Technology Assessment – Autonomous Ships

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Technology Assessment : Autonomous Ships

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Background and Purpose

Recently, advances in technology spanning digitalization, big data and Artificial Intelligence (AI) have reached a level where commercialization of not only autonomous vehicles and aircraft, but also autonomous ships are imminent. The development of technology controlling ships from shore has been progressing at a rapid pace, especially driven by the industry.[1-2] Under the circumstances, in 2017, the International Maritime Organization (IMO) decided to adopt as one of its seven Strategic Directions to be pursued for the 2018-2023 timeframe, “Integrate new and advancing technologies in the regulatory framework”.[3] In June 2018, it decided to embark on the Regulatory Scoping Exercise (RSE) to adopt and operate Maritime Autonomous Surface Ships (MASS).[4] As a result, the global community has been called to make various efforts in technical, political and social aspects to accommodate MASS.

MASS is not merely one of many sides of technological progress. It will be an innovation that disrupts and induces a paradigm shift in the shipping industry and maritime transport system as a whole. In order to guide the future in a desirable direction under such change, the international society should be able to understand the economic and social dynamics encompassing maritime safety, environmental protection, seafarer welfare, training and education, liability, insurance and ethical concerns. In addition, communication and cooperation of multiple stakeholders will be a prerequisite to ensure a safe, effective and efficient maritime transport system with MASS.

The Republic of Korea (ROK) conducted a technology assessment on MASS as per Article 15 of the Marine Science and Technology Cultivation Act that took effect in June 2017. The purpose is to explore the economic, social, cultural, ethical and environmental impact of the new technology, thereby maximizing benefits and preparing against negative side effects. The outcome would serve as a guideline for reasonable policy-making. Also, the assessment is expected to facilitate communication among diverse members of the society and contribute to forming social discourse to ease the ripple effect of new technology and promote social acceptance.

The technology assessment was led by a working group that consists of experts from a number of areas including technology, economics and society. Contributions were made by stakeholders from wide-ranging fields such as labor unions of seafarers, marine pilot groups, key industries including shipping, shipbuilding and equipment and device businesses, the public sector including Vessel Traffic Centers, and students who will drive the development of maritime transport in the future.

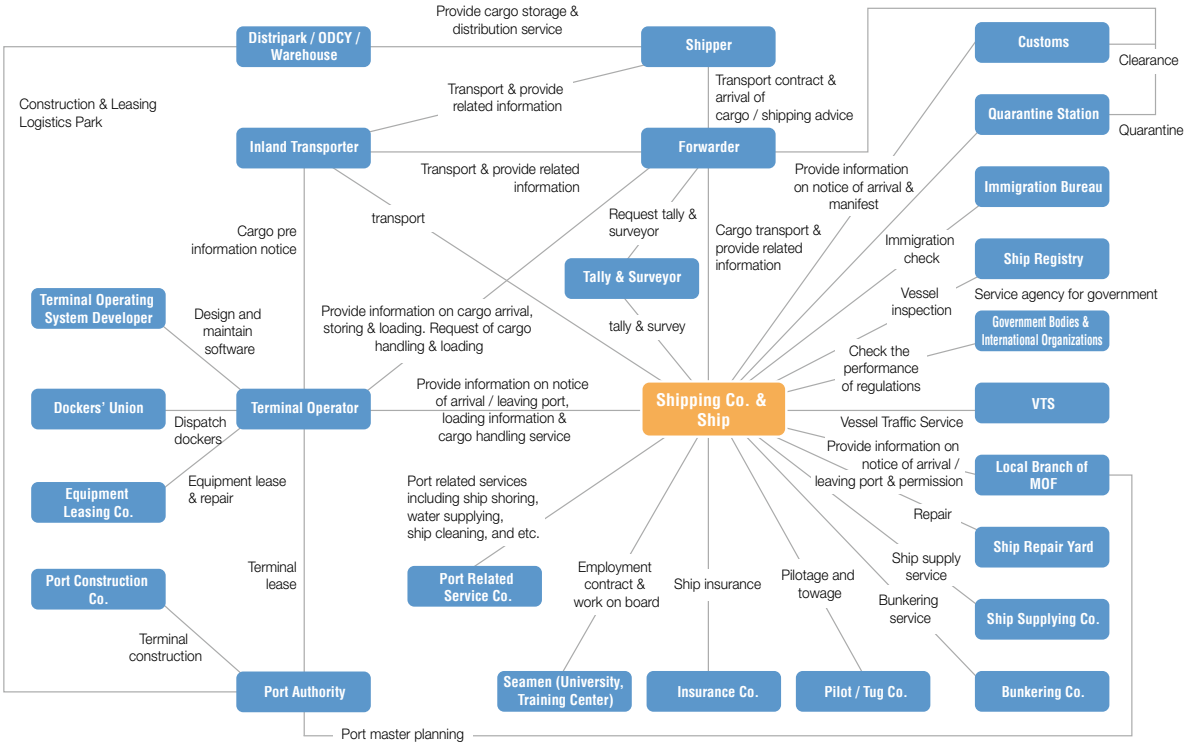
The assessment addresses key issues related to industry, safety, law, jobs, training and education, ethics, liability and insurance. This brochure is a summary of the issues considered to be valuable in sharing with the international society.

