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A Study on the Regulatory Framework for Operational Safety & Suitability Evaluation of MASS

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Abstract : *The 'Korea Autonomous Surface Ship' project has been underway from 2020 to 2025, featuring active demonstrations of key maritime technologies. In response, the 'Act on the Development and Commercialization of Autonomous Ships' will take effect on January 3, 2025, establishing a regulatory framework to support the advancement of autonomous ships. As these developments progress, there is a growing need for operational environment information that is specifically tailored to the perception and utilization of autonomous ships, ensuring their safe and efficient operation in maritime settings. This study examines the regulatory framework related to the development of 'Operational Safety and Suitability Evaluation Technology for Autonomous Ships' and proposes potential improvements for the Operational Safety and Suitability Evaluation of Maritime Autonomous Surface Ships (MASS).*

Key words : *MASS, Autonomous ship, Operational Safety & Suitability Evaluation, Autonomous Ship Act, Regulatory Sandbox, Regulatory Exceptions*

1. Introduction

The development of autonomous ship technologies is becoming increasingly competitive, accompanied by growing legislative support to promote related industries and establish standards. International Maritime Organization (IMO) is currently developing the Maritime Autonomous Surface Ships(MASS) Code, an international standard aimed at ensuring the safe operation of autonomous ships. The non-mandatory code is scheduled for adoption in 2025, followed by an Experience Building Phase (EBP) to accumulate operational experience. The mandatory version of the MASS Code is expected to come into effect in 2032.

Major countries, including Japan, China, Norway, and the European Union (EU), are actively advancing the maritime demonstration of key technologies for autonomous ships innovating regulations through the establishment of guidelines and the development of regulations for unmanned remote operations of autonomous ships. In South Korea, the 'Korea Autonomous Surface Ship' project has been underway from 2020 to 2025. As maritime demonstrations of related key technologies are actively progressing, the 'Act on the Development and Commercialization of Autonomous Ships' (hereinafter referred to as the Autonomous Ship Act), which includes provisions for the autonomous ship navigation zones, approvals of navigation, and regulatory exceptions for sea-trials, has been established and is set to take effect on January 3, 2025. (Lee, 2018).

International trends in autonomous ship technology development emphasize enhancing the autonomy and intelligence of vessels. Countries such as the EU, Finland, Norway, and the United Kingdom are actively engaged in research on key technologies, including situational awareness, autonomous navigation, berthing and deberthing, and fleet management. Moreover, these countries are facilitating the research through proactive regulatory innovation at a national level, not only advancing technological development but also contributing to the establishment of a regulatory framework that allows for the safe demonstration of autonomous ships in real operational environments.

In South Korea, 'Marine Traffic Safety Examinations' is implemented to investigate and assess navigational safety risk factors in coastal and harbor environments. Furthermore, Korea Hydrographic and Oceanographic Agency (KHOA) conducts hydrographic survey projects to generate essential data required for the maintenance and management of coastal and harbor areas. While both approaches offer partial applicability to autonomous ships,

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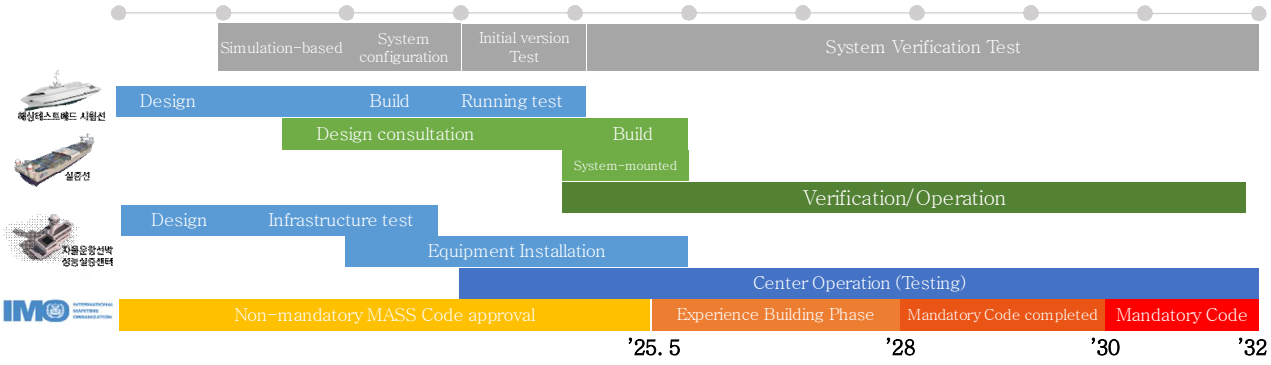

