and port workers.

The Japanese government has also taken steps to support the growth and competitiveness of its maritime industry. In 2017, the government launched the "Ocean Policy," which includes initiatives to strengthen the country's shipping and shipbuilding industries. These initiatives include providing financial support to domestic shipbuilders and promoting the development of autonomous ships and other advanced technologies.

At the same time, the Japanese shipping industry faces several challenges and weaknesses in the global market. Here are some of the major ones:

- Aging fleet: The average age of Japanese ships is relatively high, which can affect their efficiency and competitiveness.
• High operating costs: The cost of operating Japanese ships is also relatively high due to factors such as high labor costs, strict regulations, and expensive fuel.
• Competition from other Asian countries: Japan faces stiff competition from other Asian countries such as China, the Republic of Korea, and Singapore, which have rapidly expanded their shipping industries in recent years.
• Dependence on key trade routes: Japanese shipping companies heavily rely on specific trade routes, particularly those linking Asia and North America. This can leave them vulnerable to disruptions such as geopolitical tensions or shifts in global trade patterns.
• Depressed demand: The global shipping industry has also faced periods of depressed demand in recent years, which can impact Japanese shipping companies' profitability.

One of the main competitive advantages of the Japanese merchant fleet is its advanced technology and innovation. Japan has a strong reputation for producing high-quality ships and marine equipment, and its shipbuilding industry is one of the most advanced and efficient in the world. Japanese shipbuilders are known for their expertise in building high-tech vessels such as LNG carriers, container ships, and car carriers. In June 2018, the Ministry of Land, Infrastructure, Transportation and Tourism of Japan set a goal to ensure the introduction of autonomous ships in the country starting in 2025. In October 2018, the Centers for the Promotion of the Marine Innovation Strategy were established, in which Oshima Shipbuilding, MHI Marine Engineering, NYK, MTI, MOL, Mitsui E&S Shipbuilding and others were involved. In the same year, ClassNK announced the development of a Conceptual Design Guide for Automated/Autonomous Vessels. In 2019, under the auspices of the Nippon Foundation and with the support of the Japanese government, the DFFAS (Designing the Future of Full Autonomous Ship) project was launched with the aim of ensuring the introduction of autonomous ships in Japan in 2025. In cooperation with more than 30 commercial companies such as Mitsubishi Heavy Industries Group, Mitsubishi Shipbuilding Co., Ltd., and Shin Nihonkai Ferry Co., Ltd., and others this Fund has launched a MEGURI2040: the Fully Autonomous Ship Program. The companies work together using an open-innovation approach with the aim of practical implementation. A land-based Fleet Operation Center is also being built in Makuhari, Chiba Prefecture, for remote operations in emergency situations. The consortium is developing fully autonomous navigation systems for container ships and ferries. For ferries, this will include an automated navigation function within the harbor, including automated berthing and unberthing, and mooring support using drones is being developed for container ships.

![Image](5)

**Picture 5.** The land-based Fleet Operation Center.  
**Source:** Website [www.nippon-foundation.or.jp](http://www.nippon-foundation.or.jp)  

![Image](6)

**Picture 6.** The 749 gross-ton Suzau  
**Source:** Website [www.nippon-foundation.or.jp](http://www.nippon-foundation.or.jp)

---


10 Ibid
For full-scale implementation, a comprehensive fully autonomous navigation system with repeated risk assessments has been carried out at the design stage. The system has three primary components: (1) a ship-side navigation system that controls autonomous functions from the ship; (2) a land-side system that monitors and supports the ship from shore, including remote ship-handling functions; (3) and information and communication system that enables stable communication between the ship and shore. The Fleet Operation Center allows fully autonomous navigation at sea with tracking from shore the functions normally performed by the crew, like monitoring of weather and sea conditions, look out function, and control over the status of the ship’s equipment. In emergency situations, the system can switch to remote operation from the Fleet Operation Center, ensuring the overall systems’ safety and stability. ClassNK conducted a risk assessment for the project.

In 2019, Nippon Yusen Kaisha Line has conducted trials of a ship of 70,000 tons navigating day and night with the use of an automated navigation system from Xinsha, China, to Nagoya and Yokohama, Japan. There was a crew onboard doing some of the duties in coastal areas, but not in the bays. During the trial, the performance of the automated navigation system in actual sea conditions was monitored as it collected information on environmental conditions around the ship from existing navigational devices, calculated collision risk, automatically determined optimal routes and speeds that were safe and economical, and then automatically navigated the ship. Using data and experience gained through this trial but not obtainable through onshore simulators, NYK was able to ensure the feasibility of the SSR and its benefit for safe and optimal operations. The trial was approved by Panama as a Flag State, and the Ministry of Land, Infrastructure and Tourism of Japan and Japan Coast Guard.

In 2022, the container ship Suzaku, operating in a congested sea area, demonstrated the use of a comprehensive fully autonomous navigation system, including remote control and land support. The Suzaku is of 95 m and 749 gross tons navigated a round-trip route of 790 kilometers in Tokyo Bay using a comprehensive fully autonomous navigation system, including remote operation from the Fleet Operation Center in Chiba Prefecture.

![Picture 7. The container ship Suzaku](Source: 749 GT Container Ship Takes the World’s First Autonomous Trip in the Busy Waters of Japan)

![Picture 8. Remote operation at the FOC](Source: Box ship completes 790 km autonomous navigation trial)


C. Republic of Korea

The maritime industry plays a crucial role in the Republic of Korea economy, as it is an important source of foreign currency earnings and job creation. The Republic of Korea has a well-developed shipping industry, with major shipbuilding companies, shipping lines, and port operators.

The Republic of Korea's shipping industry is dominated by large conglomerates, such as Hyundai Merchant Marine, Hanjin Shipping, and Korea Line Corporation, which operate a range of vessels, including container ships, bulk carriers, tankers, and LNG carriers. These companies have strong financial backing and are able to invest in the latest technology, such as eco-friendly vessels and digitalization, which helps to enhance their competitiveness in the global market.

In terms of shipbuilding, the Republic of Korea is one of the world's leading shipbuilding countries. According to the Korea Shipbuilders' Association, the Republic of Korea's shipbuilding industry held a 39.8% share of global shipbuilding orders in 2020, the highest among all shipbuilding countries. The Republic of Korea's shipbuilding industry has continued to expand its global market share, and it is expected to maintain its position as a major shipbuilder in the coming years.

In terms of shipping lines, the Republic of Korea has several major companies, such as Hyundai Merchant Marine, Korea Line Corporation, and HMM Co., Ltd. These companies operate a large number of vessels and provide shipping services to various regions around the world. According to the United Nations Conference on Trade and Development (UNCTAD), the Republic of Korea is among seven beneficial ship-owning countries by deadweight tonnage in 2022. The Republic of Korea in 2022 had 34% of deliveries in newbuilds at the market which is 8.3% increase.