Ecosystem and Stakeholders

In the long run, MASS will bring about sea change to shipbuilding, equipment and device, and shipping and port industries. Shipping and port industries form a dynamic ecosystem, in which numerous stakeholders participate. For large parts of this ecosystem, public and private sectors are intertwined through complex regulations. On top of this, a variety of new stakeholders related to MASS are expected to emerge in the ecosystem such as telecommunication service providers and maritime cyber security businesses.

The safe, effective and efficient adoption and operation of MASS hinges on communication and collaboration among such stakeholders, especially the shipping and port industries.

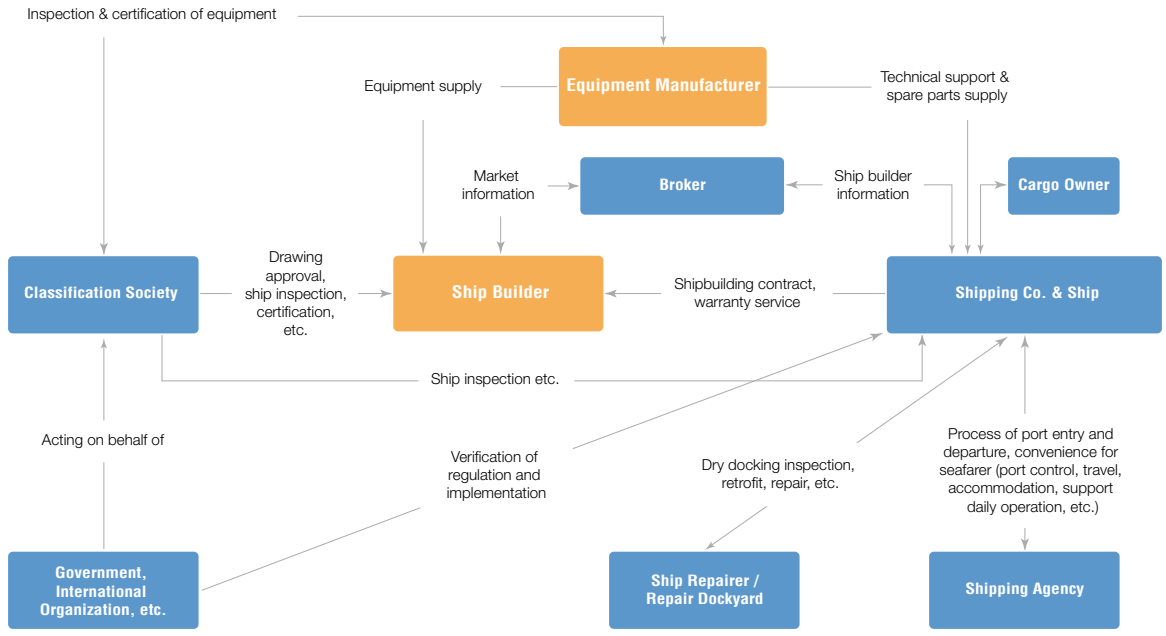
< Stakeholders of Shipping and Ports Industries of the ROK >



New Business & New Entrant

(cyber security related with ship, communications, data handling, consolidated platform, AMP, auto repairing service, auto cargo inventory solutions, etc.)

