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Strengthening Indonesia's Maritime Safety Governance: Insights From Ship Accident Trends and Regulatory Oversight

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ABSTRACT

The high rate of ship accidents highlights a persistent gap between safety regulations, supervision, and field implementation, making maritime accidents a continuing challenge for Indonesia's shipping safety system. This study examines the key components influencing maritime safety governance and identifies strategic priorities for strengthening regulation and oversight. Using the SWOT–AHP (Strengths, Weaknesses, Opportunities, and Threats–Analytic Hierarchy Process) method, internal and external factors were assessed through pairwise comparisons to establish consistent priorities. The findings indicate that international and national regulations (31.1%), maritime education and training (14.8%), and Port State Control (PSC) supervisory capacity (13.6%) are the most critical factors, while structural weaknesses such as low inspection frequency (7.2%) and the lack of safety culture (3.7%) remain major barriers. Opportunities in digital monitoring (2.6%) and threats from extreme weather (2.5%) underscore the need for adaptive, risk-based strategies. The novelty of this study lies in integrating the SWOT–AHP framework with Risk-Based Management (RBM) and strategic management theory to produce a measurable strategic priority map that directly links quantitative evidence to policy planning, implementation, and evaluation. Furthermore, the study introduces a time-phased, multi-actor policy strategy comprising short-term (1–3 years) initiatives, such as regulatory harmonization, digital monitoring, and capacity building led by the Ministry of Transportation and long-term (4–10 years) reforms emphasizing institutional integration, AI-based predictive safety systems, and national safety culture development led by cross-ministerial coordination. This combined approach provides a practical and data-driven foundation for achieving adaptive, measurable, and sustainable maritime safety governance in Indonesia.

Keywords: Indonesian maritime accidents; safety governance; regulatory oversight; SWOT-AHP; risk-based management

INTRODUCTION

In the last five years, Indonesia's maritime GDP (blue economic sectors_ has grown at average rate of 3,6% annually (Bappenas, 2024). With more than 80% of global trade volume conducted by sea, maritime transport plays a vital role in global trade. Shipping is the backbone of economic and social relations for Indonesia, the largest archipelagic country. It also offers many advantages, such as large transport capacity, inexpensive distribution between regions, and a significant contribution to the country's economic growth. In terms of sustainability, strengthening the maritime industry can help the environmental sector grow by reducing the burden on land transportation and improving supply chain efficiency. However, this sector is also highly vulnerable to accidents that often result in fatalities. (Shi & Liu, 2025), environmental damage, significant economic losses, and total loss of the ship (Zhang et al., 2025), loss of life, pollution, and supply chain disruptions (Qu et al., 2025).

Several international regulations established by the International Maritime Organization (IMO) with the aim of improving safety management and reducing the potential for maritime disasters around the world, such as SOLAS, ISM Code, and MARPOL, have been proven to improve safety management and reduce maritime risks. SOLAS effectively mitigates structural, fire, and navigation risks (Joseph & Dalaklis, 2021), ISM Code reduces serious accidents globally, although this depends on national implementation (Mok et al., 2023), MARPOL Annex V reduces marine pollution from shipping, but its effects are weakened without continuous monitoring (Serra-Gonçalves et al., 2023). These regulations are more effective when designed to be adaptive with strong enforcement (Olaniyi et al., 2024a), where compliance with SOLAS and ISM has been proven to strengthen safety barriers on ships (Mišković & Wang, 2025), and establish a comprehensive framework for risk management (Guevara & Dalaklis, 2021). However, how effective these regulations ultimately are depends on how well each country implements and enforces them consistently in practice. Yet, the effectiveness of these global frameworks ultimately depends on how well they are translated into practice at the national level. In Indonesia, implementation gaps remain evident: enforcement capacity is uneven across regions, compliance monitoring is still fragmented, and the integration of these conventions into domestic law and operational practice is inconsistent (Olaniyi et al., 2024a; Mok et al., 2023). These challenges highlight that while global standards provide a strong foundation, Indonesia's maritime policy must address national-level institutional, legal, and enforcement gaps to fully capture the safety, environmental, and economic benefits of international maritime governance.

Previous studies have revealed that the main causes of accidents are multifactorial, ranging from technical failures and extreme weather conditions to human error and non-compliance with safety standards. Research on maritime accidents in Indonesia reveals that human error is the predominant cause of ship accidents. Waskito et al. (2024) found that 70.5% of ship sinking accidents were caused by human error, primarily triggered by unsafe acts, with passenger vessels accounting for half of all sinking incidents. Similarly, Datu et al. (2024) cited international studies showing human error accounts for 75-96% of marine accidents globally, with over 80% of maritime accidents attributed to human factors. Firdaus et al. (2024) analyzed collision accidents using fault tree analysis and concluded that human-related factors, including lack of training, experience, and improper decision-making, were the most contributing factors to collisions in Indonesian waters. Yulianto (2023) reported 13 shipping accidents in Indonesian territory in 2022, emphasizing the impact of crew errors on accident occurrence.