In terms of port operations, the Republic of Korea has several major ports, such as Busan Port, Incheon Port, and Gwangyang Port. Busan Port is the fifth busiest container port in the world, with a total throughput of 21.9 million twenty-foot equivalent units (TEUs) in 2020. Incheon Port and Gwangyang Port are also significant ports, with a total throughput of 3.7 million TEUs and 2.7 million TEUs in 2020, respectively.

The Republic of Korea's government has also implemented various policies to support the development of its maritime industry, such as the establishment of a special economic zone for shipbuilding and offshore plants in 2003, and the expansion of its port infrastructure through the New Port Construction Plan in 2005.

In addition to its strong shipbuilding and ship-owning industries, the Republic of Korea also has a well-developed shipping services sector, including ship management, ship broking, and maritime law. The Republic of Korea has also established a strong presence in the global ship finance industry, with Korean banks providing significant financing for the construction and purchase of vessels.

Despite the strengths of the Republic of Korea's maritime industry, there are also several weaknesses that affect the competitiveness of its merchant fleet and shipowners in the global shipping market. Some of these weaknesses include aging fleet (that can lead to higher maintenance costs, lower fuel efficiency, and reduced competitiveness) and dependence on foreign crew: due to a shortage of domestic seafarers, the Republic of Korea's shipping companies rely heavily on foreign crew members, particularly from developing countries.
Since 2020, Republic of Korea develops a Korea Autonomous Surface Ship Project. This national R&D project is under implementation since 2020 till 2025 and includes 10 subprojects on autonomous navigation systems, autonomous engine systems, and sea test-bed & validation.

The project includes:
- development of autonomous navigation system with intelligent route planning function
- development of the next digital communication technologies for Ship2Ship2Shore
- development of cyber security for MASS
- development of shore remote control system of MASS
- incident response system and reliability assessment for autonomous ships
- development of remote management and safe operating technology of autonomous navigation system
- development of international standardization technology for autonomous ships
- development of situational awareness systems for preventing collisions and accidents
- development of performance monitoring, failure prediction and diagnosis technology for engine system of autonomous ships
- development of verification and validation testbed for autonomous ships
- development of validation and verification technique for intelligent system of autonomous ships

Korea Autonomous Surface Ship Project (KASS) project involves research institutes, commercial companies, regulatory entities of the maritime field, and others. Thus, among the participants there are Korea Research Institute of Ships and Ocean Engineering (KRISO), SafeTechResearch, Lloyd’s Register Asia branch, Korea Maritime and Ocean University (KMOU), Korea Shipbuilding & Offshore Engineering Co., Ltd. (KSOE), Samsung Heavy Industries, Electronic and Telecommunications Research Institute (ETRI), Korean Register of Shipping (KR), Korea Advanced Institute of Science & Technology (KAIST), SEADRONIX, PentaSecurity, T1 Information Technology, Korea Maritime Institute (KMI), SYNC TECHNO, COMESTA, i-Storm, Ace Antenna, Mokpo National Maritime University (MMU), Inha University, Pukyong National University, Changwon National University, Seoul National University, UANGEL. The program covers car ferry and containership with the goal to build 250 autonomous ships by 2025.

In 2022, Avikus, an autonomous navigation company belonging to one of the world’s largest shipbuilders HD Hyundai the successful voyage of the LNG carrier Prism Courage from Freeport, Texas to South Korea’s Boryeong LNG Terminal, via the Panama Canal. The 33-day voyage covered roughly 10,800 nautical miles, of which half was navigated autonomously using Avikus’ technology. The technology is a navigation system that creates optimal routes and speeds using artificial intelligence that recognizes conditions such as weather and wave heights and nearby ships, and then controls the vessel’s steering commands in real-time.

The company said that during the voyage, the system accurately recognized the locations of nearby ships and maneuvered to avoid collision about 100 times. The company also said that by allowing the system to select the optimal route, the ship was able to increase its fuel efficiency by 7% while reducing greenhouse gas emissions by about 5%.
D. The Russian Federation

The Russian Federation has a rich maritime history and a significant presence in the global shipping industry, thanks to its extensive coastline and the country's reliance on sea transport for both domestic and international trade. The Russian maritime industry is a crucial component of the country's economy, with the sector responsible for a significant portion of the country's exports and imports. The location of the Russian Federation at the crossroads of Europe and Asia has made it an essential transit hub for the transportation of goods between the two continents. The country's ports are critical gateways for the transportation of oil, gas, minerals, and other commodities.

One of the strengths of the Russian merchant fleet is its large capacity. As of 2021, the fleet had a total deadweight tonnage (DWT) of over 43 million metric tons, according to data from the United Nations Conference on Trade and Development (UNCTAD). This makes it the ninth-largest fleet in the world in terms of DWT.

The Russian Maritime Register of Shipping (RS) also provides data on the country's merchant fleet. According to RS, as of December 2021, the total number of vessels in the Russian-flagged merchant fleet was 4,009. This includes 2,213 vessels with a total gross tonnage of over 500 GT and 1,796 vessels with a gross tonnage of less than 500 GT. According to the Ministry's report for 2020, there were 3,929 vessels in the Russian merchant fleet as of January 1, 2021. The fleet includes a range of vessel types, including container ships, bulk carriers, tankers, and specialized vessels.

The Port of Novorossiysk is the largest port in the Russian Federation and one of the busiest in the Black Sea region, with an annual throughput of over 140 million tons of cargo. The port is a key transportation hub for oil and gas products and other commodities.

The Russian Federation also has a significant presence in the Arctic shipping industry. The country is home to several ports along the Northern Sea Route, which is becoming increasingly important as melting ice opens up new shipping routes between Asia and Europe. In 2020, the volume of cargo transported along the Northern Sea Route reached a record high of 33 million metric tons, with Russian-flagged vessels accounting for over 80% of the traffic.

However, there are also several weaknesses of the Russian merchant fleet and shipowners in the world market. One of the main challenges facing the industry is the aging fleet. According to UNCTAD data, the average age of vessels in the Russian fleet is over 24 years, which is higher than the global average of around 20 years. This means that Russian shipowners may struggle to compete with newer and more technologically advanced vessels operated by other countries.

Another challenge is the limited investment in the industry, both in terms of modernizing existing vessels and building new ones. According to data from the Russian Maritime Register of Shipping, the number of new vessels built in the Russian Federation has declined significantly in recent years.

Additionally, the country's shipping industry has been impacted by sanctions imposed by the international community in response to its actions in Ukraine. These sanctions have restricted the ability of Russian shipowners to access international financing and insurance, making it difficult
for them to compete with other countries in the global shipping market.

