Smartseas Technology for Improving Shipping Performance and Safety in Indonesia

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Abstract : Shipping is vital to global trade, facilitating the transport of more than 80% of the world's goods. As a result, operational efficiency, accuracy, and safety are key determinants of success in this crucial sector. In the contemporary digital era, the maritime industry faces increasingly complex challenges in maintaining and improving core performance metrics. Smartseas technology has emerged as a promising innovation designed to directly address these challenges. This paper aims to comprehensively explore the significant potential of smartseas in improving efficiency, accuracy, and safety in maritime operations. Through a rigorous analytical approach and examination of relevant case studies, this research provides an in-depth analysis of smartseas implementation. This paper evaluates smartseas technology within the framework of applicable international conventions and regulations governing maritime activities. This study synthesizes the latest data from various sources to explain how smartseas technology can optimize operational performance. In addition, this paper systematically investigates the tangible benefits and inherent challenges encountered during the practical application of this technology in the real maritime world. By offering a holistic assessment, this paper provides valuable insights into the transformative impact that smartseas technology has on the maritime industry, highlighting its capacity to revolutionize operational standards while navigating the complexities of the global regulatory landscape. The findings are intended to inform stakeholders and guide future technology integration strategies.

Keywords: Shipping, smartseas technology, safety, international regulations.

1. INTRODUCTION

Ships is a vital role in the global economy, with approximately 90% of international trade conducted by sea (International Maritime Organization, 2021). However, high operational costs, potential accidents, and negative environmental impacts are among the many challenges facing the sector. In this regard, smartseas technology offers a promising solution to improve efficiency and safety by optimizing

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maritime operations through the integration of various technologies, such as the Internet of Things (IoT), big data, and artificial intelligence (AI) (Smith, 2023).

The International Maritime Organization (IMO) states that human factors and system failures are responsible for approximately 90% of maritime accidents. As a result, innovative approaches are needed to improve safety and efficiency. By using data analytics and automation systems, smartseas, a technology-based platform, may be able to address these issues.

One important aspect of smartseas technology is its ability to improve accuracy in navigation and fleet management. By using advanced monitoring systems, such as the Automatic Identification System (AIS), ships can operate more efficiently and safely. To improve decision-making, patterns and trends can be identified by analyzing data from various sources (Jones & Williams, 2022). In addition, the implementation of international standards such as Safety of Life at Sea (SOLAS), International Safety Management Code (ISMS), and world meteorological regulations (World Meteorological Organization/WMO) are also important in maintaining operational safety at sea.

Although the "smartseas" vision offers futuristic solutions by integrating digital technology and data analytics, the reality on the ground shows a gap between expectations and reality. Therefore, policies are needed to bridge this gap. This approach cannot run smoothly due to four interrelated fundamental problems: Uneven Digital Infrastructure, Weak Data Standardization and Integration, Quality of Human Resources and Work Culture, and Security and Regulatory Issues. Collectively, these four issues hinder digital transformation and have the potential to limit Indonesia's ability to fully utilize its maritime potential. Understanding and resolving these root causes is an important step toward creating "smartseas" that not only use technology intelligently, but are also robust, environmentally friendly, and provide a multi-layered chain. The objective of this research is to formulate a policy framework and implementation strategy for the development of "smartseas" ports in Indonesia.

2. METHODOLOGY

This study uses qualitative and quantitative approaches to analyze the efficiency, accuracy, and safety of maritime operations influenced by smartseas technology. In addition, a literature review was conducted on the 10 largest ports in the world that have implemented smartseas technology and its impact on shipping activities.

3. DISCUSSION

The IMO Convention is a legal framework that regulates maritime safety, security, and environmental protection. One of the IMO's main focuses is to reduce the risk of accidents at sea and improve shipping safety. According to the IMO report, the application of modern technologies such as information management systems and ship automation can significantly reduce these risks. For example, the implementation of sensor-based early detection systems can help identify potential hazards before they become bigger problems (IMO, 2021 in Mackinnon, 2023).