< Stakeholders of Shipbuilding, and Equipment and Device Industries of the ROK >



Changes in Risk Factor

The main cause of maritime accidents is human error, which in fact takes account for around 79% of maritime accidents in the ROK. However, the introduction of MASS is predicted to change the causes of maritime accidents. MASS reaching autonomy levels 3 and 4 are widely anticipated to reduce human error since they are operated without seafarers on board.[5]

Yet, the absence of seafarers exacerbates the concern that there will be no skilled manpower capable of responding in the event of an accident. According to a study, while navigation risks such as collision and stranding may decrease, non-navigation risks including fire, explosion and flooding may rather increase on autonomous ships.[6] To ensure a safe maritime transport system, technical and institutional measures to respond to diverse types of accidents should be derived rather than vaguely anticipating that the occurrence of human errors will decline with the emergence of MASS.

< Cause of Maritime Accidents of the ROK for the Past Five Years (2013-2017) >

Cause		Cases	Ratio	Cause		Cases	Ratio
Navigational Faults	Insufficient preparation of departure	17	1.1 %	Deficiency	Deficiency of hull and machinery	81	5.3 %
	Insufficient survey of nautical conditions	0	0.0 %		Poor maintenance of machinery	98	6.4 %
	Poor management of voyage plan	4	0.3 %		Poor management of inflammable equipment and deficiency of wires	12	0.8 %
	Negligence of evaluating ship location	39	2.6 %		Total	191	12.5 %
	Inappropriate maneuvering	55	3.6 %	Others	Inappropriate stowage of passenger and cargo	14	0.9 %
	Negligence of look-out	744	48.9 %		Inappropriate management for ship operation	50	3.3 %
	Insufficient preparation and response to heavy weather	27	1.8 %		Inappropriate crew management	1	0.1 %
	Inappropriate anchoring and mooring	9	0.6 %		Inappropriate provision of AtoN service	8	0.5 %
	Violation of navigation rules	128	8.4 %		Weather and force majeure	36	2.4 %
	Negligence of duty and supervision	12	0.8 %		Others	20	1.3 %
	Negligence of watch keeping	29	1.9 %		Total	129	8.5 %
	Other navigation errors	18	1.2 %				
	Incompliance with safe working regulations on board	120	7.9 %				
	Total	1,202	79.0 %	Grand Total		1,522	100.0 %

Source: Korea Statistical Information System

In the future, causes of accidents that have been minimal in number or that have not been recognized as important risk factors could stand out as well. In particular, cyber security is recognized as one of the prerequisites to enable practical operation of MASS. It should be understood that autonomous ships equipped with the same or similar system can be exposed to cyber security threats simultaneously. Defects in equipment and devices including autonomous operating systems, information error and distortion, difficulty of recognizing accidents and challenges in cargo management could be all potential threats against maritime safety.

MASS may drive changes in the patterns of pirate, terrorist and criminal activities. Cases of human loss including hostage situations and kidnapping by pirates and armed robberies may decrease. But attempts at abducting the ship itself targeting valuable cargo may increase due to the absence of seafarers. There is also the inherent risk that MASS may be abused for crime such as transport of illegal cargo including arms and drugs. Thus, the existing Customs, Immigration and Quarantine (CIQ) procedure centered on human may turn out to be ineffective for MASS. Technical and institutional considerations should take place to strengthen port security by developing new inspection mechanisms or changing the place of inspection if needed. In this regard, the CIQ using electronic means discussed in the Facilitation Committee of IMO need to be taken into consideration with MASS.