These studies consistently demonstrate that human error significantly outweighs technical issues as the primary cause of maritime accidents in Indonesia. Maritime accidents can generally be categorized into various types, such as collision, grounding, sinking, contact, and fire/explosion (Lan et al., 2024), as well as hull/machinery damage and foundering (Pilatis et al., 2024). Many developing countries with strong maritime bases still face serious problems due to limited institutional capacity and lack of oversight. This is despite advances in navigation technology and crew training programs that have successfully reduced accident rates in some regions. Effectiveness depends on national implementation and oversight. Although the application of safety frameworks such as the ISM Code has helped reduce serious fatalities worldwide, the effects are uneven and are largely determined by weak institutional capacity and poor oversight in many developing countries/SIDS, which limits the effectiveness of safety interventions. (Mok et al., 2023; Nisa, 2022).

As the world's largest archipelago, maritime transportation is not only vital for economic growth and connectivity but also forms the foundation of national logistics and territorial integration. Strengthening maritime transport management means enhancing efficiency, safety, and resilience of all elements of sea transport ranging from regulatory oversight, vessel operations, and infrastructure, to human resource capacity. Maritime transport management therefore plays a strategic role in connecting Indonesia's 17,000 islands, ensuring equitable development, and safeguarding the safety of life at sea. In the context of this study, maritime transport management is operationalized through three core variables: regulatory governance, which captures the quality and enforcement of safety regulations; institutional supervision, which represents monitoring and inspection capacity; and human resource competence, which reflects the skills and behavior of ship operators and inspectors. These variables are crucial in assessing how management practices affect maritime accident rates and the overall effectiveness of national safety systems.

As the world's largest archipelago, maritime transportation is crucial for economic growth and connectivity. Data collected on maritime accidents over the past ten years shows that Indonesia still has a higher rate of maritime accidents compared to other maritime countries in Southeast Asia. Research on Indonesian maritime safety reveals significant challenges in the national safety system. Statistical analysis of incidents from 2018-2022 shows ship accidents at sea were among the most frequent incidents, averaging 421.6 cases per five years, indicating persistent safety issues requiring better preventive strategies (Apriantara et al., 2023; Faishal et al., 2025). Major incidents such as the sinking of KM Sinar Bangun in Lake Toba in 2018; the fire on a passenger ship in Kalimantan waters in 2020; and the collision of cargo ships in the Sunda Strait in 2023 highlight the weaknesses in the national safety system. Case studies at Merak Port identified human factors, weather conditions, and infrastructure as

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critical safety elements, with incidents like the KMP Royce 1 fire demonstrating gaps in safety training and compliance procedures (Nawawi et al., 2024). Following the KM Sinar Bangun tragedy, recovery strategies focus on strengthening transportation functions and addressing infrastructure weaknesses through SWOT analysis-based approaches (Sitio et al., 2025). These findings collectively support the need for comprehensive evaluation of technical and safety management elements in Indonesia's maritime sector.These incidents indicate that a more comprehensive evaluation of technical and safety management elements is needed.

Indonesia's maritime safety management faces systemic challenges stemming from limited supervisory resources, institutional fragmentation, and non-compliance among vessel operators. The fragmentation of maritime safety institutions has caused overlapping authorities and weak inter-agency coordination, undermining the enforcement of safety regulations(Omara, 2024). Insufficient surveillance resources—such as personnel, patrol vessels, and technical infrastructure—further diminish field supervision effectiveness (Rahman et al., 2023). Meanwhile, inconsistent communication and coordination between vessel owners, crews, and regulators contribute to persistent regulatory non-compliances (Rahmawati et al., 2025). The wide diversity of Indonesia's fleet, ranging from traditional boats to modern vessels, further complicates oversight and raises questions about the adequacy of current safety management systems. Grounded in Risk-Based Management (RBM) theory, this study emphasizes that safety management should be guided by operational risk levels (Bokau et al., 2025; Latt, 2024). Within the maritime context, RBM provides a framework for identifying and mitigating high-risk factors while highlighting the need for adaptive strategies—through stronger regulation, institutional readiness, human resource development, and digital technologies—to ensure effective and sustainable maritime safety governance (Hidayat et al., 2024; Olaniyi et al., 2024b).

The urgency of this study lies in Indonesia's persistently high maritime accident rates despite continuous regulatory improvements. Over the past decade, Indonesia has reported an average of 420 maritime accidents annually significantly higher than neighboring countries such as Malaysia or the Philippines (Apriantara et al., 2023; Faishal et al., 2025). These figures highlight systemic weaknesses in maritime transport management, particularly in inspection frequency, risk mitigation, and safety culture adoption. Strengthening maritime transport management is thus essential not only for reducing accident frequency but also for improving competitiveness in global logistics networks and ensuring alignment with the Sustainable Development Goals (SDG 9 and SDG 14). Consequently, this research aims to produce an evidence-based strategic framework to strengthen Indonesia's maritime transport management through measurable, risk-based, and adaptive governance mechanisms.