Despite these challenges, maritime industry of the Russian Federation remains a significant contributor to the country's economy and plays an essential role in global shipping trade. Also, it benefits from the advanced Russian technologies used both for commercial and Navy purposes: sonar and acoustic systems, sophisticated electronic systems, unmanned systems, etc.

Since the early 2010s, the Russian Federation has been working on developing autonomous navigation technology for its commercial vessels. The world’s largest Autonomous and Remote Navigation Trial Project (ARNTP) was successfully completed in 2019-2021, and since then, several commercial vessels have been using a-Navigation systems.

The ARNTP involves the following commercial vessels by the major Russian shipping companies:

- **Rabochaya**, motor barge owned by Rosmorport, IMO: 9838371, MMSI: 273436710, home port; Saint Petersburg, project: HB900, currently operating in the Black Sea together with REDUT dredger;

- **Pola Anfisa**, general cargo ship owned by Pola Rise, IMO: 9851115, MMSI: 273448220, home port: Saint Petersburg, project: RSD-59, currently operating in the Mediterranean and Black seas; and

- **Mikhail Ulyanov**, shuttle tanker owned by SCF, IMO: 9333670, MMSI: 273328440, home port: Saint Petersburg, project: R-70046, operating in the Barents Sea.

Experimental hardware on board has been developed and installed in accordance with the project documentation agreed by the Russian Maritime Register of Shipping (RS), surveyed by RS after installation and does not create safety risks or influence to other onboard systems of ships. The connection to existing on board systems was agreed with the systems manufacturers and shipowners, whilst the mechanical Mode Switch was installed on the connection line to actuators which provide physical link with ship bridge. In addition, a constant indication is available on board and in RCS regarding the status of mode switch and availability of autonomous navigation (a-Navigation) systems.

In 2019 a risk analysis was performed related to the functioning of new systems and arrangement of trials, which was taken into account as part of systems requirements and trial program. The trials program includes remote operation (via remote control station (RCS), with permanent contact with the supervising crew onboard), automatic navigation (using autonomous navigation system under the supervision of the crew onboard and additional control by the remote operator), and automatic navigation in heavy traffic areas. While the implemented approach supposes symbiosis of automatic, remote, and manual modes of control during the same voyage, depending on the situation, the trials of remote operation and automatic navigation were split to get more clear results about the implementation of each specific system.

Within the trial project, the Russian Federation introduced and tested a technological solution based on the principle of Complete Functional Equivalence. That is, all functions prescribed for the crew onboard by the valid Convention requirements are fulfilled at MASS automatically, without a crew on board. On one hand, it ensures that MASS interacts with other actors under the guidance of well-known and required functions, and on the other, it permits MASS to operate within the current framework of international legislation as is, without insisting that it be changed.
According to this principle, specifications for every a-Navigation system were developed, such as the requirement that the minimum parameters of visual object detection not fall below the accuracy of human vision, the requirement that the set of analyzed data match the set that an officer would receive and interpret, etc.

The architecture of the technical solutions Russia was experiencing is as below

![architecture diagram]

**Figure 2: architecture of the technical solutions Russia**

*Source: website A-navigation*¹³

The architecture is in accordance with the ones developed for the MUNIN project mentioned above.

Within the offered architecture, all systems and subsystems may be installed on already existing ship and make any ship an autonomous one.

The Autonomous Navigation System (ANS), which operates in accordance with the Complete Functional Equivalence principle, carries out automatic environmental analysis, passage along a predetermined route (in automatic mode and remote control mode), and automatic maneuvering decision-making while taking into account the vessel's parameters and COLREGs-72 provisions. Sensor Fusion Module (SFM), Automatic Collision Avoidance Module (ACAM), and ANS Client

---

¹³ https://a-nav.org/howitworks/system-architecture.html
are all components of ANS.

The Sensor Fusion Module (SFM) combines, synchronizes, and verifies navigational data from several sources, including the Optical Surveillance and Analysis System (OSA), Automatic Identification System (AIS), location, compass, weather station, and others. This is comparable to an officer on board who must combine information from all of these navigational systems with information from his eyes to create a single image.

The vessel’s maneuvering to avoid collisions with other vessels and navigational hazards are calculated by the Automatic Collision Avoidance Module (ACAM) in line with COLREGs-72 regulations. The clear guidelines with various scenarios were developed and issued in Russia at the level of Maritime Administration. The offered COLREGs-72 interpretation strictly determined algorithms assuring MASS would 100% predictable, even when placed in comparison with a traditionally crewed ship.

The ANS Client combines all the information from required and optional electronic charts (such ICE or SAT images) and any other available data before presenting it through ECDIS-like human interfaces.

An optical system that finds and recognizes nearby objects is called the Optical Surveillance and Analysis System (OSA). In addition to transmitting the video image after processing to human interfaces, it sends this data in a machine-readable format to the ANS (such as the Remote Control Station and Bridge Advisor).

The OSA successfully completes the difficult task of meeting traditional standards for providing visual observation in a fully autonomous mode while sitting in parallel to human-operated remote mode. Despite the fact that we are only now starting the process of teaching the OSA neural network to accurately recognize any items in various environments, we are certain that this automated strategy that does not rely on human-operated remote controllers will be successful in the long run. Thus, this goes beyond merely shifting human control and operation from onboard to shore.

At the same time, the OSA enables us to raise the level of human situational awareness in the Remote Control Station (RCS) as well as on board. In the near future, navigators may start using augmented reality (an image with additional suggestive information) and even fully virtual models (in case of low vision or issues with the communication line between the remote control and the vessel).

Internal CCTV provides various tasks like indoor video recording, automatic control over the condition of rooms (movement, change of geometric parameters, etc), equipment (change of indication, switch states, etc), cargo (displacement, crumbling, tilt and other parameters), and the transmission of this video information to the Bridge Advisor and Remote Control Station (RCS).

The Remote Control Station (RCS) is a workstation for a remote control operator and is designed to solve the entire range of remote monitoring and control tasks. It is located outside the controlled vessel and is the equivalent of a highly ergonomic ship's bridge and a central control station.
RCS is designed to simultaneously display to operator various data, those equivalent to the information on the ship’s navigation bridge:

- Navigation systems interface including ECDIS equivalent, autonomous navigation system and control interfaces of ship onboard radars;
- Video information display interfaces on the ambient surroundings and control of the optical surveillance and analysis system;
- Interfaces of the remote engine and technical monitoring system allowing surveillance and control of the unattended engine room;
- Interfaces of video information display and internal ship’s CCTV control;
- Interfaces of the ship motion control (joystick system);
- Radio interaction terminals for a RCS operator to interact with the onboard radio equipment (VHF and MF-HF radio stations, MF-HF radiotelex, Inmarsat station, Navtex receiver and public address system) connected to the corresponding devices onboard;
- Microphones and speakers for interaction with the public address system and receiving audio signals and video communication with the crew onboard;
- Indicators and interfaces of the a-navigation settings and diagnostics system.