< Examples of Potential New Risk Factors against Maritime Safety >

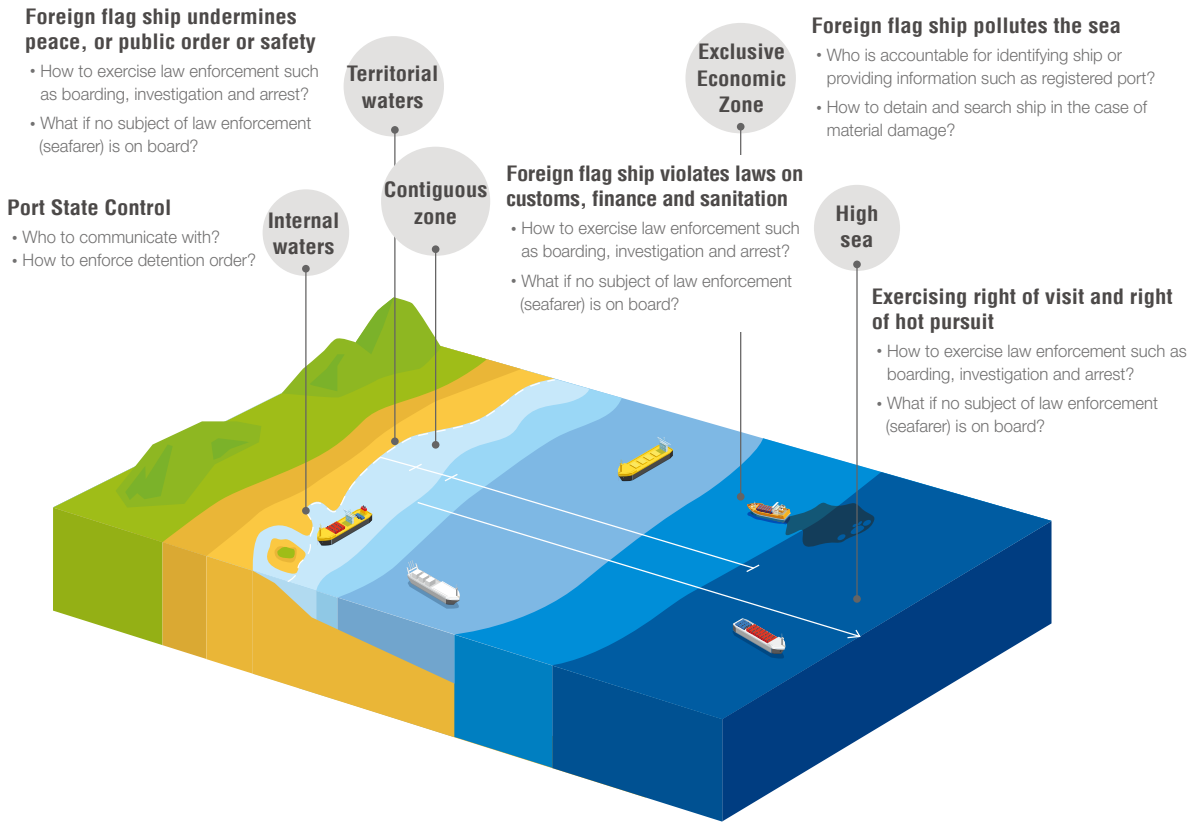
No.	Risk Factor	Example
1	Rise of cyber security threats	· Hacker attacks to abduct ship or hijack cargo · Leakage of sensitive information on cargo and customer
2	Failure of equipment or device	· Failure of ship due to failure of key operation systems including propulsion system · Failure of information and communication system required for autonomous operation such as failure of communication
3	Error or distortion of information	· Distortion of information communicated with on-shore control center including information on ship operation
4	Difficulty of recognizing accident	· Failure or delay of on-shore ship operator to recognize the occurrence of accident
5	Challenge of cargo management	· Safety-related problems such as cargo being set on fire without seafarer on board
6	Threat against port security	· Weaponization of autonomous ships

Legal Issues

The legal status of MASS is yet to be determined, but their concept is expected to change. As human seaworthiness is reduced going forward, ships will no longer remain passive subjects operated by seafarers. Instead, they may gradually transform into active agents that make small and big decisions to achieve safety and efficiency of operation.

A legal controversy surrounding MASS may emerge in regards to the United Nations Convention on the Law of the Sea (UNCLOS), most likely in that it would be difficult to secure effectiveness of enforcement when coastal states exercise jurisdiction. As most international maritime conventions such as the International Convention for the Safety of Life at Sea (SOLAS) and International Regulations for Preventing Collisions at Sea (COLREG) will be applied to MASS as well, IMO member states will need to review the scope of domestic laws alongside the RSE.

< Potential Issues Related to UNCLOS Caused by MASS >



Jobs, Education and Training

The emergence of MASS has been driving concerns on the decline in the number of seafarers and jobs. However, many experts believe that opportunity for new businesses and job creation will be accompanied. It is also anticipated that autonomous ships will enhance the quality of life of seafarers. If ships are controlled from the shore, the difficulty stemming from staying on board for a long period of time and the risks of marine accidents will be alleviated. At the same time, high-caliber workforce equipped with the skill for operating MASS from shore may be able to enjoy higher income and improved welfare.

It is clear that the advent of MASS will significantly change the landscape of jobs related to seafarers. The minimum safe manning level is sure to be decreased and the jobs will be replaced by AI and autonomous systems, just to start with. Therefore, operators capable of maneuvering the ships from shore and backed by relevant certification will be in high demand.

