The State of Autonomous Shipping in Indonesia

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Table of Contents

1. Introduction .......................................................................................................................... 3
   1.1. General Definition of Autonomous Shipping ............................................................... 3
   1.2. Background of Study ..................................................................................................... 3
   1.3. Methodology .................................................................................................................. 4

2. Autonomous Shipping Technology in Indonesia ................................................................. 6
   2.1. Current Shipping Industry and Technology Overview .................................................. 6
       2.1.1. Seagoing Fleet in Indonesia .................................................................................. 6
       2.1.2. Seaport System .................................................................................................... 8
       2.1.3. Shipbuilding and Repairing Industry ................................................................. 9
       2.1.4. Human Resources in Shipping .......................................................................... 10
       2.1.5. The Role of Women ........................................................................................... 12
   2.2. National Legal Framework ............................................................................................ 12
   2.3. Status of Autonomous Shipping Technology Research and Development .............. 13
       2.3.1. Autonomous technology R&D in different transport sectors ......................... 13
       2.3.2. Research of autonomous technologies in shipping ........................................... 14
   2.4. Opportunities and challenges for autonomous shipping technologies ................... 16
       2.4.1. Opportunities ...................................................................................................... 16
       2.4.2. Challenges in shipping development and application of autonomous shipping technologies ........................................................................................................... 19

3. Recommendations .................................................................................................................. 22
   3.1. Short-Term Phase (1-3 years) ..................................................................................... 22
   3.2. Mid-Term Phase (4-7 years) ....................................................................................... 23
   3.3. Long-Term Phase (8+ years) ...................................................................................... 23

Bibliography .............................................................................................................................. 24
1. Introduction

1.1. General Definition of Autonomous Shipping

Autonomous shipping, encompassing unmanned and self-driving ships, leverages advanced technologies and artificial intelligence to navigate and operate vessels without human intervention. This emerging technology holds the potential to revolutionize the shipping industry by enhancing efficiency, lowering costs, and bolstering safety. The private and military sectors have extensively explored the use of advanced decision support systems, such as autonomous control and artificial intelligence.

The International Maritime Organization (IMO) has defined a Maritime Autonomous Surface Ship (MASS) as a vessel capable of operating independently of human input to varying degrees. This autonomy is categorized into four different levels, from 1 to 4. At the lowest level (1), onboard seafarers maintain control and operation of the shipboard system. The autonomy increases progressively to level 4, where the ship's operating system makes decisions independently. The details of each degree are explained in Table 1.

<table>
<thead>
<tr>
<th>Degree type</th>
<th>Definition</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Degree 1</td>
<td>Ship with automated processes and decision support</td>
<td>Seafarers are on board to operate and control shipboard systems and functions. Some operations may be automated and at times be unsupervised but with seafarers on board ready to take control.</td>
</tr>
<tr>
<td>Degree 2</td>
<td>Remotely controlled ship with seafarers on board</td>
<td>The ship is controlled and operated from another location. Seafarers are available on board to take control and to operate the shipboard systems and functions.</td>
</tr>
<tr>
<td>Degree 3</td>
<td>Remotely controlled ship without seafarers on board</td>
<td>The ship is controlled and operated from another location. There are no seafarers on board.</td>
</tr>
<tr>
<td>Degree 4</td>
<td>Fully autonomous ship</td>
<td>The operating system of the ship is able to make decisions and determine actions by itself.</td>
</tr>
</tbody>
</table>

1.2. Background of Study

The International Maritime Organization (IMO) recently acknowledged MASS in its latest convention, the Facilitation Committee (FAL)-47, between 13-17 March this year\(^1\). During this event, the convention approved a regulatory scoping exercise for using MASS, underlining its

\(^1\) [https://www.imo.org/en/MediaCentre/MeetingSummaries/Pages/FAL-47th-session.aspx](https://www.imo.org/en/MediaCentre/MeetingSummaries/Pages/FAL-47th-session.aspx)
significance in the global maritime transport technology landscape. The Committee further recognized that seminars addressing MASS's legal aspects and technological advancements effectively disseminate knowledge among academics, regulators, and industry professionals, enriching IMO's discussions.

The readiness to implement this concept varies across different regions, particularly among individual countries. This study aims to investigate the readiness and implementation plan for MASS in Indonesia, utilizing interviews and desk research as primary methods for data collection.