Fig. 1 IMO MASS CODE development roadmap and KASS schedule (as of May 2024)

existing systems focus primarily on the operational environment of conventional merchant vessels, emphasizing the need for parallel assessments of communication environments, which are critical factors for autonomous ships. Furthermore, the navigational information currently used by manned vessels, such as electronic nautical charts, is developed to provide information to human navigators. Thus, a comprehensive evaluation of the communication environment, a critical factor for autonomous ship operations, must be conducted as well.

This study examines the current regulatory framework associated with the development of 'Operational Safety and Suitability Evaluation Technology for Autonomous Ship,' which assesses the infrastructure and operational environment for autonomous ship operations in coastal and port areas beyond the key technologies of autonomous ships. Additionally, it seeks to address the legal constraints within the regulatory framework that arise during the technological development process and explore improvement directions through regulatory innovation.

2. Operational safety & suitability evaluation of MASS

Three key technologies have been identified to evaluate and provide environmental information for autonomous ship operations in coastal or harbor. Fig. 2 shows the system configuration and data flow between the MASS and the remote operation centre (ROC).

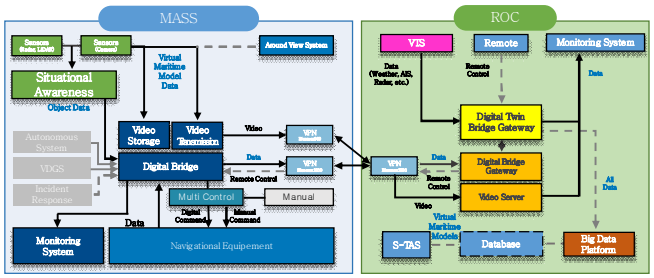

Fig. 2 MASS-ROC Configuration

2.1 Data acquisition

2.1.1 Onshore data

Ship traffic measurement infrastructure, fixed objects (Island, aids to navigation, fishing nets) and sea state acquisition system are organized to obtain data for operational safety & suitability evaluation of MASS. As shown in Fig. 3, ship traffic data is acquired using Automatic identification system(AIS) and a radar. By fusing object information detected by the radar with AIS, accurate location can be obtained.