Against this backdrop, the present study is guided by three key research questions: (1) What types of maritime accidents are most common in Indonesia in recent years? (2) How effective are applicable laws and institutional mechanisms in reducing accidents? (3) What governance issues exist, and what strategies can improve national shipping safety? By addressing these questions, the study seeks to evaluate maritime accident trends, assess the effectiveness of Indonesia's safety management and oversight systems, and provide evidence-based recommendations for strengthening governance. This study was conducted from January to June 2025 in several major Indonesian ports, including Tanjung Priok, Tanjung Perak, and Bitung, representing the western, central, and eastern maritime corridors. The research employed a SWOT–AHP (Strengths, Weaknesses, Opportunities, and Threats–Analytic Hierarchy Process) method to identify and prioritize strategic factors influencing maritime safety governance. Primary data were collected through structured expert interviews with policymakers, port authorities, and maritime safety inspectors, complemented by secondary data from accident statistics, regulatory documents, and institutional reports.

The analytical process combined qualitative assessments of governance challenges with quantitative pairwise comparisons to determine priority weights, producing a measurable strategic priority map that supports decision-making for maritime transport management strengthening. Specifically, the purpose of this article is to identify the strengths, weaknesses, opportunities, and threats related to these ship accident trends, as well as their relative levels of importance. Strengths, weaknesses, opportunities, and threats (SWOT) analysis and the analytical hierarchy process (AHP) were used as decision-making tools to achieve this. Figure 1 shows the methodology used in this study.

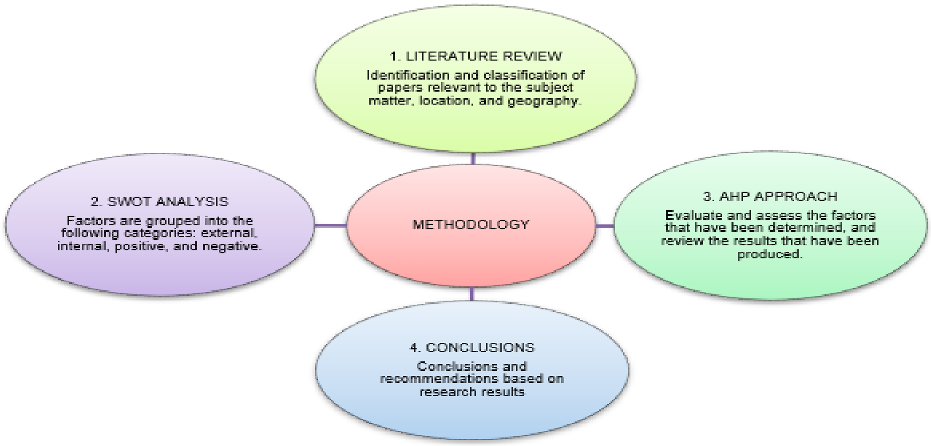

Figure 1. Research Methodology Used (author's elaboration).

METHOD

Opportunities and Obstacles: Swot Analysis

Based on a review of literature and national regulations related to shipping safety, a number of factors can be identified that influence maritime accident trends in Indonesia, particularly in the context of ship disasters and regulatory oversight mechanisms. To analyze these factors, the SWOT method was used, which assesses internal conditions in terms of strengths (S) and weaknesses (W), as well as external factors in terms of opportunities (O) and threats (T) (Ben Ali & Rauch, 2024). This approach helps identify priorities, risks, and urgent governance change needs in improving shipping safety.

The main strength lies in the existence of international and national regulations that form the basis of the safety system, while weaknesses arise from limited supervisory resources and a lack of field inspections. Opportunities can be seen in the development of digital ship monitoring technology and government policy support, while threats come from extreme weather, the complexity of ship traffic, and low operator compliance. This SWOT analysis forms the basis for formulating a strategy to strengthen maritime safety governance in Indonesia, as summarized in Table 1.

Table 1. Internal and External Factors.

Internal Factors	
Strengths	**Weaknesses**
1. The existence of international regulations (IMO, SOLAS, STCW) and national regulations (Shipping Law, Minister of Transportation Regulations) as the legal basis for safety.	1. Limited number and capacity of Port State Control Officers (PSCOs) in both large and small ports.
2. The maritime education and training network of the Shipping Polytechnic (Human Resources Development Agency, Ministry of Transportation) that supports shipping safety.	2. Low frequency of field inspections and periodic monitoring of cargo ships, traditional ships, and passenger ships..
3. The government's commitment to strengthening maritime governance through port digitization and VTS (Vessel Traffic Service) systems.	3. Low safety culture among crew and ship operators.
4. Bilateral and regional cooperation (Tokyo MoU, ASEAN maritime cooperation) that supports safety harmonization.	4. Safety facilities on ships (alarms, life jackets, lifeboats) are often not well maintained.
External Factors	
(Opportunities)	**(Threats)**
1. Utilization of digital ship monitoring technology (AIS, IoT, big data) to improve the effectiveness of surveillance, (Jain et al., 2025).	Extreme weather and climate change increase the risk of maritime accidents, (Brandt et al., 2024).
2. Global support for realizing green and safe shipping (safety & sustainability) in accordance with IMO standards.	2. High passenger and vehicle traffic on strategic routes (e.g., Merak–Bakauheni), which increases the vulnerability to accidents.
3. The potential for private investment in the development of port safety infrastructure and modern evacuation systems.	