The ship actuators get ANS commands from the Coordinated Motion Control system (CMS). Thus, CMS fulfills the same duties as the helmsman who translates the officer’s commands into steering and engine control operations. By CMS, we mean a trajectory control system or ship heading that is already known and employed on a small but expanding group of highly automated vessels. Within the scheme, CMS supports human control or accurately follows a predetermined course while taking into account the current weather and the ship model. We can automatically and remotely operate the propulsion and steering systems by linking CMS to ANS.

The trial program featured autonomous navigation utilizing an autonomous navigation system under the supervision of the crew aboard and additional management by the remote operator, remote operation using a remote control station (RCS), and automatic navigation in busy regions. The

---

14 https://a-nav.org/howitworks/remote-control-station.html
trials of remote operation and automatic navigation were divided to obtain more precise results regarding the implementation of each particular system, even though the implemented approach presupposes symbiosis of automatic, remote, and manual modes of control during the same voyage, depending on the situation.

Trial project resulted in the wide national experiment on autonomous shipping where every company can equip its ships with autonomous navigation equipment and commercially operates such ships in Russian ports.

It was reported, that in 2023 two largest Russian railway/vehicle carriers equipped with autonomous navigation systems are expected to be firstly in the world classified for MASS ships with reduced number of crew onboard. Both ships operate in Baltic Sea connecting Saint Petersburg and Kaliningrad.

In 2022, the Russian Federation reported to the IMO about development of advanced training programs for seafarers working on MASS, including certification programs and simulators.

Russian universities dealing with crew education and training considered the skills which may be required and developed the advanced training syllabus for the following roles: master of MASS Remote Control Center, master operating semi-autonomous ships, chief mate operating semi-autonomous ships, officer in charge of the navigation watch for semi-autonomous ship operations, management level engineer for semi-autonomous ship operations, officer in charge of engineering watch for semi-autonomous ship operations, electrical engineer for semi-autonomous ship operations, remote crew engineer officer of autonomous ship, VTS operator for traffic management and interaction with semi-autonomous and autonomous ships in the VTS area, GMDSS radio operator engaged in the maintenance of equipment and remote control station systems of autonomous ships (communications engineer).

The training with dedicatedly developed VR simulator is planned to start on 2023. The attendees are required to meet the requirements imposed to associated crew members in accordance with STCW Convention and STCW Code.

E. Singapore

Singapore is known for its vibrant and thriving maritime industry, with a strategic location at the crossroads of international shipping lanes. The city-state has built a reputation as a premier global hub port and an important maritime center in the region. In this response, we will provide a detailed overview of Singapore's maritime industry, including its role in the shipping industry, the shipowners, and the number of vessels in its fleet.

Singapore is one of the world's busiest shipping ports, handling millions of containers and bulk cargoes each year. The country's strategic location at the southern tip of the Malay Peninsula has made it a vital transshipment hub for goods flowing in and out of Asia. The Port of Singapore is also a critical gateway to the rest of Southeast Asia, connecting major economies like China, India, and Japan to the region. According to the Maritime and Port Authority of Singapore (MPA), the port handled a total of 36.6 million Twenty-Foot Equivalent Units (TEUs) of containers in 2020, making it the world's second-busiest container port after Shanghai.
Singapore is home to some of the world's largest shipping companies and shipowners, including Neptune Orient Lines, Pacific International Lines, and APL. These companies have invested heavily in building and operating large container ships, bulk carriers, tankers, and other vessels. In addition, many foreign shipowners have also established a presence in Singapore, taking advantage of the country's favorable tax and regulatory environment. As of January 2021, the total tonnage of ships under the Singapore flag was 97.3 million Gross Tonnage (GT), making it the fifth-largest ship registry in the world.

As of January 2021, there were a total of 4,651 vessels registered under the Singapore flag, according to the MPA. These vessels ranged from large container ships and bulk carriers to smaller tugboats and barges. In addition to ships registered under the Singapore flag, there were also many foreign-owned vessels operating in and out of the country's ports. The total fleet size of Singapore-registered vessels was 102.2 million Deadweight Tonnage (DWT) as of January 2021.

Singapore's merchant fleet is one of the most competitive in the world shipping market. One factor contributing to Singapore's competitiveness is its strategic location at the crossroads of major shipping lanes connecting Asia, Europe, and the Americas. The country has also invested heavily in its port infrastructure, with the Port of Singapore being one of the busiest and most advanced ports in the world.

Singapore's government has also been proactive in supporting the growth of its shipping industry, providing incentives for companies to register their vessels under the Singapore flag and offering a range of maritime-related services, including ship financing, insurance, and legal services. The country's maritime cluster contributes around 7% of its GDP and employs more than 170,000 people.

Another key factor contributing to Singapore's competitiveness is the quality of its shipping companies and shipowners. Many of these companies have a strong reputation for professionalism, reliability, and efficiency, with some of them ranking among the largest and most respected shipping companies in the world.

One major challenge is the high cost of operating in Singapore. Due to its status as a developed country and a major financial center, labor and other costs can be high. This can make it difficult for some shipowners to operate profitably in the country.

Singapore's reliance on foreign workers is also a potential weakness. Due to a lack of domestic labor supply, many jobs in the maritime sector are filled by foreign workers. This can create issues with labor supply and management, particularly during times of crisis like the COVID-19 pandemic.

Singapore has wide access to foreign advanced developments in autonomous navigation. In October 2019, ABB signed a contract with Keppel Offshore & Marine for the trial operation of an autonomous tug at the Port of Singapore with the support of the Government of Singapore and the American Bureau of Shipping ABS.

F. The United States of America

The US merchant fleet is owned by private companies, and the federal government plays a
significant role in promoting and regulating the industry. The government operates the Maritime Administration (MARAD), which is responsible for the promotion and development of the U.S. merchant marine, including the provision of funding for vessel construction, maintenance, and operation.

The US shipping industry is dominated by large international companies such as Maersk, MSC, CMA CGM, and COSCO. However, there are also numerous smaller companies and independent shipowners operating vessels in the U.S. fleet.

The US shipping industry plays a vital role in supporting the country's international trade. In 2020, US ports handled over 2.4 billion metric tons of cargo, with a total value of $2.3 trillion. The majority of this cargo is moved by container ships, with the Port of Los Angeles alone handling over 9.2 million twenty-foot equivalent units (TEUs) of containerized cargo in 2020. The US shipping industry also supports the country's energy sector, with crude oil and petroleum products being among the top cargo types moved by US vessels.

In terms of competitiveness, the US shipping industry faces challenges from low-cost competitors in Asia and Europe, as well as high regulatory costs and an aging fleet. However, the industry remains competitive due to its advanced technology, highly skilled workforce, and strategic location. The US government also provides support to the industry through various programs, including the Jones Act, which requires all vessels operating between US ports to be built, owned, and crewed by US citizens. The Jones Act, a US law that requires goods transported between US ports to be carried on American-owned and crewed vessels, can also be a barrier to competitiveness by limiting the ability of foreign ships to operate in domestic U.S. trade.