1.3. Methodology

The author conducted desk studies and interviews to understand the problems, challenges, and opportunities related to MASS implementation in Indonesia. The desk study of MASS in Indonesia captures the existing literature, news, and regulations (if any) regarding the MASS concept and implementation in the country. More information on MASS is needed due to the prematureness of this concept in Indonesia. Thus, interviews are conducted to gain insights from regulators, industry players, and academicians. Table 2 provides the list of sectors that are being analyzed, with related stakeholders and methodology.

<table>
<thead>
<tr>
<th>Stakeholders</th>
<th>Sector</th>
<th>Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ministry of Transportation</td>
<td>Regulation</td>
<td>Desk study, interview</td>
</tr>
<tr>
<td>Samudera Indonesia Research Initiative, Pelindo</td>
<td>Business Players</td>
<td>Desk study, interview</td>
</tr>
<tr>
<td>Indonesia Transport Society, Indonesia Association of Seafarers</td>
<td>Related Association</td>
<td>Desk study</td>
</tr>
<tr>
<td>Institut Teknologi Sepuluh Nopember (ITS)</td>
<td>Academia</td>
<td>Desk study, interview</td>
</tr>
</tbody>
</table>

A list of questions has been addressed to structure the discussion. Different questions have been formulated, but these still cover the sectors that need to be understood, such as regulations, technology, human resources, and potential policies or an action roadmap. The list of questions is summarized in Table 3.
### Table 3: Question lists for interviews with different stakeholders

<table>
<thead>
<tr>
<th>Type of Stakeholder</th>
<th>Ministry of Transportation</th>
<th>Question</th>
<th>Question</th>
<th>Question</th>
<th>Question</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>What is the Ministry’s perspective on the potential of autonomous shipping in Indonesia?</td>
<td>How does the Ministry plan to regulate and govern autonomous shipping operations to ensure safety, security, and compliance with international standards?</td>
<td>What challenges or obstacles does the Ministry anticipate in implementing autonomous shipping in Indonesian waters?</td>
<td>Are there any specific initiatives or programs the Ministry is considering to promote the adoption of autonomous shipping technology in the country?</td>
</tr>
<tr>
<td><strong>Type of Stakeholder</strong></td>
<td><strong>Shipping Players</strong></td>
<td>Question</td>
<td>Question</td>
<td>Question</td>
<td>Question</td>
</tr>
<tr>
<td></td>
<td></td>
<td>What are the main motivations for shipping players to explore and invest in autonomous shipping technologies?</td>
<td>What specific operational challenges or opportunities do shipping players foresee in the context of autonomous shipping in Indonesian waters?</td>
<td>How do shipping players plan to address the regulatory and legal aspects of autonomous shipping in Indonesia?</td>
<td>What kind of investments or partnerships that are considered by shipping players in adopting and integrating autonomous shipping technologies into their fleets?</td>
</tr>
<tr>
<td><strong>Type of Stakeholder</strong></td>
<td><strong>Academician</strong></td>
<td>Question</td>
<td>Question</td>
<td>Question</td>
<td>Question</td>
</tr>
<tr>
<td></td>
<td></td>
<td>How do academics view the role of research and development in advancing autonomous shipping in Indonesia?</td>
<td>What are the key technological advancements or innovations required to facilitate the implementation of autonomous shipping in Indonesian waters?</td>
<td>Are there any ongoing research projects or initiatives focused on autonomous shipping? If so, what are the main areas of research?</td>
<td>How can academia contribute to the development of a skilled workforce and specialized training programs for autonomous shipping operations?</td>
</tr>
</tbody>
</table>
2. Autonomous Shipping Technology in Indonesia

This chapter will elaborate on an analysis of MASS technology in Indonesia. It includes an explanation of the seagoing fleet industry, the seaport system, the shipbuilding and repairing industry, human resources in shipping, and the role of women in shipping.

2.1. Current Shipping Industry and Technology Overview

2.1.1. Seagoing Fleet in Indonesia

The seagoing fleet industry in Indonesia plays a crucial role in the country’s maritime transportation system. The seagoing fleet industry in Indonesia comprises a diverse range of vessels, including cargo ships, oil tankers, and passenger ferries. These vessels are essential for transporting goods and people within and outside the country. In 2021, 72,313 seagoing vessels operated in Indonesia (Ministry of Transportation, 2022). This number increased by 14% year-on-year compared to 2020. The number is growing by a CAGR\(^2\) of 21% from 2017 to 2021 (from 33,008 to 72,313).

An interesting trend regarding MASS is the increasing share of foreign agent vessels compared to the reduced share of national vessels. The share of foreign agent vessels has risen from only 28% in 2017 to 48% in 2021. On the other hand, the share of national vessels reduced from 72% to 52% in the same period. The rise in the presence of foreign vessels can be attributed to the adoption of more favorable regulations, which have attracted an increased number of foreign agents and services operating within Indonesian waters.