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Continue Table 1.

External Factors	
(Opportunities)	**(Threats)**
4. The increasingly critical role of the media and civil society in monitoring public safety issues. 5. The existence of government programs towards Net Zero Emission and the blue economy that encourage improved safety and environmental standards., (Ministry of National Development Planning/National Development Planning Agency (BAPPENAS) of the Republic of Indonesia, 2023). 6. The development of maritime technology (autonomous vessels, e-navigation, smart ports) that can support navigation system risk management, (Laakso et al., 2025). 7. International and regional cooperation (IMO, IALA, ASEAN, Tokyo MoU) in regulatory harmonization and surveillance capacity building.	3. Global competition in compliance with IMO standards, which puts pressure on the competitiveness of the national fleet. 4. Limited state budget for the modernization of traditional ships and port safety facilities.

Analytical Hierarchy Process (AHP)

The Analytic Hierarchy Process (AHP) is a decision-making method that helps you make the best decisions in complex situations. This technique, created by Thomas L. Saaty in the 1970s, is widely used in various fields, including engineering, business, and environmental studies (Costa et al., 2023). The Analytical Hierarchy Process (AHP) breaks down decision-making problems into a hierarchical structure of criteria and alternatives, which helps decision-makers evaluate and prioritize various factors systematically. This combination of SWOT and AHP methods has been approved in various fields of research. This methodical decision-making method ensures that each factor is correctly prioritized and has been considered and given the appropriate value to encourage smarter and more efficient decision-making. This method is also widely used in various shipping and maritime studies, such as applying fuzzy-AHP to rank safety investment needs for Arctic shipping operations in extreme environments. (Wan et al., 2024), determining the weight of key factors causing port congestion using AHP to support operational decision-making (Bolat et al., 2020), Ranking alternative ports of call for shipping operators when designing the most efficient routes (Georgoulas et al., 2023).

The Analytical Hierarchy Process (AHP) can be explained in three main steps that are necessary to ensure that the factors are prioritized and validated as well as possible (as shown in figure 4. Next, the Analytical Hierarchy Process (AHP) method uses pairwise comparisons to prioritize SWOT factors. AHP balances two factors with a scale value from one to nine, see (Figure 2) and considers the value of each factor. Finally, to ensure the consistency of the matrix, the consistency ratio (CR) is used to determine whether the decision maker is consistent when comparing factors. If the CR is less than 10% (see Equation (1)), the value is relatively consistent, and the evaluation must be repeated (Manik, 2023). To ensure consistency, each comparison result is converted into a matrix (see Equation (1), (Gago et al., 2022).

Figure 2. AHP General Process.

$$\text{Equation 1}: A = (a_{ij}) = \begin{bmatrix} 1 & \frac{W1}{W2} & \cdots & \frac{W1}{Wn} \\ \frac{W1}{W2} & 1 & & \vdots \\ \vdots & & \ddots & \\ \frac{Wn}{W1} & \frac{W1}{Wn} & \cdots & 1 \end{bmatrix}$$

This matrix is created based on the assumption that if factor 1 is considered more important than factor 2, then factor 2 must be prioritized over factor 1 by a ratio of 1/X times based on the scale found in Table 2. In matrix A, the rows show the weight of each factor relative to the other factors, when i = j and aij = 1. Furthermore, when the transpose of the weight vector (w) is multiplied by matrix A, the result is a vector represented by λ_{max} w, where λ_{max} is the largest eigenvalue of matrix A and w is the transpose of the weight vector (Gago et al., 2022). For example, equation (2) can be written as.

$$\text{Equation 2 : } (A - \lambda_{max}\, I)W = 0$$

Where I serves as the identity matrix. The largest eigenvalue, λ_{max}, is equal to or greater than n, or the number of rows or columns in matrix A. If there is more consistency among the responses, λ_{max} approaches n, and if all responses are perfectly consistent, λ_{max} is equal to n. (Gago et al., 2022). Next, Equation (3) is used to calculate the consistency index (CI) for each matrix.

$$\text{Equation 3 : } CI = \frac{\lambda\max - n}{n-1}$$

Finally, CR, as shown in Equation (4), is used to determine the level of consistency and depends on the calculation of CI and Random Index, RI (see Table 3).

$$\text{Equation 4 : } CR = \frac{CI}{RI}$$

Table 2. General Comparison Scale for the AHP Method.