Additionally, the US shipping industry faces challenges in attracting and retaining qualified seafarers, as well as in financing new vessel construction and maintenance. The aging U.S. fleet also requires significant investment in order to remain competitive in the global market.

In the autonomous navigation, the US developments are mostly focused on the US Navy, the world’s largest navy known to be at the forefront of technological advancements. Unmanned Systems (variety of unmanned systems, including unmanned aerial vehicles (UAVs), unmanned surface vehicles (USVs), and unmanned underwater vehicles (UUVs)) are already used in the USA. At the same time, there are some developments, like Sea Robotics, converting these technologies for merchant fleet: primarily targeting at foreign shipping companies.
V. SELECTED ASIA-PACIFIC COUNTRIES REQUIRING THE NEW-TECHNOLOGY

While the above-mentioned group of countries has strong leading positions in autonomous navigation implementation, a number of major countries of the region don’t have access to the new technology. This creates both a growing imbalance in the regional maritime industry and risks of losing competitiveness of these countries in the global maritime industry.

A. India

The maritime industry plays a significant role in India's economy, as the country is surrounded by water on three sides and has a long coastline of approximately 7,500 km. The shipping industry is a critical component of the maritime business, facilitating international trade and commerce. According to the Ministry of Shipping, the maritime sector contributes around 5% of India's GDP.

The shipping industry in India is primarily dominated by private shipowners who own and operate vessels for both domestic and international trade. The sector includes various segments such as bulk carriers, container ships, tankers, and specialized vessels for transporting goods such as automobiles and chemicals. According to data from the Ministry of Ports, Shipping and Waterways of India, there were a total of 1,384 Indian-flagged vessels as of June 2021, with a total capacity of 19.97 million gross tonnage.

The Indian merchant fleet has been steadily growing in size and competitiveness in the world shipping market. One of the main factors contributing to India's competitiveness in the world shipping market is its large pool of skilled and low-cost seafarers. India has a vast workforce of seafarers who are well-trained and proficient in English, making them highly sought after by shipping companies around the world.

India's strategic location and vast coastline also play a significant role in its competitiveness. India is strategically located on major shipping routes connecting the Middle East, Africa, Europe, and Asia. Its ports serve as important transshipment hubs for cargo from neighboring countries, making it a critical link in the global supply chain.

Moreover, the Indian government has taken steps to modernize its ports and shipping infrastructure, making them more efficient and cost-effective. The introduction of advanced technology, such as electronic data interchange (EDI) and the use of containerization, has helped to streamline cargo handling processes and reduce transit times. The government has also implemented various policies to promote the growth of the domestic shipping industry, such as offering tax incentives for Indian shipping companies, providing subsidies for shipbuilding, and facilitating access to finance for shipping projects.

The Sagarmala program, launched in 2015, aims to promote port-led development and increase the efficiency of the logistics chain. Under this program, the government plans to develop new ports and modernize existing ones to increase their capacity and efficiency.

As a result of these efforts, the Indian merchant fleet has grown significantly in recent years. According to the Ministry of Shipping, the total tonnage of the Indian fleet has increased from
8.26 million gross tonnage (GT) in 2014 to 19.54 million GT in 2020. The number of Indian-owned vessels has also increased from 1,296 in 2014 to 1,516 in 2020.

Despite these efforts, the shipping industry in India has faced challenges in recent years. The COVID-19 pandemic led to a decline in global trade, resulting in reduced demand for shipping services. Additionally, the sector has faced issues such as high operating costs, limited access to finance, and competition from foreign shipping companies. Some of the major weaknesses are fleet aging (the average age of the Indian merchant fleet is around 18 years), lack of Investment (due to high capital costs, Indian shipowners are often unable to invest in new ships and in modern technology such as automation, digitalization, and artificial intelligence), limited domestic demand (unlike many other countries, India has limited domestic demand for shipping services, which makes it more difficult for Indian shipowners to achieve economies of scale).

**B. Indonesia**

Indonesia is the largest archipelagic country in the world, with more than 17,000 islands scattered across the country. This has made the maritime industry play a significant role in Indonesia's economic development, with the shipping industry being a major player. The shipping industry contributes significantly to Indonesia's economy, as it is the backbone of the country's transportation and trade.

As of January 2022, the Indonesian merchant fleet consists of 1,652 vessels, with a total capacity of 21.34 million gross tons. The fleet comprises various types of vessels, including container ships, bulk carriers, tankers, and general cargo ships. The majority of the fleet is domestically owned, with 1,494 vessels being Indonesian-owned, while the remaining 158 are foreign-owned. The average age of the fleet is 16.9 years, which is relatively old compared to other countries in the region.

The shipping industry in Indonesia is mainly dominated by domestically-owned enterprises, such as PT Pelabuhan Indonesia (Pelindo) and PT Pelayaran Nasional Indonesia (Pelni). Pelindo manages the 126 commercial ports, while Pelni operates passenger and cargo ships that connect major ports throughout the archipelago. Private Indonesian shipowners also play a significant role in the industry, with PT Berlian Laju Tanker, PT Meratus Line, PT Samudera Indonesia, and PT Soechi Lines being some of the largest private shipowners. These companies primarily operate in the bulk carrier, tanker, and container ship segments.

The Indonesian government has recognized the importance of the maritime industry and has been implementing policies to support its development. One of the government's primary focuses is to increase the domestic shipbuilding capacity to support the growth of the domestic fleet. In 2020, Indonesia's Ministry of Industry announced a plan to build a shipyard in Batam, with the capacity to build ships of up to 300,000 deadweight tons (DWT).

Despite the significant role played by the shipping industry in Indonesia's economy, there are several challenges that need to be addressed to improve its competitiveness in the global market. One of the main challenges is the high logistics cost in the country, which is primarily due to poor infrastructure and inefficient logistics systems. This makes it difficult for Indonesian shippers to compete with other countries in the region.
Another challenge is the lack of modernization and technology adoption in the industry. Most of the vessels in the Indonesian fleet are relatively old and do not have the latest technology and equipment. This makes them less efficient and less environmentally friendly compared to newer vessels.

The implementation of autonomous navigation technology in Indonesia's shipping industry could bring significant benefits, including increased efficiency, safety, and cost savings. However, there are also challenges to its implementation, such as the need for appropriate infrastructure and regulatory frameworks. The Indonesian government has recognized the potential benefits of autonomous navigation and has been taking steps to support its development. In 2018, the Indonesian Ministry of Transportation issued regulations allowing for the testing of autonomous vessels in the country's waters. This is a positive step towards the implementation of autonomous navigation technology in Indonesia's shipping industry.