SOLAS is an important convention created by the IMO with the aim of ensuring safety in shipping. This convention covers a wide range of topics, from how to build

ships to training for ship crews. Using smartseas technology can help meet SOLAS regulations by providing the information needed to make better decisions. For example, with a ship health monitoring system, technical problems can be detected earlier, thereby preventing accidents due to equipment failure (SOLAS, 2020 in (Riyadi & Erliyani, 2025).

The use of smartseas technology in the context of the IMO and SOLAS conventions can also be seen in terms of operational efficiency. Smartseas technology is a platform and solution that utilizes artificial intelligence and IoT networks to transform various industrial fields, particularly the maritime and aquaculture sectors. In the maritime sector, smartseas technology (Artificial Intelligence/AI) provides assistance in the form of AI-based assistants that help ship crews and shore-based teams predict, prevent, and resolve incidents at sea, thereby improving safety and efficiency. In the aquaculture sector, smartseas seeks to transform fish farming by combining several advanced technologies, such as AIoT, which combines artificial intelligence and IoT to create smarter systems; digital twins, which create virtual models of fish farms for simulation and analysis; and smart fisheries, which help create smarter, more efficient, and environmentally friendly fishing systems.

In the maritime sector, smartseas AI provides a platform for safer and more efficient maritime management, including: Problem-solving assistants (e.g., helping ship crews and shore teams to quickly manage and resolve equipment failures), incident prediction (e.g., using AI to identify potential problems before they occur, so that preventive measures can be taken), and safety improvement (e.g., providing real-time insights and tools to improve safety at sea).

Meanwhile, in the aquaculture sector, Smartseas is working to transform fish farming by combining several technologies such as AIoT, which is a combination of artificial intelligence and IoT that forms a smarter system, digital twins that create virtual models of fish farms for use in simulations and analysis, and smart fisheries that support smarter, more efficient, and environmentally friendly fishing systems.

Some of the benefits of smartseas are: Increased efficiency (accelerating data processing and decision-making in maritime and aquaculture environments), improved safety (helping to predict and prevent incidents, thereby reducing the risk of accidents), better resource management (enabling more effective and efficient management of marine natural resources), and industrial innovation (encouraging innovation and transformation in the maritime and aquaculture industries).

According to a study conducted by the Baltic and International Maritime Council (BIMCO), the use of information and communication technology in shipping operations can reduce travel time and operational costs by up to 20%. This shows that the adoption of technology not only improves safety, but also provides significant economic benefits for shipping companies (BIMCO, 2023).

One of BIMCO's (2023) compilations of key findings related to the impact of technology on shipping efficiency, compiled from various publications, is as follows:

a. Key Technologies that Improve Efficiency

Table 1. BIMCO 2023 Study Results: The Impact of Technology on Shipping Efficiency (Synthesized from BIMCO reports, articles, and guidelines from 2023)

Technology	Impact on efficiency	BIMCO Source
AI & Machine Learning	Reduces fuel consumption by up to 15% through real-time route optimization	BIMCO Cyber Security Report 2023 (https://www.bimco.org/cyber-security)
	Predictive ship maintenance reduces downtime by up to 30%	
IoT & Sensors	Real-time engine performance monitoring improves fuel efficiency by 8-12%	BIMCO Smart Shipping Guidelines (https://www.bimco.org/smart-shipping)
	Automatic cargo damage detection reduces insurance claims by 20%	
Document Digitization	Port clearance processes accelerated by 70% through e-Bill of Lading (e-BL)	BIMCO e-BL Adoption Report https://www.bimco.org/contracts/clauses/e-bill-of-lading)
	Administrative cost savings of up to $50,000/ship/year	
Autonomous Ships	Autonomous ship trials show a 40% reduction in operating costs (although still in the development stage)	BIMCO Maritime Autonomous Surface Ships (MASS) Policy (https://www.bimco.org/mass)

b. Technology Implementation Challenges

- Cyber Security: 78% of BIMCO members reported cyberattacks in 2023, up from 65% in 2022.
- Regulatory inconsistency: 62% of operators face legal uncertainty regarding the use of AI and autonomous ships.
- Investment costs: 55% of SME shipping companies find it difficult to adopt technology due to high initial costs.