Number	Meaning
1	Equally important
3	Moderately more important
5	Immensely more important
7	Much more important
9	Entirely more important
2, 4, 6, 3	Interior values

Source: (Pramanik et al., 2017)

Overview of Maritime Accident Trends in Indonesia

Indonesia's maritime transport sector continues to face persistent safety challenges despite ongoing policy reforms. Data from the National Transportation Safety Committee (KNKT, 2025) indicate fluctuating accident trends between 2020 and 2025. In 2020, 12 maritime accident cases were recorded, increasing sharply to 19 cases in 2021 before declining to 14 in 2022 and further dropping to 6 in 2024. However, a slight uptick to 7 cases occurred in 2025 (Figure 3). These fluctuations suggest that while accident reduction efforts have made progress, risks remain, particularly within conventional passenger vessels still operating in remote areas. This pattern highlights that accidents in Indonesia cannot yet be fully eradicated without more adaptive and systemic maritime safety governance.

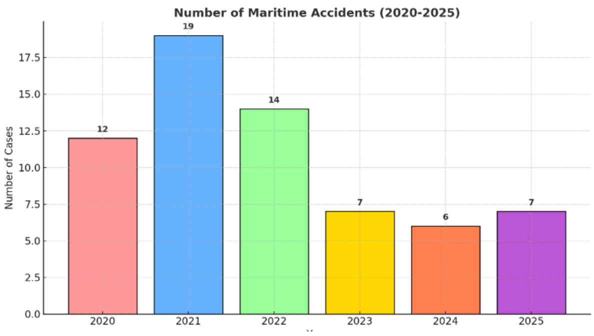

Figure 3. Number of Shipping Accidents in Indonesia.

During the same period, accidents in Singapore ranged from 3 to 8 cases per year. This figure was highest in 2022 with 8 cases, but fell again to 6 cases in 2023 and 2024, and in 2025 there were no official reports of accidents (Figure 4), (Marine Safety Investigation Reports, 2025). This fact shows that Singapore has a strict maritime safety surveillance system and strong regulations. Strict maritime safety management policies, comprehensive surveillance and regulatory systems, and consistent law enforcement by the

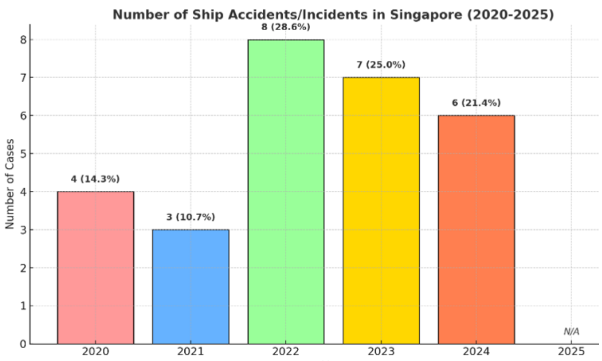

Figure 4. Number of Shipping Accidents in Singapore.

Table 3. Random Indexs (RI).

n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
(RI)	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48	1.56	1.57	1.59

Source: (Pramanik et al., 2017)

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Singaporean government are the main factors driving this achievement. Since 2010, the country has improved international safety standards through the implementation of IMO regulations, regular inspections, and the development of advanced navigation technology. The strict implementation of Port State Control (PSC) inspections has helped Singapore reduce the potential for shipping accidents. (Sheriff et al., 2025), in line with its commitment to strengthen maritime safety standards through IMO regulations and routine inspections (Beckman, 2008). Significant investments have also been allocated to port infrastructure and vessel monitoring systems, which will help accelerate early detection and rapid response to potential incidents. This success demonstrates that integrated safety management, combined with risk management principles through strict regulatory planning and oversight, institutional strengthening, and the use of technology, can significantly reduce accident rates and strengthen global maritime competitiveness.

Institutional and Human Factors Affecting Maritime Safety

Maritime safety governance in Indonesia involves multiple actors regulators, ship operators, shipping companies, and the wider maritime community whose coordination determines the effectiveness of safety policies. Despite Indonesia's long-standing commitment to international maritime conventions, accident rates remain high, particularly in domestic ferry operations. Empirical studies identify *human error* as the dominant causal factor in maritime accidents, accounting for approximately 70.5% of incidents (Bowo et al., 2024). Inadequate training, lack of situational awareness, and weak safety culture continue to undermine operational safety.

Herno Della et al. (2020) demonstrated that structured and periodic safety training significantly improves compliance and crew behavior, emphasizing the importance of sustainable capacity-building programs. However, weak interagency coordination often reduces regulatory consistency, as noted by Arifin et al. (2024), who recommend stronger cross-agency collaboration and digital data integration. These institutional weaknesses limit Indonesia's ability to enforce uniform safety oversight, highlighting the need for a more unified governance structure under a coordinated maritime safety authority.

Technological and Regulatory Gaps in Safety Oversight

Recent research emphasizes the importance of technology and regulation harmonization in improving maritime safety. Karahalios (2025) found that inconsistencies in PSC procedures across the Asia-Pacific region can be mitigated through the adoption of digital inspection and certification systems. Similarly, Arifin et al. (2024) recommend aligning national safety frameworks with IMO standards to ensure interoperability and credibility in international shipping.