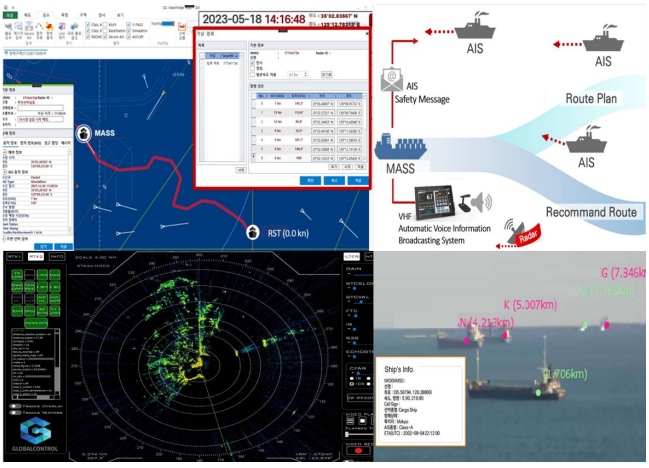

Fig. 3 Vessel Traffic Service for MASS Sea-trial Test Area

2.1.2 Sea-trial data

Communication is a dominant environmental factor in the operation of MASS, and Table 1 shows the communication network parameters for real-time monitoring of autonomous ships and evaluation of the suitability of the ship-to-shore communication environment for remote control system. A grid based on the arrival and departure routes of ships in the target area is generated, and while the ship navigates along arbitrary routes, the communication network parameters in specific grid sections are automatically measured and the data is accumulated. In open sea, autonomous ships have limited access to available communication networks. However, in coastal or harbor, commercial networks such as LTE and 5G, as well as LTE-M and satellite communications can be used. In addition, video data and location information (such as radar and LiDAR) will be measured to generate a high-precision virtual maritime area for the target areas.

Table 1 Communication Parameters

Type	Item
Network Performance	Bandwidth (Mbps or Gbps)
	Latency (ms)
	Packet Loss (%)
Signal Quality	RSSI (dBm)
	RSRP (dBm)
	RSRQ (dBm)
	SINR (dB)
	PCI (-)

2.2 MASS operational safety & suitability evaluation based on sea-trial

A comprehensive analysis of operational environment data for autonomous ships, including ship traffic, fixed objects, sea state, and communication is conducted to derive safety and suitability evaluation indices. Fig. 4 shows the ships navigating through Jangsaengpo Port and the aids to navigation, which are used to evaluate the encounter relationship with the own ship and the safe distance. Statistical analysis for each grid will be conducted using communication network parameters, and evaluation models related to autonomous navigation and remote control will be developed. Fig. 5 presents the frequency of encounters experienced by a vessel during its arrival and departure at Jangsaengpo Port

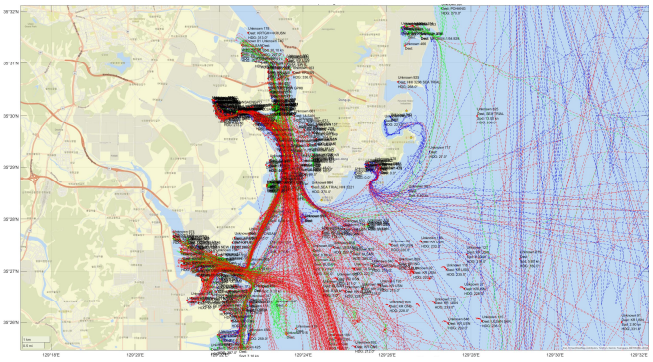

Fig. 4 Data at Jangsaengpo Port (4 Days)

2.3 MASS operational safety & suitability evaluation based on virtual maritime area

Simulation-based testbed for autonomous ship (S-TAS) is equipped with interfaces for performance verification of autonomous navigation algorithms and is designed to carry out safety and suitability evaluations. High-precision virtual maritime models will be included to assess environments where the operation of autonomous ships is restricted. A reliable simulation system will be established by implementing fixed object information obtained through onshore data and the communication environment distribution acquired from sea-trial data. Fig. 6 shows the virtual maritime model of Ulsan Port currently implemented in S-TAS.

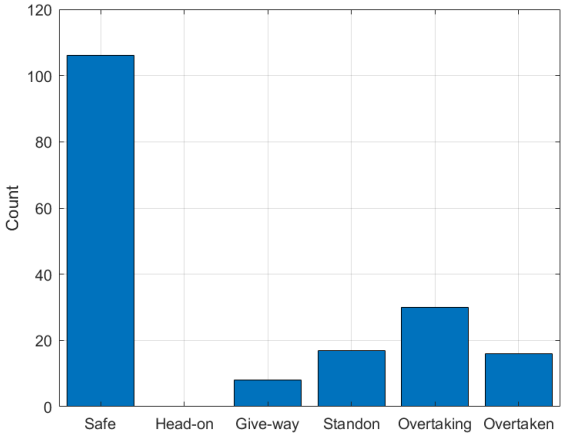

Fig. 5 Encounter analysis during arrival & departure

Fig. 6 Virtual Ulsan Port in S-TAS

3. Current Status of Domestic Regulatory Framework

To develop operational safety and suitability evaluation technologies for autonomous ships, it is essential to improve the current regulatory framework to enable the effective use of operational environment measurement data (such as navigation data, virtual environment model data, etc.) In the existing legal framework prior to the enactment of the Autonomous Ship Act, there is a lack of legal basis for the testing and validation of autonomous navigation in areas such as port data measurement and utilization, manning standards, and designated navigation zones, which are essential to meet legal requirements for evaluation technology development.