![Figure 1: Number of seagoing fleets in Indonesia. Source: Ministry of Transportation, 2022](image)

\(^{2}\) Compound Annual Growth Rate
Of the flagged Indonesian vessels\(^3\), cargo vessels make up 50%, while fishing vessels make up 45%, with the rest being passenger vessels.

Most Indonesian vessels' characteristics depend on the port draft in Indonesia (which will be discussed later in the sub-chapter of the port system). Due to the prevailing shallow draft in commercial ports in Indonesia, small vessels are more commonly used than large ones. The vessel composition in the country is dominated by small feeder vessels (<300 TEUs) and feeder vessels (300-1,000 TEUs). In Indonesia, 74% of the total domestic fleets are dominated by small vessels. The number of small vessels in Indonesia is very high compared to other countries, like Malaysia, India, and China (see Figure 3). The small vessels create high operation costs due to fuel inefficiency and load inefficiency.

\(^3\) A vessel that enacts Indonesian law onboard, including foreign agent vessels
2.1.2. Seaport System

In the port system, Indonesia has 3,672 ports as of 2022 (Ministry of Transportation, 2022). There are 2,012 public ports and 1,394 private ports/terminals. Of 2,012 public ports, 111 are commercially managed by Pelindo, a State-Owned Enterprise (SOE) port operator. The Ministry of Transportation (1,846) and private entities (55) manage the others.

Figure 4: Share of port types in Indonesia. Source: (Ministry of Transportation, 2023)

Previously, Pelindo managed the aforementioned 111 ports by dividing itself into Pelindo 1 to 4. In 2022, Pelindo 1 to 4 merged into one unit. It started to manage the whole country commercial ports. It aimed to provide uniform service throughout the managed port system.

Figure 5: Map of Port of Pelindo. Source: Annual Report of Pelindo, 2021
Regarding physical characteristics, ports in Indonesia are dominated by small ports with drafts that are not too deep (4-8 m). This range of depth only can handle small feeder vessels (<1,000 Twenty Equivalent Units, TEUs) and feeder vessels (1,000-2,000 TEUs). Most natural deep channel ports (more than 8 m, for more than 2,000 TEUs) are located in the east of Indonesia. Many western ports dredged their channels to accommodate Panamax and other larger vessels.

Figure 6: Domination of small vessels in Indonesia

2.1.3. Shipbuilding and Repairing Industry

Shipyard production in Indonesia relies on domestic (small-scale) and international (large-scale) shipyards. Nationally, Indonesia has 250 shipyard companies. The production capacity is 1 million Deadweight Tonnage (DWT) annually for new ship construction and 12 million DWT for ship maintenance and reparation (Ministry of Industry, 2022). The shipyard industry constructs passenger ships, cargo ships, and special needs vessels. The largest graving dock in the country has a capacity of 150,000 DWT. PT PAL, the SOE shipyard company in Surabaya, is the largest shipyard company in the country. Most of the products are tanker vessels with sizes of 30,000 DWT and 17,500 DWT.

The industry is experiencing difficulties due to the need for more spare parts and shipbuilding capacity. The required components and materials (more than 65% of materials) are still imported from other countries. With a lack of capacity and materials availability, the local shipyard industry cannot compete with Japanese and Korean manufacturers that can deliver larger ships more quickly (Bachtiar, Marimin, Adrianto, & Bura, 2021).
Globally, the shipbuilding capacity has reduced from 57.7 million Compensated Gross Tonnage (CGT) in 2013 to 39.5 CGT. The capacity has reduced greatly because of the 2008 financial crisis and the weakening of vessel prices (OECD, 2017). Indonesia needs to catch up in the shipyard industry compared to other maritime giants (China, South Korea, and Japan).

PT PAL is currently developing an unmanned or autonomous submarine. This SOE has also partnered with a German company, Thyssen-Krupp Marine System. This collaboration aims to uphold national sovereignty and meet Indonesia's underwater defense needs. The details of the project are confidential concerning the national defense matter.