In the context of Indonesia, technological integration remains uneven. For example, Nurwahyudy et al. (2024) identified the need for integrated traffic management and digital emergency response systems in the Sunda Strait ferry routes. Meanwhile, Priadi et al. (2024) proposed the addition of a Traffic Separation Scheme (TSS) at Merak's VTS and the use of IoT-based vessel monitoring to minimize collision risks. Sheriff et al. (2025) further highlighted deficiencies in evacuation readiness and emergency systems, calling for upgraded alarms, equipment, and rescue drills. These studies collectively stress that digitalization and emergency preparedness are indispensable pillars in building a resilient maritime safety system.

Comparative Insights and Lessons Learned

Indonesia's maritime safety governance involves multiple stakeholders—regulators, ship operators, shipping companies, and the maritime transport user community—requiring strong cooperation and innovation. Despite long-standing commitments, accident rates, particularly among traditional passenger vessels, remain high through 2025. Research highlights that safety training significantly improves crew compliance (Herno Della et al., 2020), while human error accounts for about 70.5% of incidents (Bowo et al., 2024). Weak interagency coordination further limits regulatory effectiveness, underscoring the need for cross-agency collaboration and digital integration (Arifin et al., 2024).

Recent studies recommend digital inspection systems to address inconsistencies in Port State Control (PSC) procedures (Karahalios, 2025) and emphasize harmonization with IMO standards (Arifin et al., 2024). Ferry safety in the Sunda Strait requires integrated traffic management, digital technologies, and stronger emergency preparedness (Nurwahyudy et al., 2024). while Ro-Ro safety improvements include adding a Traffic Separation

Table 4. Summary of Key Research on Maritime Safety in Indonesia.

References	Focus	Key Findings	Recommendations/Implications
Herno Della et al. (2020)	Crew training	Training improves safety behavior	Expand crew training programs
Bowo et al. (2024)	Accident causation	70.5% of accidents due to human error	Strengthen human factor mitigation
Arifin et al. (2024)	Regulatory coordination	Weak cross-agency coordination	Strengthen collaboration; integrate digital systems
Karahalios (2025)	PSC inspections	Procedural inconsistencies in Asia-Pacific	Adopt digital inspection/ certification
Arifin et al. (2024, bibliometric)	PSC global research	Detention factors, inspection effectiveness	Harmonize regulations with IMO standards
Nurwahyudy et al. (2024)	Ferry safety (Sunda Strait)	Gaps in traffic and emergency management	Integrate traffic management, digital tech, preparedness
Priadi et al. (2024)	Ro-Ro vessel safety	Collision and monitoring issues	Add TSS at Merak VTS, deploy IoT monitoring
Sheriff et al. (2025)	Risk analysis (fuzzy-BWM)	Weak evacuation and response systems	Strengthen alarms, equipment, and rescue drills
KNKT (2025)	Accident trends	Peak in 2021, decline afterward	Governance reform, stronger safety culture

Scheme (TSS) to Merak VTS and applying IoT monitoring (Priadi et al., 2024) Evacuation and emergency response remain critical risks, with calls for better alarms, equipment, and rescue drills (Sheriff et al., 2025).

National accident data show fluctuating trends, peaking in 2021 before declining (KNKT, 2025), reinforcing the need for comprehensive governance reforms. Overall, strengthening maritime safety requires not only regulatory and technological improvements but also enhanced oversight, infrastructure investment, and human resource capacity, supported by a multidisciplinary approach integrating technical, institutional, and cultural dimensions.

Strategic Prioritization through SWOT–AHP Analysis

To determine how important each criterion is, the prioritization process begins after dividing the problem into smaller parts and establishing a hierarchy. Criteria are compared at each level based on their influence on the criteria established at the highest level. As shown in the previous subsection, the Analytical Hierarchy Process (AHP) method uses a standard nine-level comparison scale. This helps make effective decisions and understand the relative importance of factors. The priority values indicate the author's opinion about the relative relevance of the standards based on expertise in the field. Basically, this is the answer to the question of which factors are more important in providing a positive or negative impact on the project. As a result of combining the SWOT and Analytical Hierarchy Process (AHP) methods, the SWOT factors are prioritized. Table 5 shows the SWOT factor rankings, and the overall priority score results from SWOT factors and subfactors shows in Table 6.

The overall priority score results from SWOT factors and subfactors (Tabel 6) show that strength factors continue to dominate, with the main weight on factor S1 (international/national regulations) at 25.1%. This shows that this factor is the most important element in Indonesia's maritime safety management. Furthermore, S3 (Port Digitalization & VTS) ranks second with 16.3%, while S2 (Maritime Education and Training) ranks first with 9.7%. Thus, these three components contribute more than 51% of the total weight, so it can be concluded that improving regulations, accelerating digitalization, and improving maritime education capabilities are the main pillars that must be prioritized. These results also show that regulations that are not supported by trained human resources and digital surveillance systems will not be successful.

Table 5. Comparison Matrix of SWOT Factors.

	(S)	(W)	(O)	(T)	Geometric Mean	Priority
(S)	1	3	5	7	3.201	0.564
(W)	0.33	1	3	5	1.495	0.263
(O)	0.2	0.33	1	3	0.669	0.118
(T)	0.14	0.2	0.33	1	0.312	0.055

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Table 6. Total SWOT Factor And Subfactor Priority Scores.