C. Malaysia

Malaysia is one of the key players in the maritime industry in the Asia-Pacific region. The country is strategically located on major shipping routes connecting the East and West, which makes it an important member of the global shipping industry. Malaysia has a strong presence in the tanker and container shipping markets. According to the Malaysia Shipowners' Association (MASA), there are more than 1,000 Malaysian-owned vessels registered in Malaysia. The Malaysian International Shipping Corporation (MISC) is the largest Malaysian shipping company.

In terms of the type of vessels, the majority are bulk carriers, tankers, and container ships. In addition to MISC, there are several other ship-owners in Malaysia, including small and medium-sized enterprises (SMEs). According to MASA, there are about 70 ship-owners in the country, with the majority operating small to medium-sized vessels.

The port sector in Malaysia is also a significant contributor to the economy. Malaysia has several major ports, including Port Klang, which is the largest container port in the country and one of the busiest ports in the region. Other major ports include the Port of Tanjung Pelepas, Penang Port and Johor Port. In total, Malaysia has eight federal ports and over 30 state ports spread along the 4,675 km coastlines of Peninsular Malaysia, Sabah and Sarawak.

The role of the shipping industry in Malaysia's economy is significant. According to the Malaysia Institute of Transport (MITRANS), the maritime industry contributes about 3% of Malaysia's Gross Domestic Product (GDP) and provides employment for over 400,000 people. The shipping industry alone contributes about MYR 18 billion (approximately USD 4.4 billion) annually to the Malaysian economy.

According to the United Nations Conference on Trade and Development (UNCTAD), Malaysia was ranked 25th among the world's top 50 maritime nations in 2020, based on the country's total fleet size of 1,274 vessels with a total tonnage of 20.9 million gross tons (GT).

Malaysia has been actively developing its maritime infrastructure to support the growth of its shipping industry. The country has invested heavily in port development and expansion, with major projects such as the Kuala Linggi International Port and the Carey Island Container Terminal currently underway. In addition, Malaysia has established several free trade zones and maritime
hubs, such as the Port of Tanjung Pelepas, which offer attractive tax incentives and other benefits to shipping companies.

The Malaysian government has been taking steps to further develop and promote the country's maritime industry. This includes initiatives such as the Malaysia Shipping Master Plan, which aims to enhance the competitiveness of the shipping industry through measures such as improving port infrastructure, reducing port costs, and promoting the use of advanced technology.

Despite these strengths, the Malaysian shipping industry also faces some challenges. One of the main challenges is the shortage of skilled labor, particularly in the areas of ship design, construction, and repair. The country's shipbuilding and repair industry is relatively small and concentrated in a few key players, which limits competition and innovation. In addition, the industry has been impacted by the COVID-19 pandemic, which has led to disruptions in global supply chains and reduced demand for shipping services.

Like any other country, the Malaysian maritime industry faces several challenges. One of the major challenges is the competition from other countries in the region, such as Singapore and China. These countries have larger and more established maritime industries and are able to offer more competitive rates for shipping services. Another challenge is the high operating costs due to the country's strict regulations and taxes. This has resulted in some Malaysian shipowners registering their vessels in other countries with lower costs.

One major challenge is the high cost of operations, including fuel and labor costs, which can make it difficult for Malaysian shipowners to compete with other countries that have lower operating costs. In addition, there is a shortage of skilled and trained seafarers in Malaysia, which can impact the quality of the workforce and the competitiveness of the industry.

Another challenge is the lack of modernization and investment in the Malaysian shipping industry. While some improvements have been made, such as the development of new ports and shipping facilities, there is still a need for further investment in technology, infrastructure, and training to improve efficiency and competitiveness.

D. The Philippines

The country is one of the top providers of maritime manpower. According to the Philippine Overseas Employment Administration (POEA), the country is the largest supplier of seafarers, with over 400,000 Filipinos working on ships around the world as of 2021. This accounts for approximately 25% of the global seafaring workforce.

In terms of ship ownership, the Philippines ranks among the top countries in the world, with a total of 1,796 registered ships as of 2021. These include both domestic and foreign-owned vessels, with a total gross tonnage of 22.7 million. The Philippines also has a significant shipbuilding industry, with a number of shipyards operating throughout the country. In 2020, the country was the sixth-largest shipbuilder in the world, with a total output of 126,000 compensated gross tons (CGT).

The maritime industry in the Philippines also plays a significant role in the country's economy, with the Philippine Ports Authority (PPA) reporting a total cargo volume of 300.5 million metric tons in 2020. This included both domestic and foreign cargoes, with the Port of Manila being the
largest container port in the country. The PPA also reported a total of 9,679 vessel calls in 2020, with an average gross tonnage of 18,485 per vessel.

The country's shipping industry is one of the largest in the world, and its geographical location makes it a natural hub for maritime trade in the Asia-Pacific region. The Philippines' competitive advantage lies in its large pool of skilled seafarers, who are recognized for their technical expertise and proficiency in English. The Philippines' merchant fleet is also competitive in terms of its size and modernity. According to the Philippine Maritime Industry Authority (MARINA), the country's registered fleet stood at 4,466 vessels as of September 2021, with a total gross tonnage (GT) of 26.22 million. This fleet is composed of a mix of cargo ships, tankers, passenger vessels, and other types of vessels.

The Philippines' competitive edge is further bolstered by its favorable policies and incentives for the shipping industry. The government has implemented various measures to promote the growth of the maritime sector, including tax exemptions for local shipbuilders, subsidies for the construction of new vessels, and the establishment of economic zones for maritime-related activities.

The maritime industry in the Philippines is regulated by the Maritime Industry Authority (MARINA), which is responsible for the registration and inspection of ships as well as the certification of seafarers. The agency is also responsible for the development and implementation of policies and programs aimed at promoting the growth and competitiveness of the Philippine maritime industry.

The Philippines has also been actively pursuing bilateral and regional agreements to enhance its maritime connectivity and trade relations with other countries. For instance, the country has signed several maritime cooperation agreements with neighboring countries such as Japan, the Republic of Korea, and China, which aim to promote trade and investment in the maritime sector.

**E. Thailand**

Thailand has a coastline of 3,219 km, more than 250 islands, and over 4,000 km of inland waterways. Thailand has multiple strategically located ports and comparatively advanced port infrastructure and efficiency. Its largest port, Laem Chabang Port, is ranked 22nd globally and handles 54% of Thailand’s total import and export.

The shipping industry in Thailand is primarily owned and operated by private companies. According to the Marine Department of Thailand, as of 2021, there were approximately 3,444 registered ships in Thailand, with a total gross tonnage of 8.4 million. Of these, approximately 2,062 ships were engaged in domestic trade, while 1,382 were involved in international trade.