Source: BIMCO Shipping Industry Outlook 2023 (https://www.bimco.org/news/news/20231219-shipping-industry-outlook-2024)

c. Case Studies: Successful Implementation

- Maersk: Use of AI for route optimization saved 1.1 million tons of CO_2 in 2023.
- Mitsui O.S.K. Lines (MOL): IoT system for engine performance monitoring reduced maintenance costs by $12 million/year.
- One Ocean Platform: BIMCO's digital platform for document management accelerated port transactions by up to 50%.

Source: BIMCO Technology Case Studies 2023 (https://www.bimco.org/smart-shipping/case-studies)

d. BIMCO Recommendations for the Industry
   - Technology Standardization: Encourage the adoption of global standards for e-BL and data sharing (e.g., FONASBA).
   - Investment in Human Resources: Training crew members to operate digital technology (BIMCO Cyber Security Training program).
   - Regulatory Cooperation: Urging the IMO to accelerate MASS (Maritime Autonomous Surface Ships) regulations.

   Source: BIMCO Annual Report 2023 (https://www.bimco.org/about/annual-report)

The following is data from the 10 largest ports in the world that have implemented smartseas technology and its impact:

Table 2. The 10 Largest Ports in the World that Have Implemented Smartseas Technology and Its Impact

No	Port (Country)	The Implementation Year of Smartseas	Impact on Effectiveness	Impact on Efficiency	Impact on Data Accuracy	Impact on Maritime Safety and Security
1	Shanghai (China)	2020	Improved intermodal coordination and a 30% reduction in ship waiting times	15% increase in container throughput and 10% reduction in operating costs	Improved accuracy of ship arrival and departure predictions to 95%	Early warning system for security threats, and 20% reduction in shipping incidents
2	Singapore (Singapore)	2021	Full integration of the digital supply chain and improved customer service	Reduction in loading and unloading time by up to 25%, and 20% increase in port capacity	*Real-time data tracking with 99% accuracy*	Intelligent navigation systems to avoid collisions, and improved cyber security
3	Rotterdam (Netherland)	2020	Digitization of document processes and improved port connectivity	A reduction in carbon emissions of up to 20%, and an increase in energy efficiency of 15%	Improved accuracy of weather and sea condition predictions up to 90%	Automated environmental monitoring systems and real-time security

						threat detection
4	Ningbo-Zhoushan (China)	2021	Full automation of container terminals and increased handling capacity	Productivity increases of up to 30% and logistics cost reductions of 18%	Real-time cargo monitoring system with 98% accuracy	Improved worker safety through automation and integrated security systems
5	Shenzhen (China)	2022	AI integration for storage optimization and service improvement	Throughput increased by up to 18%, and waiting time reduced by 25%	Demand forecasting with 95% accuracy, and real-time cargo tracking	Intelligent security system with AI, and 25% reduction in security incidents
6	Busan (South Korea)	2021	Development of a smart port ecosystem and improvement of regional connectivity	Reduction in loading and unloading time by up to 22%, and 15% increase in capacity	Logistics data integration with 97% accuracy	Autonomous navigation systems and improved maritime safety
7	Antwerp (Belgium)	2022	Digitization of administrative processes and improvement of customer service	Up to 20% improvement in operational efficiency and 12% reduction in costs	Integrated logistics information system with 96% accuracy	Improved cyber security and maritime threat detection systems
8	Hamburg (Germany)	2021	Automation of container terminals and improved connectivity with land transport	Reduction in administrative processing time by up to 40%, and 16%	*Real-time data exchange with 98% accuracy*	Environmental monitoring systems and improved navigation safety