These legal limitations restrict the measurement, sharing, and utilization of data needed to develop operational safety and suitability evaluation technologies for MASS. They also hinder the smooth execution of autonomous navigation and remote-control testing, posing challenges in securing diverse validation data and deriving relevant evaluation metrics.

3.1 Current Status of Regulatory framework for Data Measurement, Sharing, and Utilization

Fig. 7-8 shows the sea-trial testbed vessel "Haeyang Nuri" and its onboard sensors (such as cameras and radar), which are used to measure and collect operational environment data near major domestic ports for safety and suitability evaluations. This data will be analyzed and utilized to establish safety and suitability evaluation database, as well as to develop and design models for virtual port evaluation. During the research process, operational environment data (such as water depth and terrain) will be measured in real time through Haeyang Nuri's onboard sensors. Table 2 presents key specifications of Haeyang Nuri, which will be used for data measurement and testing purposes in the development of operational safety and suitability evaluation technology for MASS.

Fig. 7 Haeyang Nuri

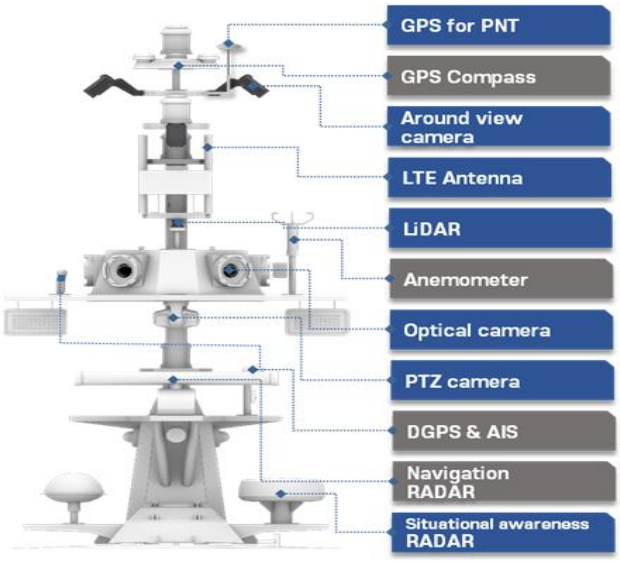

Fig. 8 Sensors on Haeyang Nuri

Table 2 Sea-trial Testbed Vessel "Haeyang Nuri" Specification

Specification	Content
Ship name	Haeyang Nuri
Class	KOMSA
Hull Material	Composite material
Design Speed	12 Knots
Length O.A.	26.5 m
Length B.P.	22.44 m
Breadth, MLD	5.40 m
Depth. MLD	2.47 m
Planned Draft at Full Load	1.35 m
Gross Tonnage	69 tons
No. of Person on Board	Crew (3 persons), Researchers (17 persons)

According to Article 33, Paragraph 1, Item 4 of the " International Ship and Port Facility Security Act" and Paragraph 2 of the same Act, prior approval from the port facility security officer is required for the filming and utilization of data related to port facilities (such as maritime traffic facilities and navigational aids). However, due to the characteristics of the sensors onboard autonomous ships, which capture and reprocess data in real time, there are limitations to the uniform application of the current law. Additionally, under the "Act on the Protection and Use of Location Information" (hereinafter referred to as the Location Information Act) and Article 35 of the "Sea Traffic Safety Act," it is challenging to disclose or utilize individual vessel and personal location information.