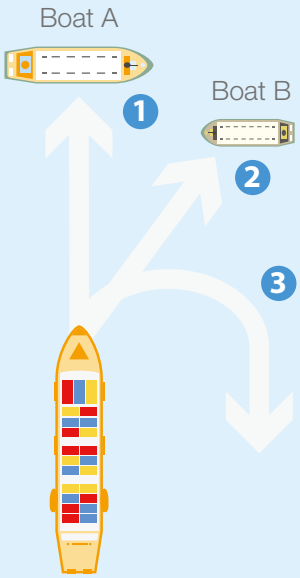
In the face of the decreasing number of seafarers, it would be significant to develop qualification standards for on-shore operators of MASS and to provide relevant training and education. Operators must have basic knowledge on issues such as navigation safety, terrestrial and coastal navigation, planning and conducting passage and determining position, navigation equipment, meteorology and emergency procedures. In the case of an emergency on board, operators must be able to clearly recognize the situation and mobilize basic skills and knowledge as deck officers to respond to danger. Hence, they should be certified as appropriate under the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW) Convention. If needed, it might be necessary to add new qualification standards in the STCW Convention or new Knowledge, Understanding and Proficiencies (KUP). These efforts will help appeal the attractiveness of working as seafarers or on-shore operators to the youth. Given the short on-board experience of young seafarers as evidenced in the past, hiring them as on-shore operators of MASS may contribute to guaranteeing continuity of their career as seafarers.

Ethical Concerns

In the process of developing and adopting autonomous ships, a wide variety of ethical issues are expected to be raised. The controversy surrounding autonomous vehicles in the auto industry, which is a step ahead in applying automation, gives a glimpse of what the future holds for autonomous ships. Yet, ethical concerns can be compounded with autonomous ships given the special circumstances of navigating on sea. Thus, such issues should be dealt with in a serious manner.

There will be a lot of cases where it is challenging to find universal solutions as with the trolley dilemma. These questions are fundamentally difficult to answer due to the absence of consensus over normativity in ethics itself. However, it would be inevitable to face these issues for us humans to be able to delegate big and small decisions to ships and autonomous systems in the future. In fact, a survey on the ethical dilemma regarding autonomous vehicles showed that around 76% of the respondents answered that it would be desirable to save ten pedestrians at the sacrifice of one driver. As it turned out, around 50% responded that when buying an autonomous vehicle, they would choose one that protects the driver over a pedestrian.[7] Given the ambivalence of the survey results, discussing diverse ethical issues regarding autonomous ships is imperative and the idea of establishing a guideline for the global community to comply with should be considered, if necessary.

< MASS Version of the Trolley Dilemma >



Dilemma

An autonomous ship going straight is about to collide with a fishing boat with ten crew aboard (boat A). At the right side is a fishing boat with only one crew on board (boat B). What would you do if you are controlling the ship?

1st choice

Keep original course and collide with boat A.

2nd choice

Avoid boat A and collide with boat B.

3rd choice

Make a fast turn to avoid both boats at the risk of capsizing.

Up until now, it was up to the seafarer to avoid risk during ship operation. It is likely that reliance on technology over decisions of seafarers will gradually increase with the adoption of MASS. Thus, we must be wary of losing vigilance against the risks posed by the sea due to overdependence on technology including autonomous systems. It should still be the basic task of a seafarer to make ethical and moral judgment when needed.

Above all, the fact that autonomous ships are controlled from shore separates the safety of ships from that of seafarers. Under the circumstance, it would be crucial to fend off moral hazard of taking maritime accidents lightly.

< Separation of Ship Safety and Seafarer Safety >

Conventional (Manned) Ships	Autonomous (Unmanned) Ships
· Ship safety is directly related with seafarer safety. · Upon maritime accidents, not only ship safety but also seafarer safety on board are threatened.	· Ship safety is separated from seafarer safety. · Even when maritime accidents result in property loss including ships and cargo, safety of humans including operators on shore is secured. ▶ Desirable in terms of saving lives, but concerns of moral hazards in the case of collision with other (manned) ships exist.

Also, communication for ship operation has been dominated by human in the past. In the case of MASS, it is expected to be diversified to man-machine and machine-machine communication. This leads to concerns that the level of uncertainty will grow particularly during communication between human (i.e. seafarers) and machines (i.e. MASS), namely, manned systems and unmanned systems. It is because rather than machines, unpredictable actions of human carry a higher risk of causing maritime accidents. Autonomous vehicles provide humans (pedestrians) with information such as speed or whether it is safe to cross the road. However, an experiment revealed that most people showed unpredictable behavior by acting on their own decision while ignoring signals from machines. [8] The importance of ensuring effective and reliable communication should be recognized when developing autonomous systems including MASS. Scenarios in which communication with machines fail or is refused should be reviewed.