				increase in throughput		
9	Los Angeles (United States of America)	2023	Blockchain implementation for documentation and increased transparency	Reduction in ship waiting time by up to 30%, and 22% increase in capacity	Container tracking accuracy up to 99%, and better demand forecasting	Integrated security systems and enhanced cybersecurity
10	Dubai (UEA)	2022	Development of smart port infrastructure and improvement of digital services	Up to 35% improvement in operational efficiency and 20% reduction in costs	Integrated data management system with 97% accuracy	Improved physical and cyber security, and early detection systems

Thus, the application of smartseas technology is not only in line with international regulations, but can also contribute to improving efficiency and safety in maritime operations. Further research is needed to explore the full potential of this technology in a broader context.

The application of smartseas technology has shown great potential in improving the efficiency of maritime operations. According to a report from the International Maritime Organization (2023), the use of IoT-based monitoring systems can reduce fuel consumption by up to 20% by optimizing shipping routes and ship speeds. A concrete example can be seen at the port of Rotterdam, which has implemented a smartseas system to manage ship traffic in real-time, reducing ship waiting times at the port by up to 30% (Van Dijk, 2023).

Navigation accuracy has also improved with the implementation of smartseas technology. With the use of advanced monitoring systems, ships can avoid high-risk areas and reduce the likelihood of accidents. For example, a study by the Maritime Safety Research Institute (2023) found that the use of AI-based monitoring technology can reduce ship collision incidents by up to 40%. This shows that technology not only improves efficiency, but also contributes to overall maritime safety by preventing collisions, collisions, sinkings, fires, groundings, piracy, environmental pollution, fish theft, and domestic or international route violations.

However, the challenges in implementing smartseas technology cannot be ignored. One of the main issues is the need to train skilled workers in the use of this technology. According to a report from the World Maritime University (2024), around 60% of

professionals in the maritime industry feel unprepared to use the new technology that has been introduced. Therefore, it is important to develop effective training programs to ensure that all personnel can make optimal use of Smartseas technology.

The problem of "smartseas" in Indonesian shipping

Although the concept of "smartseas" offers promising solutions, its implementation in Indonesia faces a number of challenges. In order to achieve optimal efficiency, accuracy, and maritime operational safety, there are several issues that require resolution and policy measures, including the following:

a. Uneven Digital Infrastructure

The uneven distribution of digital infrastructure between large ports in western Indonesia and small ports in the eastern region has resulted in:

- Connectivity and Networks: Many port areas, especially in remote regions, still have limited or unstable internet access. This hinders the implementation of IoT technology, which requires a constant data connection to send real-time data from ships to land, resulting in bandwidth issues and intermittent data transmission.
- Port Technology Lag: Ports are designed in accordance with applicable regulations, but not all ports have integrated terminal management systems or automatic sensors. Some ports still operate manually, which causes delays, data errors, and a lack of visibility into cargo movements.

To equalize digital infrastructure in order to support smartseas technology in Indonesia, the following activities are planned to be implemented over the next 20 years (2025-2045):

Table 3. Digital Infrastructure Distribution Plan

Phase	Period	Primary Focus
Foundation	2025-2028	Regulations, maritime satellites, smart VTS, cybersecurity, and technology trials
Acceleration	2029-2035	Network expansion to eastern Indonesia, 3D digital maps, and autonomous test vessels
Optimization	2036-2045	Full autonomous navigation, predictive AI integration, and global coverage smartseas

b. Weak Data Standardization and Integration

The lack of standardization in data collection and exchange between various parties is a major obstacle to accuracy and efficiency.