2.1.4. Human Resources in Shipping

In Indonesia, 80 seafarers' academies are spread throughout the main islands. The curriculum varies significantly from the basic skill of seafaring to understanding the Automated Identification System, AIS, data. The leading academies are located on the Java and Sulawesi Islands. Currently, these academies need to adapt their curriculum to the change of automation in shipping. The role of seafarers is still needed in the future operation of vessels—to control the course, etc., depending on the automation level. It will be included if the automated shipping blueprint from the Ministry of Transport triggers a real demand in the field.
Indonesia is the world’s third-largest country of seafarers (see Figure 8). This statistic is considered one of the main reasons for not prioritizing the agenda of MASS within the MoT. Adopting autonomous shipping would significantly impact countries that heavily rely on the maritime industry and have a large population of seafarers. The maritime industry contributed 11% of Indonesia’s GDP (Ministry of Coordinating of Maritime Affairs, 2022).

The displacement of seafarers could lead to high levels of unemployment, lower wages, and reduced living standards, causing social and economic implications. Additionally, seafaring is essential to many countries’ cultural heritage and identity. Thus, rapid developments in autonomous shipping could negatively impact their social fabric.

Concerning the advancement of automation and human resources, the automation level in shipping needs to be understood. The IMO has simplified the definition of the automation level into four levels: (i) Degree One: ship with the crew and features automated process and decision support; (ii) Degree Two: remotely controlled vessel where the seafarers are on board; (iii) Degree Three: remotely controlled vessel where the seafarers are off the board, and (iv) Degree Four: fully autonomous vessel.

The current ship operation in Indonesia is still at Degree One. It has no autonomous function in either actions or decision-making. The onboard system introduces the provision of data. The data usually comes from an AIS satellite that provides three types of data: static, dynamic, and voyage-related. The ship crew needs to understand how to translate the data to make decisions based on this degree. This requires certain human resource qualities, not just basic seafarer skills.
2.1.5. The Role of Women

The International Maritime Organization (IMO) has established the Women in Maritime Program to empower women in the maritime industry, and it intends to carry on with this initiative in the years ahead (Ministry of Transport, 2019). Through this program, IMO offers scholarships specifically designed for women, facilitates their access to advanced technical training in the maritime sector in developing nations, and fosters an environment that encourages the recognition of women and provides them with opportunities to progress in careers related to maritime administration, port management, and maritime training institutions.

In 2019, according to the Ministry of Transportation information, Indonesia had 18,572 female sailors with diverse roles, educational backgrounds, and sailing statuses (Ministry of Transport, 2020). Unfortunately, the stereotype that women should confine their employment to domestic settings remains in Indonesia.

Women in Maritime Association Indonesia (WIMA) has become a renowned organization. However, it is not specifically only for women who work in shipping; it also covers women’s work in maritime law, consultancy, etc. Interestingly, the Indonesia National Shipowner Association (INSA) is under the female leader Carmelita Hartoto, although most shipowners are men.

2.2. National Legal Framework

In Indonesia, The Directorate General of Sea Transport (DGST) regulates ship traffic, ownership, industry, and seafarers under Indonesia’s Ministry of Transport (MoT). Under this DGST, various directorates are related to sea transport regulation: Directorate Sea Transport and Traffic, Directorate Port, Directorate Ship and Seafarer, Directorate Navigation, and Directorate Offshore Safety. The Author interviewed the Directorate Ship and Seafarer as part of the initial discussion of MASS. The complete directorate list is shown in 9.

Nevertheless, it is also worth mentioning the Directorate General Land Transport (DGLT). Under Indonesian regulation, the Roll-On Roll-Off (RoRo) vessel is under this jurisdiction. RoRo is worth noting because in Europe, this type of vessel has been automated and utilized as the primary means of transportation for passengers traveling between islands. Therefore, the desk study in the RoRo vessel domain should take into account the regulations established by DGLT. Figure 10 10 shows the structure of directorates in DGLT.
A new regulation in Indonesia’s transportation sector, especially for MASS, requires a thorough blueprint or road map. For MASS, such a blueprint does not currently exist. In April 2023, the Joint Maritime Safety Committee (MSC)-Legal Committee (LEG)-Facilitation Committee (FAL) Working Group on Maritime Autonomous Surface Ships (MASS-JWG) of IMO discussed the legal framework related to MASS. Indonesia currently is a council member of IMO. With more discussions, Indonesia needs to adapt the MASS concept sooner or later.

A regulation is needed to support MASS adoption in Indonesia. With no regulation, there is very little innovation in terms of technology in MASS systems, such as shore control centers and other related sensors (e.g., speed log, echo sounder, shaft motor, etc.).