SWOT Group	Subfactor	Factor Priority	Subfactor Priority	Overall Priority
Strengths (S)	S1. International/National Regulations (IMO, SOLAS, STCW, Shipping Law)	0.57	0.441	0.251
	S2. Maritime Education & Training Institutions		0.170	0.097
	S3. Port Digitalization & VTS		0.286	0.163
	S4. Regional & Bilateral Cooperation		0.103	0.059
Weaknesses (W)	W1. Limited Capacity of Port State Control Officers (PSCO)	0.27	0.451	0.122
	W2. Low Frequency of Ship Inspections		0.254	0.069
	W3. Low Safety Culture among Crews		0.146	0.039
	W4. Poor Maintenance of Safety Equipment		0.087	0.023
Opportunities (O)	O1. Digital Monitoring Technologies (AIS, IoT, Big Data)	0.12	0.201	0.024
	O2. Global Support for Green & Safe Shipping		0.159	0.019
	O3. Private Investment in Port Safety Infrastructure		0.131	0.016
	O4. Role of Media & Civil Society		0.093	0.011
	O5. Government Programs: Net Zero & Blue Economy		0.159	0.019
	O6. Emerging Maritime Technologies (e-Navigation, Smart Ports)		0.131	0.016
	O7. International & Regional Cooperation (IMO, IALA, ASEAN)		0.127	0.015
Threats (T)	T1. Extreme Weather & Climate Change	0.04	0.529	0.021
	T2. High Passenger & Vehicle Traffic (e.g., Merak–Bakauheni)		0.250	0.010
	T3. Global Competition in IMO Standards		0.134	0.005
	T4. Limited Budget for Safety Modernization		0.072	0.003

On the downside, W1 (PSCO limitations) occupies a critical position with a weight of 12.2%, making it the biggest weakness that must be addressed immediately. This shows that regulations without adequate support in terms of the number and competence of supervisors will not be able to prevent violations in the field. Other weaknesses such as W2 (Low Frequency of Inspections, 6.9%) and W3 (Low Safety Culture, 3.9%) indicate that there are still significant structural and cultural problems. Although these percentages are smaller than the strengths, they are still important because limited inspections and a lack of safety culture can lead to less effective regulatory governance.

Meanwhile, the opportunity and threat factors with lower weights are O1 (Digital Surveillance), which only scored 2.4%, followed by O2/O5 (Green & Safe Shipping, Net Zero, each at 1.9%), indicating that there are strategic opportunities, but their weight is still much smaller than internal aspects. T1 (Extreme Weather & Climate Change, 2.1%) is the main risk in terms of threats, while factors such as T2 (High Passenger Flow, 1.0%) and T4 (Budget Limitations, 0.3%) indicate that external constraints still exist, although their impact is smaller in the total weighting framework. The analysis shows that regulation (S1), port and VTS digitalization (S3), and education and training (S2) are key strengths that should be leveraged. Meanwhile, PSCO limitations (W1) emerge as a critical weakness that needs to be addressed, with regional cooperation (S4) remaining an important supporting factor (see Figure 5).

From a strategic management perspective, these findings illustrate the need to integrate the SWOT–AHP results into a practical maritime governance framework. Regulations and supervisory capacity, as the highest-priority components, must guide planning, organization, implementation, and evaluation processes. Adopting a Risk-Based Management (RBM) approach allows policymakers to focus resources on the highest-risk areas—such as congested routes, high-passenger ferries, and extreme weather zones—thereby improving resilience and efficiency. Strengthening regulatory clarity and inspection consistency in the short term s hould be followed by long-term reforms emphasizing digital transformation and human capital development. Continuous evaluation using AHP-derived priority weights as performance indicators can link strategic objectives to measurable safety outcomes, such as accident-reduction and compliance improvement targets. Ultimately, the integration of SWOT–AHP, strategic management theory, and RBM provides a quantitative, adaptable, and sustainable foundation for Indonesia's maritime safety governance.

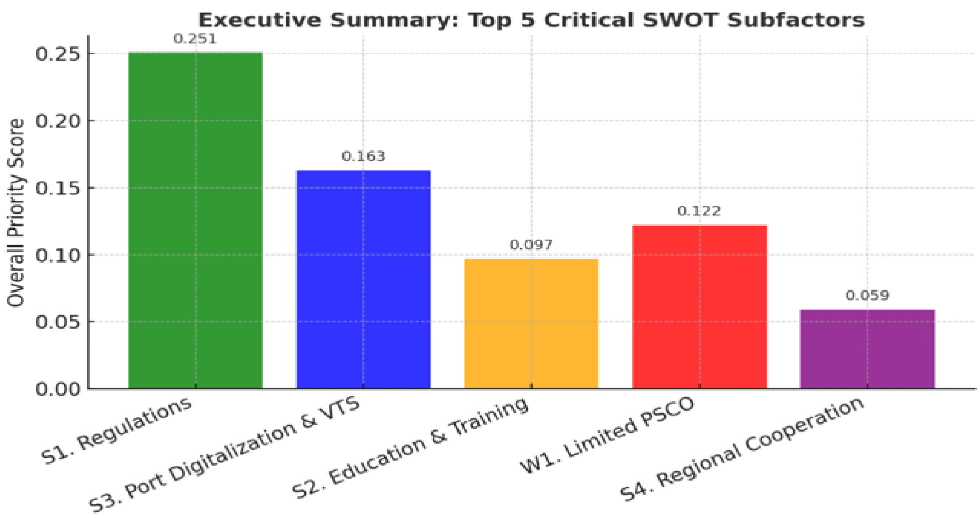

Figure 5. Executive Summary Visuals The Most Critical SWOT Subfactors.