Prior to the enactment of the Autonomous Ship Act, the constraints imposed by existing legislation limit the acquisition and utilization of data, allowing only for restricted access through the regulatory sandbox system that provides certain regulatory exceptions. Upon the implementation of the Autonomous Ship Act in 2025, regulatory exceptions will apply to the filming of port facilities utilizing the sensors specified in Table 3. Furthermore, in instances where the captured video data and personal location information are anonymized, such data will take precedence for continuous utilization, thereby superseding other applicable legal provisions.

3.2 Current Status of Regulatory framework for Autonomous Navigation and Remote Control

To develop safety and suitability assessment indicators based on actual operating areas, it is essential to analyze risk through the measurement of not only vessel traffic and environmental data but also communication environments and shadow zone data within the operational area. To achieve this, testing of autonomous navigation and remote control in specific navigation zones is required, followed by an analysis of the results.

Under the current regulatory framework, there is no legal basis for conducting tests on autonomous navigation and remote control systems, as there are no designated navigation zones or safety standards for such tests. In particular, the operational standards outlined in the current “Ship Officers Act“ assume that vessel navigation is conducted by human personnel, making it difficult to apply existing regulations to tests involving system-based autonomous navigation and remote control. Before the enactment of the Autonomous Ship Act, vessels utilizing new technologies, such as autonomous ships, can only conduct individual demonstrations by determining the operational period and area for each vessel based on Article 3, Paragraph 3 of the Ship Safety Act or through applications to the regulatory sandbox system.

Table 3 Regulatory Exceptions Under the Autonomous Ship Act (Article 21, Article 24)

Legal Provision	Main Content
「Ship Safety Act」 Articles 7 to 17	Regulatory Exceptions for Ship Survey
「Ship Safety Act」 Articles 26 to 30	Regulatory Exceptions for Ship facility standards
「Ship Safety Act」 Articles 31 to 33	Regulatory Exceptions for Measures to Safe Navigation
「Ship Officers Act」 Articles 11 to 13	Regulatory Exceptions for Manning Standards and Duties of Ship officers
「International Ship and Port Facility Security Act」 Article 33, Paragraph 1, Item 4	Regulatory Exceptions for Port Facility Filming Sharing Industrial Data
「Location Information Act」 Article 2, Item 2	Exemption from Other Regulations When Utilizing Anonymized Personal Location Information

Following the enactment of the Autonomous Ship Act, a legal basis will be established for the continuous testing of autonomous navigation and remote control in designated navigations zones for autonomous ships. Regulatory exceptions concerning manning standards and duties of ship officer as stipulated in the Ship Safety Act and the Ship Officers Act will be applicable, allowing for exceptions to existing regulations. This will enable the derivation of various safety and suitability assessment indicators based on communication environment data measurement and the establishment of control transition zones, thereby contributing to the advancement and commercialization of autonomous ship technologies through regulatory innovation.

4. Directions for the Improvement of Domestic Regulatory Framework

4.1 Implementation of Regulatory Sandbox Prior to the Enactment of the Autonomous Ship Act

Before the enforcement of the Autonomous Ship Act,

there are difficulties in securing a demonstration track record and ensuring the continuity of research due to constraints such as the acquisition and utilization of measurement data for developing operational safety and suitability assessment technologies for autonomous ships, as well as the establishment of specific navigation zones and periods. In order to promote the continuity of research and development and regulatory easing within the current regulatory framework, key government agencies related to regulatory improvements for new technologies and new industries, including the Office for Government Policy Coordination, the Ministry of Science and ICT, the Ministry of Trade, Industry and Energy, the Ministry of SMEs and Startups, and the Financial Services Commission, operate a "Regulatory Sandbox" system.