2.3. Status of Autonomous Shipping Technology Research and Development

2.3.1. Autonomous technology R&D in different transport sectors

Only one transport mode has adopted autonomous technology in Indonesia and is commercially used. It is a Light Rail Transit (LRT). It operates in the Greater Area of Jabodebek (Jakarta-Bogor-Depok-Bekasi). This area encompasses the population density of the working area and the people in Indonesia. The train system has three Grades of Automation (GoA). LRT Jabodebek has the highest GoA, meaning it is fully automated. The system uses the Communication-Based Train Control (CBTC). The CBTC
system operates trains based on communication, allowing for automatic train operation and schedule projections, which are also automatically supervised by the Operation Control Center (OCC).

![Figure 11: LRT Jabodebek. Source: Tye Wong, 2023](image)

Nevertheless, there are still operational staff present within the train to address emergency situations and assist passengers. In the case of infrastructure or equipment disruptions, the Train Attendants will assume manual control of the train, operating it at reduced speeds.

2.3.2. Research of autonomous technologies in shipping

At the academic level, Institut Teknologi Sepuluh Nopember (ITS) in Surabaya has a research group on shipping automation. This research group has explored issues of automation shipping to be used in small-sized cargo vessels in Eastern Indonesia. The Ministry of Transport has asked ITS for this research in recent years. High tides and strong winds characterize the seas of Eastern Indonesia. Thus, small-sized cargo vessels with automation are safer than sending manned vessels. This concept also aims to promote economic equality in the remote islands of Eastern Indonesia.

This institution launched an innovative unmanned autonomous Intelligent Boat (I-Boat) in 2020. This unmanned vessel utilizes a combination of artificial intelligence and Internet of Things technologies. It can identify potential dangers and prevent collisions with objects at sea. Moreover, it can reduce the risk of ship accidents and optimize its
propulsion. The I-Boat can be controlled through a user interface application or a mobile phone. The operator can direct the vessel to sail toward the desired coordinates.

![I-Boat](image1.png)  
*Figure 12: I-Boat. Source: ITS, 2022*

The invention of Remotely Operated Vehicles, ROV, W-101 in 2022 by ITS enables the surveillance activities of underwater equipment to be carried out by ROVs autonomously, without the need for human operators. It will streamline the process of monitoring underwater cables and pipelines and conducting marine exploration in Indonesia.

![Prototype of Aksanawa](image2.png)  
*Figure 13: Prototype of Aksanawa. Source: ITS (2023)*
In January 2023, ITS developed a prototype of Aksanawa, an autonomous surface ship, for Search and Rescue (SAR) purposes. It aims to search and rescue survivors of ship accidents at sea. Indonesia has had at least a hundred sea transport accidents in the past 5 years. This prototype is designed to conduct searches following the pattern used in International Aeronautical and Maritime Search and Rescue (IAMSAR) operations. The ship’s operator will send the order via a microcontroller, and then the ship automatically moves following the designed pattern.

2.4. Opportunities and challenges for autonomous shipping technologies

2.4.1. Opportunities

An asset of human resources

Indonesia can maximize its human resources to be a global human resources supply for experts in autonomous shipping operations. Awareness of autonomous shipping operations at different levels must be created to bring positive economic value. The seafarer community can be trained further as the controller of MASS operation in the shore center. Several subjects can be added to the curriculum:

- Autonomous Systems: Providing seafarers with a comprehensive understanding of autonomous systems, including their components, sensors, communication networks, and control mechanisms. This subject would cover the technical aspects of autonomous technologies relevant to MASS operations.
- Data Analytics and Artificial Intelligence (AI): Introducing seafarers to the fundamentals of data analytics and AI algorithms that underpin autonomous systems. This subject would focus on data processing, machine learning, and pattern recognition techniques to enable seafarers to interpret and utilize data collected by autonomous vessels.
- Cybersecurity: Educating seafarers about the importance of cybersecurity in the context of MASS. This subject would cover cybersecurity best practices, threats to autonomous systems, and methods to protect communication and control systems from cyber-attacks.
- Human-Machine Interaction: Addressing the human element in MASS operations and emphasizing the importance of effective human-machine interaction. This subject would cover topics such as situational awareness, decision-making in autonomous environments, and understanding the roles and responsibilities of seafarers when operating alongside autonomous systems.
- Regulatory and Legal Frameworks: Familiarizing seafarers with MASS operations' relevant regulations, guidelines, and legal aspects. This subject would cover international conventions, national regulations, and industry standards governing the use of autonomous vessels.
• Ethical and Social Implications: Discuss the ethical considerations and social implications of adopting MASS in the maritime industry. This subject would explore the impact on seafarer employment, safety and accountability, and the societal acceptance of autonomous technologies.