Shipowners in Thailand range from small-scale operators with just a few vessels to large conglomerates with substantial fleets. Some of the largest shipping companies in Thailand include Precious Shipping, Thoresen Thai Agencies, and RCL Group. These companies operate a range of vessel types, including bulk carriers, container ships, and tankers, and provide transportation services to destinations around the world.
The role of the shipping industry in Thailand is to facilitate the movement of goods to and from the country. In 2020, Thailand exported approximately $215 billion worth of goods, with the top destinations including China, Japan, and the United States. The country also imported approximately $191 billion worth of goods, with the top sources of imports including China, Japan, and the United States.

The shipping industry plays a critical role in supporting these trade flows by providing efficient and cost-effective transportation services. For example, in 2020, Thailand's top exports by sea included motor cars, refined petroleum, and rubber, while the top imports included crude petroleum, integrated circuits, and gold. These goods were transported by a range of vessel types, including container ships, tankers, and bulk carriers.

In addition to supporting the country's trade flows, the shipping industry in Thailand also contributes to the local economy through the employment of seafarers and other maritime professionals. According to the International Transport Workers' Federation, there were approximately 62,000 seafarers employed in the Thai shipping industry as of 2021. These seafarers work on a range of vessel types, including container ships, bulk carriers, and oil tankers.

F. Viet Nam

Viet Nam is a rapidly developing country located in Southeast Asia and is known for its long coastline stretching over 3,260 km. With its extensive coastline and abundant natural resources, Vietnam has a thriving maritime industry that plays a vital role in its economic growth.

The shipping industry in Vietnam is primarily concentrated in two main areas: the northern region, centered around the port of Hai Phong, and the southern region, with the port of Ho Chi Minh City being the hub. The country has 45 seaports, including 12 major ports and 33 other ports, with the majority of the ports owned and operated by the state-owned Vietnam National Shipping Lines (Vinalines). The ports handle a wide variety of cargo, including containerized goods, bulk cargo, and petroleum products, with the majority of the cargo being handled by foreign shipping companies.

In terms of ownership, Vietnam has a relatively small fleet compared to some of its neighbors in the region. According to data from the Vietnam Maritime Administration, as of 2021, Vietnam's shipping fleet consisted of around 1,500 vessels with a total capacity of approximately 7 million deadweight tons (DWT). The majority of the vessels are small and medium-sized, with an average age of around 15 years.

Despite the small size of its fleet, Vietnam is an important player in the global shipping industry. The country is a major producer and exporter of goods such as electronics, textiles, and footwear, and the shipping industry plays a vital role in transporting these products to markets around the world. According to data from the World Bank, in 2020, the value of Vietnam's exports was $281 billion, and the country ranked 14th in the world in terms of total trade volume.

The shipping industry also plays an important role in Vietnam's economy in terms of employment. According to data from the Vietnam Maritime Administration, the industry employs around 35,000 seafarers, with an additional 20,000 workers employed in port-related activities.
In recent years, the Vietnamese government has been working to modernize and expand its maritime infrastructure in order to support the country's growing economy. This has included the construction of new ports and the expansion of existing ones, as well as investments in new vessels and other maritime equipment. The government has also been working to attract more foreign investment in the shipping industry, with a particular focus on the development of the country's shipbuilding sector.
VI. STRENGTHENING THE REGION’S CAPABILITIES

The above-mentioned imbalance of access to the new technology should be a point for the ESCAP cooperation. Implementation of innovative autonomous shipping technologies ensures the sustainability of regional and global shipping in the Asia-Pacific region.

Strengthening the Asia-Pacific countries' capabilities to implement innovative autonomous navigation technologies will require a comprehensive approach that addresses several key factors:

1. Policy and regulatory frameworks: Governments in the Asia-Pacific region need to develop clear and supportive policy and regulatory frameworks that encourage the development and adoption of autonomous navigation technologies. This includes creating a favorable investment climate, providing tax incentives and subsidies, and establishing clear rules and standards for safety, security, and data privacy.

2. Research and development: Investment in research and development is critical to advancing autonomous navigation technology in the Asia-Pacific region. Governments, universities, and private companies can collaborate on R&D projects to develop new technologies and improve existing ones. This includes developing new algorithms and sensors, improving machine learning capabilities, and testing and validating new systems.

3. Education and training: Developing a skilled workforce is essential to implementing autonomous navigation technologies. This includes providing education and training opportunities to engineers, data scientists, and other professionals to ensure that they have the skills and knowledge needed to design, develop, and operate autonomous navigation systems.

4. Infrastructure and connectivity: Autonomous navigation technologies require advanced digital infrastructure and connectivity to function effectively (like e-Navigation, EDI, etc). Governments in the Asia-Pacific region need to invest in developing and upgrading the necessary infrastructure, including high-speed networks, data centers, and communication systems. This will ensure that autonomous navigation technologies can operate reliably and securely in diverse environments.

5. Collaboration and knowledge-sharing: Collaboration and knowledge-sharing among countries, companies, and research institutions are critical to advancing autonomous navigation technologies. Governments can facilitate collaboration by creating networks and platforms that enable knowledge-sharing and collaboration among stakeholders. This includes creating innovation hubs, research centers, and regulatory sandboxes that allow stakeholders to test and validate new technologies in a controlled environment.

Overall, strengthening the Asia-Pacific countries' capabilities to implement innovative autonomous navigation technologies will require a coordinated effort by governments, industry stakeholders, and civil society. By creating supportive national programs for developing countries, the region can realize the full potential of autonomous navigation technologies to improve connectivity, logistics, and mobility while promoting sustainable and inclusive development.
National programs for the implementation of autonomous shipping technologies would vary depending on the country and its specific maritime needs and challenges. However, here are some general components that might be included in such a plan:

1. **Regulatory framework**: A national program for the implementation of autonomous shipping technologies should include a clear regulatory framework that addresses the legal and liability issues associated with these technologies. This should include standards for autonomous vessel design, operation, and maintenance, as well as regulations for data privacy and cybersecurity.

2. **Research and development**: A national program for the implementation of autonomous shipping technologies should include funding for research and development to support the innovation and testing of these technologies. This may include partnerships between industry and academia to develop and test new technologies.

3. **Infrastructure development**: A national program for the implementation of autonomous shipping technologies should include investments in infrastructure needed to support these technologies. This may include the development of autonomous ports, shore-based control centers, and communication networks to support the operation of autonomous vessels.

4. **Skills development**: A national program for the implementation of autonomous shipping technologies should include programs to develop the skills and knowledge needed to operate and maintain these technologies. This may include training programs for seafarers, engineers, and other stakeholders.

5. **Public engagement**: A national program for the implementation of autonomous shipping technologies should include efforts to engage the public and build support for these technologies. This may include public consultations, stakeholder engagement, and communication campaigns to raise awareness of the benefits and risks associated with autonomous shipping.