POLICY IMPLICATIONS

Maritime safety is an important part of Indonesia's maritime management, and still faces many problems, such as a lack of regulatory oversight and a lack of safety culture among ship operators. Using a quantitative approach, this study aims to determine the most important components in maritime safety governance management. The goal is to produce a measurable strategic priority map that can be used as a basis for more targeted policies. The SWOT-AHP method combines qualitative analysis and quantitative assessment. The analysis begins by identifying internal and external factors, determining their level of importance through pairwise comparisons, and selecting the most important factors. Because the priority calculation results can be directly translated into a management framework, this method provides a relatively new empirical contribution to maritime safety research in Indonesia. The priority scores can be considered as a basis for planning, organizing, implementing, and evaluating safety policies from a strategic management theory perspective. The strategic implications of the SWOT-AHP results emphasize that maritime safety governance needs to be managed with a strategic management framework that is closely linked to Risk-Based Management (RBM). Regulations and supervisory capacity that received the highest scores should be used as the basis for policy planning, institutional organization, inspection implementation, and continuous evaluation. Regulations and supervision serve as a means of reducing risk because, from an RBM perspective, the highest risk areas are identified as priority areas. Therefore, maritime safety strategies must be more adaptable to extreme weather, passenger density, and global competition. By combining SWOT-AHP and strategic management theory and RBM, quantitative evidence can be directly mapped to management functions, making policies measurable, operational, and sustainable. This study still has limitations, such as the scope of data that focuses on macro factors and does not cover variations in conditions in all Indonesian ports, as well as potential bias in expert assessments in the paired comparison matrix. Therefore, the future research agenda needs to expand the scope of more representative field data, integrate risk analysis based on climate change and traffic density scenarios, and empirically test the effectiveness of digital monitoring technology in strategic ports. In addition, exploring hybrid methods such as SWARA-AHP or Fuzzy-AHP can provide more refined and adaptive measurements in the context of maritime safety complexity.

The SWOT–AHP findings highlight that strengthening regulatory frameworks and supervisory capacity represents Indonesia's highest maritime safety priorities. From a Risk-Based Management (RBM) perspective, these areas correspond to the nation's most significant operational risks and must guide both immediate and long-term policy directions. In the short term (1–3 years), the Ministry of Transportation, the Directorate General of Sea Transportation, and the Indonesian Classification Bureau (BKI) should take the lead in revising and harmonizing domestic safety regulations with international conventions such as SOLAS and ISM. Efforts should also

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focus on forming inter-agency task forces to address institutional fragmentation, enhancing the consistency of Port State Control (PSC) procedures, and deploying real-time digital monitoring systems alongside expanded Vessel Traffic Services (VTS) in high-density ports. In parallel, targeted training, certification, and capacity-building programs for inspectors and ship crews are essential to strengthen safety competencies and ensure effective policy implementation. These short-term actions are expected to yield clearer regulations, standardized inspections, improved coordination, and foundational progress in digitalization.

In the long term (4–10 years), the Coordinating Ministry for Maritime Affairs and Investment, in collaboration with the Ministry of Transportation, the National Research and Innovation Agency (BRIN), and local port authorities, should implement comprehensive institutional reforms through the establishment of an integrated Maritime Safety Authority. Long-term strategies must also prioritize the development of digital safety ecosystems utilizing Internet of Things (IoT) technology, big data analytics, and AI-based predictive monitoring to enhance proactive safety management. Equally important are sustained investments in human capital through maritime academies and continuous professional training, as well as the promotion of a national maritime safety culture campaign involving local governments, private operators, and coastal communities. These efforts aim to create a unified governance structure, technologically advanced monitoring systems, resilient maritime infrastructure, and an embedded culture of safety at all operational levels. Continuous evaluation should underpin both stages, with priority weights from the SWOT–AHP analysis serving as measurable performance indicators tied to accident reduction and compliance improvement. Ultimately, Indonesia's maritime safety governance requires a decisive, multi-actor strategy that integrates regulatory enhancement, institutional coordination, technological innovation, and human capital development to ensure adaptive, measurable, and sustainable safety outcomes.

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AUTHORS CONTRIBUTION STATEMENT

We hereby state that regarding the contribution of each author in the creation of the paper, the contributing authors are Slamet Riyadi as the main contributor and Dian Erliyani as contributor members.

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