The scope of decision-making authority that will be delegated to autonomous ships can also be an issue. Even the most perfectly implemented technology can be exposed to various unexpected situations at sea. Humans or seafarers are capable of making a judgment call that is appropriate for such occasions based on their experience. But machines cannot. It is difficult to develop technology equipped with the ability to respond to every possible scenario. Yet, enabling a decision-making algorithm to identify cases in which moral or ethical judgment is required and setting the boundary for delegating authority will be a challenge of another level.

Moreover, it should be taken into account that AI applied to MASS can train itself with data acquired during operation. Although ships will start out with exactly the same algorithms and features at the point of manufacturing or development, they may transform into a completely different kind of ship depending on the type of data collected. Although AI will be beneficial in improving the economic feasibility and safety of ship operation, technical and institutional mechanisms should be devised so that the technology does not make predictions or decisions that human intelligence cannot grasp.

Lastly, there is the issue of privacy. Autonomous ships may collect and share data from communication with other ships for the purpose of ship operation, ranging from information on seafarers on other ships to cargo. In this regard, appropriate measures should be taken to prevent violation of privacy.

< Can Autonomous Ships Make Ethical Decisions at All Times? >

Liability and Insurance

Just like other unmanned vehicles, MASS is expected to bring about a shift in the liability structure regarding maritime accidents. It is likely that the liability of manufacturers in the case of MASS will increase in relativity to conventional manned ships. However, pinpointing who to blame can be even more of a challenge due to reasons including modification of ships and failure to update autonomous operation systems in a timely manner.

Especially, setting reasonable criteria and scope on liability between shipowner and manufacturer, and an appropriate security structure for insurance coverage such as who should make compensations first and exercise the right to indemnity afterwards will be tricky issues. In this regard, views of multiple stakeholders should be reflected to consider the public benefit of accommodating MASS while allowing swift remedy for victims in a comprehensive manner. Other issues to be deliberated include whether it is appropriate to maintain the shipowners' limitation of liability system in the case of MASS in light of higher ship price, different liability structure and subsequent burden. It would be worthwhile considering to adopt the mandatory insurance system following certain international maritime conventions including the International Convention on Civil Liability for Bunker Oil Pollution Damage, the Nairobi International Convention on the Removal of Wrecks and the case of autonomous vehicles in several countries.

Appendix

Terminology : Autonomous Ship

A definition on “Autonomous Ship” that is universally agreed upon in the international society is yet to exist. “Autonomous” and “Unmanned" are clearly different ideas. However, the “Autonomous Ship” studied in the technology assessment by the ROK is defined as “all ships equipped with full-scale or partial autonomous systems operated without human intervention”. Thus, it includes “Unmanned Ship” such as ships remotely operated from shore without any seafarer on board.

Scope

The technology assessment has been focused on surface cargo ships such as containerships and bulk carriers. However, ships that transport hazardous materials including oil tankers were precluded from the study in that their acceptance levels are predicted to be relatively low. Passenger ships, cruises, fishing vessels and warships were also excluded.

Future Technologies for the Autonomous Ships

As a multidisciplinary review, the technology assessment has been implemented to forecast diverse impacts in a wide-ranging area including the economy, society, culture, ethics and environment. Basic assumptions must be set for experts from numerous fields and members of the society to explore a single theme together. The following are the key technology of the future and subsequent changes that were presumed for the assessment:

- Ships will be operated by remote control from shore or even without remote control from shore, in which case minimum human intervention is made only in emergency.
- Bridge and accommodation will be removed to expand cargo space and improve arrangement of on-board equipment and devices.
- Key information on ships will be monitored from the shore. Frequency of maintenance and repair will be optimized through the use of big data. Even during operation on waters, minimum maintenance and repair can be conducted with the help of technology such as drones.
- Exterior design of ships will change. Closed structure design could be adopted to prevent hijacking of cargo by pirates. But external access for maintenance and repair, and ease of unloading will also be considered.

- Every equipment and device installed on board will be interconnected and integrated to enable collection, management and analysis of data. They will be equipped with a high level of redundancy and durability, and will be highly modular to avoid failure.
- Not only navigation, but also docking and maneuvering will be remotely controlled or fully automated. In support, port infrastructure will be transformed.

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KIMST is

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