The Regulatory Sandbox system provides exceptions from existing regulatory applications to participating businesses, thereby rapidly supporting research, development, and industrialization of new industries. In South Korea, a regulatory sandbox has been introduced for new industrial sectors that stipulates rapid regulatory confirmation, regulatory exceptions for demonstrations, and temporary permits as core measures. Within the regulatory sandbox, regulatory exceptions apply to the existing regulatory framework, allowing products and services utilizing new technologies such as autonomous navigation technology to be researched and industrialized without regulation under certain conditions.

Currently, regulatory sandbox for autonomous ships is in operation, and proactive maritime demonstrations of key technologies for autonomous ships, such as collision avoidance and remote control, are expected to take place before the enforcement of the Autonomous ship Act. During the project period, regulatory exceptions to existing maritime laws will be applied, which will play a role in providing demonstration information during the process of establishing detailed standards for the subordinate regulations of the Autonomous Ship Act that is set to be enacted, through safety verification of related technologies and the collection and utilization of demonstration records.

4.2 Directions for the Improvement of Domestic Regulatory Framework Following the Enactment of the Autonomous Ship Act

Following the enforcement of the Autonomous Ship Act, it is anticipated that maritime demonstrations of autonomous navigation technology will be conducted under the framework of the Autonomous Ship Act and the Regulatory Sandbox system. As the Autonomous Ship Act is scheduled to take effect in January 2025, drafts of the subordinate regulations (enforcement decree, enforcement rules, and regulations on safe navigation) have been prepared. however, there is currently a lack of specific standards and corresponding demonstration data to support these standards.

When new technologies or services, such as autonomous navigation vessel technology, do not yet possess sufficient technical safety or have not undergone risk assessments, the Regulatory Sandbox allows for an opportunity to secure safety and risk assessments of relevant regulations through regulatory exceptions. Through proactive demonstration operations within a specified period in the Regulatory Sandbox, not only can the safety and suitability assessment technology for operating autonomous ships be developed, but also demonstration data can be gathered to verify the safety and reliability of related key technologies.

Participants in the Regulatory Sandbox can test their services or product solutions for a certain period, regardless of regulatory constraints, to assess their positive impact on customers and the market. Regulatory agencies can then examine the effects of new solutions and promptly implement regulatory innovations if improvements or relaxations of regulations are deemed necessary.

Even after the enforcement of the Autonomous Ship Act, providing supporting materials for legislative improvements to resolve discrepancies or inconsistencies between the Regulatory Sandbox and related regulations will enable ongoing adjustments and the incorporation of standards into subordinate regulations. This will contribute to reasonable regulatory improvements and meticulous regulatory design.