- Data Fragmentation: Information about ships, cargo, and schedules is often scattered across various systems that are not interconnected, such as those belonging to ports, customs, shipping companies, and maritime authorities. As a result, it is difficult to obtain a complete and accurate picture quickly.
- Bureaucracy and Manual Administration: Many administrative processes, such as licensing documents and manifests, still rely on physical documents. This is not only time-consuming but also prone to human error, which impacts data

accuracy and operational speed. The implementation of digital administration in ports is urgently needed. To truly transform ports, the adoption of technology must continue to be encouraged by creating:
Electronic Documents: All documents, including waybills and manifests, must be in electronic form and digitally validated, which increases the legal certainty of these documents and reduces paper usage, and;
Automation of Routine Tasks: Implement automation for routine tasks such as container gate-in/gate-out using a license plate recognition system with sensors.

To address weak data standardization and integration in order to support smartseas technology in Indonesia, the following activities are planned to be implemented over the next 20 years (2025-2045):

Table 4. Plan for Strengthening Data Standardization and Integration

Phase	Period	Primary Focus
Understanding the Problem and Laying the Groundwork	2025-2030	Comprehensive Assessment: A thorough evaluation of the existing maritime data in Indonesia
		International Comparative Study: Learning from international maritime data standards that have proven effective
		National Consensus Building: Building mutual agreement among all stakeholders
		Prototype Development: Building a limited data integration system prototype for proof of concept
Development and Initial Implementation	2031-2035	Phased Implementation: Implementing data standards gradually, starting with major ports
		Infrastructure Development: Building technological infrastructure that supports maritime data integration
		Human Resource Capacity Building: Training and improving human resource competencies
		Public-Private Partnerships: Developing partnerships to accelerate implementation and innovation
Expansion and Optimization	2036-2040	Regional Expansion: Collaborating with ASEAN countries for regional data standardization
		System Optimization: Improving the performance of data integration systems based on evaluation

		Technological Innovation: Promoting the development and adoption of advanced technologies
		Community Empowerment: Involving the community in the utilization of maritime data
Sustainable Maintenance and Innovation	2041-2045	Periodic Updates: Performing periodic updates to data standards
		Research and Innovation: Promoting fundamental and applied research for future technologies
		Global Leadership: Positioning Indonesia as a leader in global standardization
		Sustainability: Ensuring the sustainability of the maritime data ecosystem

c. Quality of Human Resources and Work Culture

Human factors play a crucial role. The adoption of new technology requires readiness on the part of operators and ship crews.

- Skills Gap: Many workers in the maritime sector still lack adequate digital skills. The lack of training in operating modern systems such as ECDIS (Electronic Chart Display and Information System) or analyzing AIS data means that technology is not being used to its full potential.
- Effective and Safe Use of ECDIS ECDIS is a modern navigation system that replaces traditional paper charts on ships. Effective use of ECDIS is crucial to ensure the safety, accuracy, and efficiency of voyages.
- Resistance to Change: Old habits and resistance to technological change can hinder the transition to a smarter system. There needs to be a strong education program and incentives to encourage a change in work culture.
- Implementing adaptive and collaborative work culture transformation by at least the following means: Changing long-standing mindsets and work practices, implementing a reward and incentive system based on individual and team performance, creating open lines of communication between leaders and employees at all levels, and making safety a core value in the work culture.

To address human resource quality and work culture in order to support smartseas technology in Indonesia, the following activities are planned to be implemented over the next 20 years (2025-2045):

Table 5. Plan for Improving Human Resource Quality and Work Culture

Phase	Period	Primary Focus
Foundation of Transformation	2025-2030	Competency Mapping: Identify gaps between current maritime human resource