In Western Europe, there has been a noticeable decrease in seafarers, particularly in maritime nations such as Greece, the Netherlands, and Italy, as noted by Papachristou in 2023. Consequently, Indonesia should seize this opportunity to enhance the skill sets of its seafarers, enabling them to pursue opportunities beyond the nation's borders.

**Potential adoption of MASS in Indonesia**

The high upfront investment required for MASS operations presents a challenge. Nevertheless, Indonesia has opportunities to overcome this obstacle and benefit from adopting autonomous technologies in the maritime industry. Here are some potential opportunities:

• Technology Localization: Indonesia can explore opportunities to localize the production and integration of autonomous systems and components. By establishing partnerships with technology providers and encouraging the development of domestic capabilities, the country can reduce reliance on imports and potentially lower the costs associated with implementing MASS technologies.

• Public-Private Partnerships: Collaboration between the government, private sector, and research institutions can lead to public-private partnerships focused on financing, researching, and deploying MASS technologies. These partnerships can help pool resources, share risks, and leverage expertise to overcome financial barriers and promote the adoption of autonomous systems.

• Leveraging Existing Infrastructure: Indonesia can capitalize on its existing maritime infrastructure and capabilities to facilitate the adoption of MASS. By retrofitting existing vessels with autonomous systems or leveraging established shipbuilding facilities, the country can optimize its resources and minimize the need for extensive infrastructure development.

**Continuous adoption can lower MASS cost**

As the adoption of MASS becomes more widespread, there is a potential for cost reductions and economies of scale to materialize. For instance, with increasing number of autonomous vessels in operation, autonomous technologies' production and procurement costs can decrease. Standardization and mass production of
components and systems can lead to economies of scale, making them more affordable.

Furthermore, operating costs can be reduced in the long term. Autonomous vessels have the potential to optimize routes, improve fuel efficiency, and enhance overall operational efficiency, which can lead to a reduction of 7% in costs (Nguyen, Ruzaeva, Góez, & Guajardo, 2022). By leveraging advanced algorithms and real-time data, autonomous vessels can optimize voyage planning, reduce idle time, and minimize fuel consumption. These factors can result in significant cost savings over time, as shown in Table 3 above.

Table 4 shows the relationship between increases and decreases in cost along the lifetime of autonomous vessel operation. Different carriers have different characteristics in cost fluctuation along the lifetime cost cycle of ships (Ziajka-Poznanska & Montewka, 2021). Along the ship life cycle, additional costs, such as removing the deckhouse and hotel system and procuring the shore control center, are not mentioned in most autonomous shipping characteristics.

<table>
<thead>
<tr>
<th>Component</th>
<th>Sub-components</th>
<th>Autonomous container ship</th>
<th>Autonomous bulk carrier</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voyage costs</td>
<td>Bunker fuel</td>
<td>The fuel consumption is reduced by 13-15%&lt;sup&gt;a&lt;/sup&gt;</td>
<td>the fuel consumption is reduced by 6-15%&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>Cargo handling</td>
<td>Constant&lt;sup&gt;a,c&lt;/sup&gt;</td>
<td>Constant&lt;sup&gt;a,c&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>Port charges</td>
<td>Berth charges are constant&lt;sup&gt;a,c&lt;/sup&gt;; Boarding crew cost is not estimated</td>
<td>Berth charges are constant&lt;sup&gt;a,c&lt;/sup&gt;; Boarding crew cost +20%</td>
</tr>
<tr>
<td>Operating costs</td>
<td>Crew wages</td>
<td>-30 – 35% due to removal of crew cost; cost of shore control center +250k USD</td>
<td>-945,000 USD cost of wages; additional cost of shore control center +149k USD</td>
</tr>
<tr>
<td></td>
<td>Lubricants</td>
<td>Constant&lt;sup&gt;a,c&lt;/sup&gt;</td>
<td>Constant&lt;sup&gt;a,c&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>Stores</td>
<td>Removal of stores concerning crew is not estimated</td>
<td>-67k USD</td>
</tr>
<tr>
<td></td>
<td>Insurance: Protection and Indemnity (P&amp;I) + Hull and Machinery (H&amp;M)</td>
<td>Constant&lt;sup&gt;a,c&lt;/sup&gt;</td>
<td>Constant&lt;sup&gt;a,c&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>Maintenance and Repairs</td>
<td>Maintenance of autonomous systems</td>
<td>Maintenance of autonomous systems</td>
</tr>
</tbody>
</table>
### The State of Autonomous Shipping Concept in Indonesia