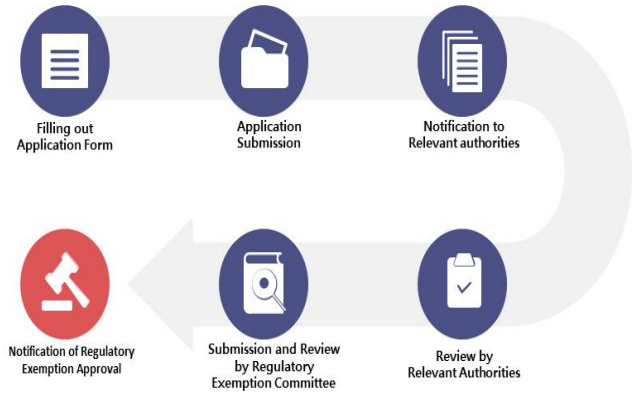

Fig. 9 Regulatory Sandbox Procedure

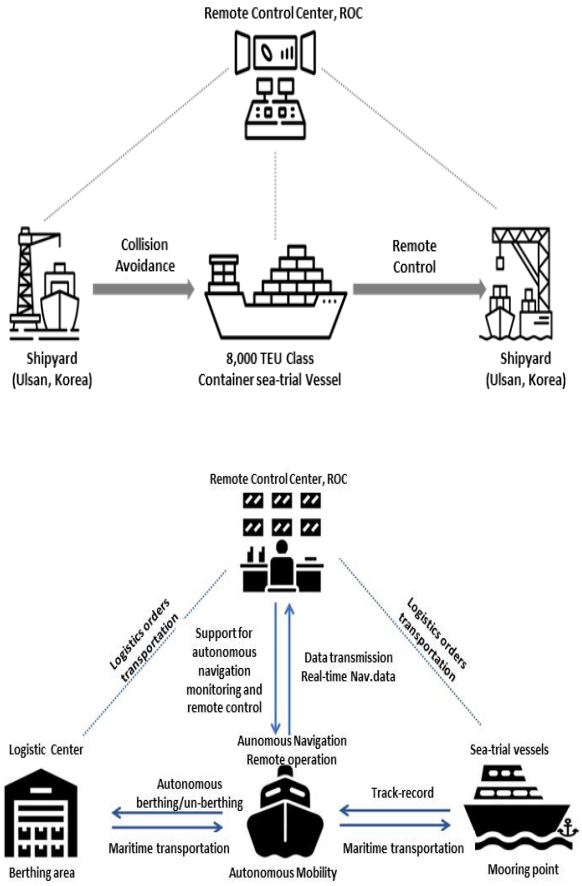

Fig. 10 Overview of the Regulatory Sandbox in the Field of MASS

4.2.1 Data Collection and Utilization

In accordance with Articles 21 and 24 of the Autonomous Ship Act, the use of onboard sensor imaging and personal location data has become more accessible. However, constraints still exist for data utilization by private enterprises.

The Autonomous Ship Act defines an "Autonomous Ship Industry Data Platform" to support the efficient use of data related to autonomous ships and associated industries. However, due to the lack of detailed standards regarding operational methods, legal authority, and funding, challenges remain for participants who have conducted demonstrations and tests in utilizing their data. Establishing relevant detailed standards will be necessary to facilitate the efficient use of industrial data.

4.2.2 Navigation zones

In accordance with Articles 9 and 20 of the Autonomous Ship Act, designated navigation zones for conducting autonomous navigation and remote control tests have been established, and the approval procedures for these operations are underway. To ensure safe maritime demonstrations, it is essential to establish detailed safety standards for the navigation zones and to provide guidelines for the announcement procedures regarding these areas.

4.2.3 Liability Insurance Terms and Conditions

According to Article 20 of the Autonomous Ship Act, the entity conducting the demonstration must obtain liability insurance to compensate for any damages that may occur during maritime demonstrations in the approved navigation zones. During this study, it has been observed that conducting autonomous navigation and remote control tests requires insurance products and terms specifically for autonomous ships or small unmanned vessels, which currently do not exist within the existing maritime insurance framework.

To ensure the continuity of long-term research, the introduction of dedicated liability insurance for autonomous ships or demonstration liability insurance is essential. Additionally, efforts should be made to design insurance products that include coverage for related equipment and manufacturers' liability from shipyards. It is anticipated that in this case, insurance premiums will rise significantly. therefore, policy support such as premium subsidies and legislative improvements will be necessary to provide assistance (Lee, 2024).

5. Conclusion

This study aims to examine the current regulatory framework for developing operational safety and suitability assessment technologies for autonomous navigation vessels and to propose necessary regulatory improvements accordingly. To ensure the safe demonstration of autonomous navigation vessels, key issues are expected to emerge regarding the measurement and utilization of data from sensors installed on maritime testbed vessels, as well as the responsibilities and compensation related to demonstrations based on navigation areas and entities involved.

If the proposed improvement directions in this study are reflected in the detailed standards and subordinate regulations of the Autonomous Ship Act, it could contribute to enhancing the collection of demonstration data and the safety of maritime demonstration procedures for assessing

the operational safety and suitability of autonomous ships in the future. However, since regulatory improvements related to autonomous ships have not yet been completed, the need for ongoing research and regulatory system refinement is emphasized. This study aims to contribute to establishing a legal foundation for collecting demonstration data and safety assessments through future related research and to explore the specific legal requirements necessary to support the practical operation of autonomous ships.

Acknowledgements

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