		competencies and smartseas technology requirements
		Educational Transformation: Curriculum and teaching method reform in maritime schools/colleges
		Safety Culture Development: Integrating technology into maritime safety work culture
		Learning Model Development: Hybrid learning (online/offline) with smartseas technology simulation
Implementation and Development	2031-2035	Continuing Education: A system of continuous competency development for maritime professionals
		Digital Leadership Development: A specialized program for maritime industry leaders
		Strengthening a Culture of Innovation: Encouraging a culture of experimentation and learning from failure
		Industry-Education Partnership: Close collaboration between educational institutions and industry
Strengthening and Expansion	2036-2040	Development of Innovation Ecosystem: Building an ecosystem that supports maritime technology innovation
		Strengthening Professional Networks: Developing national and international digital maritime professional networks
		Empowering Coastal Communities: Engaging coastal communities in the maritime technology ecosystem
		Applied Research Development: Promoting applied research for smartseas technology solutions
Sustainability and Leadership	2041-2045	Global Standards Development: Influencing the development of global digital maritime competency standards
		Intergenerational Learning: Mechanisms for transferring knowledge from older generations to younger generations
		Future Competency Development: Anticipating competency requirements for future maritime technology

		Strengthening the Ecosystem: Ensuring the sustainability of the digital maritime human resource ecosystem

d. Security and Regulatory Issues

Safety aspects, despite being enhanced by technology, also face regulatory and cybersecurity challenges.

- Regulations that Have Not Kept Pace with Technological Developments: Existing regulatory frameworks sometimes fail to accommodate rapid developments in maritime technology, such as autonomous ships or smart navigation systems. This can lead to legal uncertainty and hinder innovation.
- Cyber Security Risks: Digitally connected systems can be targets for cyberattacks. Without proper security policies in place, information about a ship's direction and operations could be altered, potentially endangering safety at sea.

To address human resource quality and work culture in order to support smartseas technology in Indonesia, the following activities are planned to be implemented over the next 20 years (2025-2045):

Table 6. Security and Regulatory Strengthening Plan

Phase	Period	Primary Focus
Establishing Regulatory and Security Foundations	2025-2030	Development of a Comprehensive Regulatory Framework: Establishing regulations that cover all aspects of smartseas technology
		Cybersecurity Capacity Building: Developing cybersecurity capabilities for maritime infrastructure
		Harmonization of National and International Regulations: Aligning Indonesian regulations with international standards
		Supervision System Development: Developing a supervision and law enforcement system for regulatory compliance
Implementation and Development	2031-2035	Strengthening Critical Infrastructure Security: Protecting critical maritime infrastructure from cyber threats
		Dynamic Regulation Development: Building a regulatory system that can adapt to technological developments
		Enhanced International Cooperation: Strengthening cooperation in maritime security with other countries

		Development of Operational Safety Standards: Establishing safety standards for smartseas technology operations
Strengthening and Expansion	2036-2040	Maritime Security Ecosystem Development: Building an ecosystem that supports comprehensive maritime security
		Enhancing Rapid Response Capacity: Developing rapid response capabilities to security threats
		Strengthening Public-Private Partnerships: Promoting collaboration between government and industry in maritime security
		Global Standards Development: Contributing to the development of global maritime safety standards
Sustainability and Leadership	2041-2045	Global Standards Development: Leading the development of global maritime safety standards
		Enhancing Anticipatory Capacity: Developing the ability to anticipate future security threats
		Strengthening the Innovation Ecosystem: Driving innovation in maritime security technology
		Building a Security Legacy: Creating a sustainable security system for future generations.

The solution to this problem must focus on a holistic approach that includes infrastructure investment, policy development, and sustainable human capacity building. Implementing the results of the 2023 BIMCO study, namely increasing fuel efficiency by up to 20% by optimizing shipping routes and ship speeds, implementing cybersecurity, and employing workers who can analyze AIS data and utilize ECDIS systems.

4. CONCLUSION

Smartseas technology offers many opportunities to improve the efficiency, accuracy, and safety of maritime operations. Its benefits, including chain benefits or multilayer "neutron energy," far outweigh the risks, despite the difficulties in implementing it.

With the support of international organizations such as the IMO and the implementation of strict safety standards, the maritime industry can carry out more efficient and safer operations.

Further research is needed to explore the full potential of this technology and to overcome the challenges faced in its implementation.

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