6. **Trial projects**: A national program for the implementation of autonomous shipping technologies should include trial projects to test these technologies in a real-world environment. This may include partnerships between industry and government to test autonomous vessels in different operating conditions and assess their performance and safety.

By addressing the key components outlined above, countries like Indonesia, India, Malaysia, Thailand, Viet Nam and the Philippines can develop a roadmap for the safe and sustainable adoption of these technologies in their maritime industries to prevent long-term imbalance and lagging behind in the development of the global industry.

At the same time, the leading countries like the Russian Federation, Japan, China, and the Republic of Korea should be encouraged to share their experience and technologies, provide transfer and access to the new technology. It should include knowledge-sharing and joint R&D, practical implementation of new technologies in training, shipping and shore infrastructure.
The international shipping industry is facing an important turning point. In the next decade, we will see the introduction of autonomous ships – vessels that can sail without a crew on board. This technology has the potential to revolutionize the shipping industry.

The benefits of autonomous shipping are many and varied, but developing countries in particular stand to benefit greatly from the implementation of these technologies. Efficient transportation and reduced expenditures related to crew onboard are just two of the potential advantages.

Speaking purely in terms of economics, the benefits of autonomous shipping are quite clear. Developing countries stand to benefit the most, as they are often the ones who lack the infrastructure and manpower needed to maintain a modern fleet of cargo ships. Additionally, crew costs can be extremely high, so anything that can reduce those expenses would be a major boon. With fewer crew members required on board, food and lodging expenses would also be reduced. All of these cost savings could eventually be passed on to consumers in the form of lower prices for goods transported via autonomous vessels.

But beyond mere economic considerations, there are many other very important factors, like positive environmental impact, social impact and gender equality.

Developing countries like Indonesia, India, Malaysia, Thailand, Viet Nam and Philippines have a tremendous opportunity to leapfrog into the next generation of the maritime industry by adopting new technologies. The key to achieving this is the development of a clear roadmap that addresses the crucial components such as safety, sustainability, and competitiveness. By adopting these technologies, these countries can prevent long-term imbalance and lagging behind in the global industry.

One of the critical components that must be addressed is safety. The implementation of new technologies such as autonomous vessels, e-navigation systems, and other innovative solutions must be done in a way that ensures the safety of vessels, crew members, and the environment. It is vital that these countries develop robust safety protocols and standards for the adoption of these new technologies to prevent any mishaps or accidents.

Another crucial component is sustainability. The maritime industry is responsible for a significant portion of global carbon emissions, and there is a growing awareness of the need to reduce its impact on the environment. The adoption of new technologies can help reduce emissions and promote sustainable practices in the industry. Countries must, therefore, develop policies and incentives that encourage the use of green technologies, such as electric and hybrid vessels, renewable energy sources, and other sustainable solutions.

Competitiveness is also a crucial component that must be addressed to ensure that these countries remain on the proper level in the global maritime industry. Adopting new technologies can enhance productivity, efficiency, and reduce costs, all of which can help increase competitiveness. Countries must develop strategies and policies that encourage the use of new technologies, such as digitalization, big data analytics, and other innovative solutions.

Moreover, to ensure a smooth transition to the new technology, leading countries like the Russian Federation, Japan, China, and the Republic of Korea should share their experience and technologies with developing countries. It is important to provide transfer and access to new technology.
and develop knowledge-sharing and joint R&D. The practical implementation of new technologies in training, shipping, and shore infrastructure will help to develop the necessary skills and knowledge required to manage and operate these technologies effectively.
List of abbreviations

AAWA – Advanced Autonomous Waterborne Applications
ABB – a Swedish-Swiss multinational corporation
ABS – American Bureau of Shipping
ACAM – Automatic Collision Avoidance Module
AI – Artificial Intelligence
AIS – Automatic Identification System
ANS – Autonomous Navigation System
ARNTP – Autonomous and Remote Navigation Trial Project
a-Navigation – Autonomous Navigation
Autoship – Autonomous Shipping Initiative for European Waters
CCTV – Closed Circuit Television
CGT – compensated gross tons
COLREG – Convention on the International Regulations for Preventing Collisions at Sea
DFFAS – Designing the Future of Full Autonomous Ship
DNV – Det Norske Veritas
DWT – deadweight tons
EDI – electronic data interchange
ETRI – Electronic and Telecommunications Research Institute
EU – European Union
FAL – Facilitation Committee of the International Maritime Organization
FPSU – floating production and storage unit
GDP – Gross Domestic Product
IMF – International Monetary Fund
IMO – International Maritime Organization
KAIST – Korea Advanced Institute of Science & Technology
KASS – Korea Autonomous Surface Ship Project
KMI – Korea Maritime Institute
KMOU – Korea Maritime and Ocean University
KR – Korea Register of Shipping
KRISO – Korea Research Institute of Ships and Ocean Engineering
KSOE – Korea Shipbuilding & Offshore Engineering Co., Ltd.
LEG – Legal Committee of the International Maritime Organization
LNG – liquefied natural gas
MARINA – Philippine Maritime Industry Authority
MASA – Malaysia Shipowners' Association
MASS – Maritime Autonomous Surface Ships
MEPC – Marine Environment Protection Committee of the International Maritime Organization
MINT Fund – Maritime Innovation and Technology Fund (Singapore)
MISC – Malaysian International Shipping Corporation
MITRANS – Malaysia Institute of Transport
MMU – Mokpo National Maritime University
MOL – MOL Marine & Engineering Co., Ltd.
MSC – Maritime Safety Committee of the International Maritime Organization
MSC MASS CG – Correspondence Group on MASS managed by Maritime Safety Committee of the International Maritime Organization
MTI – Japanese private company
MUNIN – Maritime Unmanned Navigation through Intelligence in Networks
MYR – Malaysian Ringgit
NYK – Nippon Yūsen Kabushiki Kaisha, a Japanese shipping company
OSA – Optical Surveillance and Analysis System
POEA – Philippine Overseas Employment Administration
PPA – Philippine Ports Authority
RAP – Regional Action Programme
R&D – Research and Design
RCC – Remote Control Centre
RCS – Remote Control Station
ROSS – Remotely Operated Service at Sea
RS – Russian Maritime Register of Shipping
RSE – Regulatory Scoping Exercise of the International Maritime Organization
SEADRONIX – Korean company
SFM – Sensor Fusion Module
SME – small and medium-sized enterprise
SOLAS – International Convention for the Safety of Life at Sea
TEU – twenty-foot equivalent unit
TC – Technical Cooperation Committee of the International Maritime Organization
VTT – Technical Research Center of Finland
UANGEL – Korean company
UAV – unmanned aerial vehicle
UK – United Kingdom
UNCTAD – United Nation Conference on Trade and Development
USD – United States’ dollars
USV – unmanned surface vehicle
UUV – unmanned surface vehicle