<table>
<thead>
<tr>
<th>Capital Cost</th>
<th>Description</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purchase cost</td>
<td>Additional cost of redundancies, removed deckhouse, and hotel system – not estimated</td>
<td>Additional cost of redundancies (+10%), removed deckhouse (+5%), and hotel system (1-10%)</td>
</tr>
<tr>
<td>Mortgage repayments</td>
<td>Constant a,c</td>
<td>Constant a,c</td>
</tr>
<tr>
<td>Leasing charges</td>
<td>Constant a,c</td>
<td>Constant a,c</td>
</tr>
<tr>
<td>Loans</td>
<td>Constant a,c</td>
<td>Constant a,c</td>
</tr>
<tr>
<td>Registration fees</td>
<td>Constant a,c</td>
<td>Constant a,c</td>
</tr>
<tr>
<td>Taxes</td>
<td>Constant a,c</td>
<td>Constant a,c</td>
</tr>
</tbody>
</table>

*a = autonomous, c = conventional

However, it is important to note that the economy of scale in MASS operations is contingent on various factors, including the scale of operations, the nature of the shipping routes, the cargo volume, and the regulatory frameworks in place. Additionally, the economic benefits of MASS must be evaluated on a case-by-case basis, considering each maritime sector's specific operational context and cost structure.

Overall, while the upfront costs of adopting MASS may present challenges in the short term, the potential for economies of scale, enhanced operational efficiency, and cost savings in the long term can make autonomous shipping economically viable and attractive for industries such as container shipping.

### 2.4.2. Challenges in shipping development and application of autonomous shipping technologies

**High upfront investment**

One of the main challenges associated with a potential economy of scale in MASS operations is the high upfront investment required to develop, integrate, and deploy autonomous technologies. The initial costs of retrofitting existing vessels or constructing new autonomous vessels with advanced systems, sensors, and communication infrastructure can be significant. Additionally, there may be expenses related to the implementation of supporting infrastructure, such as shore-based control centers, data management systems, and training facilities.
There are several systems and requirements for related operations in realizing the autonomous shipping concept—the different components adapted to the different degrees of automation. Table 5 shows the distinction of each component.

Table 5: List of required systems and infrastructure components. Source: Adapted from (Fiedler, Bosse, Gehlken, Brümmerstedt, & Burmeister, 2019)

<table>
<thead>
<tr>
<th>Component</th>
<th>Type</th>
<th>Automation Degree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shore control center for remotely controlled vessels</td>
<td>System</td>
<td>Degree 2, 3, and 4</td>
</tr>
<tr>
<td>Data integration to support Vessel Traffic services</td>
<td>System</td>
<td>Degree 1, 2, 3, 4</td>
</tr>
<tr>
<td>Automated mooring facilities for complete unmanned sailing to the terminals</td>
<td>Infrastructure</td>
<td>Degree 3 and 4</td>
</tr>
<tr>
<td>Training for new process in automation</td>
<td>Human resource related</td>
<td>Degree 1, 2, 3, and 4</td>
</tr>
<tr>
<td>Adjustment of berthing infrastructure for small ports</td>
<td>Infrastructure</td>
<td>Degree 3 and 4</td>
</tr>
</tbody>
</table>

Once the automation degree 1 and beyond can be used by humans, it can support in decision-making. There will be a need to procure shore control centers, data integration systems to support vessel traffic services, and training for personnel. Certain components of automated mooring facilities and berth infrastructure upgrades are required in the third and fourth degrees of automation (complete unmanned operation). The mooring systems can be classified as fully⁴ or semi-automated⁵.

**Economies of Scale**

Due to the non-existent regulation of autonomous shipping, the economy of scale⁶ of MASS is still in question, especially from the perspective expressed by the business player during the interview. The business players are open to this concept, but it requires regulation and shipyard industry readiness for autonomous shipping operations.

A study in 2020 estimated that an operation on the average autonomous ship reduces fuel consumption by 9.75% compared to the conventional ship. The crewing cost contributes significantly to the total weekly charter cost. If there is no human crew, like on an autonomous ship, the weekly charter cost can be reduced by 35.86% on

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⁴ Complete mooring and unmooring controlled remotely by the vessel
⁵ Cruising to the quay can be automated but crew is required to do docking securely
⁶ Cost advantages reaped by companies when production becomes efficient
average (Akbar, et al., 2020). The same study shows that removing the deck house\(^7\) from an autonomous ship can reduce the construction cost by 5-10%. This shows the potential savings of long-term operation costs in MASS.

Table 6: Comparison of conventional and autonomous shipping operational cost  . Source: (Akbar, et al., 2020)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Ship size</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacity (TEU)</td>
<td></td>
<td>1,000</td>
<td>1,350</td>
<td>2,000</td>
<td>2,550</td>
<td>3,500</td>
</tr>
<tr>
<td>Conventional ship</td>
<td>Fuel usage (ton/hr)</td>
<td>0.61</td>
<td>0.69</td>
<td>0.75</td>
<td>0.80</td>
<td>0.85</td>
</tr>
<tr>
<td></td>
<td>Weekly time charter cost (kUSD)</td>
<td>53</td>
<td>54</td>
<td>56</td>
<td>58</td>
<td>64</td>
</tr>
<tr>
<td>Autonomous ship</td>
<td>Fuel usage (ton/hr)</td>
<td>0.55</td>
<td>0.62</td>
<td>0.68</td>
<td>0.72</td>
<td>0.77</td>
</tr>
<tr>
<td></td>
<td>Weekly time charter cost (kUSD)</td>
<td>32.5</td>
<td>33.5</td>
<td>35.6</td>
<td>37.7</td>
<td>44.0</td>
</tr>
</tbody>
</table>

The possibility of an economy of scale is an important aspect to consider when analyzing the adoption of MASS in Indonesia. The economy of scale refers to the cost advantages gained from increased production or operation, leading to lower unit costs as volume or scale increases. In the context of MASS, it pertains to the potential cost implications and economic feasibility of deploying and operating autonomous vessels compared to traditional manned vessels.

\(^7\) Part of vessel where crews stay
3. Recommendations

The previous chapters showcased that Indonesia has yet to be ready for the implementation of the MASS concept. Several challenges have been summarized. To adopt the MASS concept, Indonesia can foresee the short, mid, and long-term approaches outlined in Figure 14 below.

![Figure 14: Suggested roadmap of MASS implementation in Indonesia](image)

3.1. Short-Term Phase (1-3 years)

The short-term phase would be the introduction period of the MASS concept in the country. The awareness and education stage involves collaborating with local maritime transport stakeholders and IMO through workshops and seminars to focus on the local adoption of MASS. The aim is to educate the key stakeholders about the guidelines, regulatory developments, and safety aspects of MASS issued by IMO. As a country that specializes in seafaring, Indonesia should emphasize the potential benefits of implementing MASS and address concerns regarding job security or the impact on the existing workforce.

Also, the relevant regulatory framework of Indonesia should be brought into conformity with the guidelines of the International Maritime Organization (IMO). Framework for Decision-Making (FDM) by IMO is useful for adapting to instruments of safety, security, and environmental risks related to autonomous vessel operation in Indonesia.

Initiating pilot projects to test autonomous vessels’ performance, safety, and efficiency in Indonesian maritime conditions is necessary. The test runs of autonomous vessels will provide data on navigational challenges, vessel interactions, and environmental impacts to inform the development of national guidelines and regulations.
3.2. Mid-Term Phase (4-7 years)

The mid-term phase should focus on national regulations and guidelines, infrastructure upgrades, and capacity building. The development of national regulation and policies concern the operation of autonomous vessels in Indonesia, considering the IMO’s Interim Guidelines on Maritime Autonomous Surface Ships. These regulations should cover safety, collision avoidance, communication protocols, contingency plans, and remote monitoring requirements.

The infrastructure will require an upgrade once the regulations are adopted. It includes upgrading maritime infrastructure such as ports, navigation aids, and communication systems. This can support autonomous operations and collaborations with the IMO and other countries to adopt standardized communication protocols (such as the IMO’s Maritime Autonomous Ships Communication) and ensure compatibility with global systems.

The training program will be needed in collaboration with the IMO and national maritime academies to enhance the skill sets of sailors, engineers, and shore-based personnel. It should focus on remote vessel operations, data analysis, cyber resilience, and maintenance of autonomous systems.

3.3. Long-Term Phase (8+ years)

The long-term phase includes the identification of specific autonomous shipping corridors, continuously developing the required regulations, and further collaborating with international partners. Specific corridors must be identified and designated so autonomous vessels can operate safely and efficiently. Indonesia can collaborate with neighboring countries and the IMO to facilitate seamless and harmonized operations across borders.

The continuous review and update of national regulations in alignment with the IMO’s evolving guidelines on MASS will be significant by participating actively in IMO meetings and working groups. This can contribute to developing international regulations, standards, and best practices for autonomous shipping.

Indonesia must strengthen collaboration with the IMO and other countries to share knowledge, experiences, and lessons learned in autonomous shipping. This country should actively engage in international discussions on liability, insurance, and cybersecurity to ensure a comprehensive and harmonized approach.
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