International Journal of Safety and Security Engineering
Vol. 15, No. 10, October, 2025, pp. 2103-2109
Journal homepage: http://iieta.org/journals/ijsse

Safety Risk Evaluation by Vessel Type and Accident Category in an Archipelagic State: An Empirical Data Analysis from Indonesia

Sunardi[1*], Aleik Nurwahyudi[2], Eko Sulkhany[1], Arief Setyanto[1], Heri Supomo[3], Sapto P Kertorahardjo[4]

[1] Department of Marine and Fisheries Resources Utilization, Fisheries and Marine Science Faculty, Universitas Brawijaya, Malang 60145, Indonesia
[2] National Transportation Safety Committee (KNKT), National Transportation Department, Jakarta Pusat 10110, Indonesia
[3] Department of Naval Architecture, Faculty of Marine Technology, Institut Teknologi Sepuluh Nopember, Surabaya 60111, Indonesia
[4] Fisheries Capture Center, Ministry of Marine Affairs and Fisheries, Semarang 50175, Indonesia

Corresponding Author Email: sunardi@ub.ac.id

https://doi.org/10.18280/ijsse.151013

Received: 26 September 2025
Revised: 26 October 2025
Accepted: 29 October 2025
Available online: 31 October 2025

Keywords:
maritime safety, risk assessment, archipelagic state, Indonesia, vessel accident analysis

ABSTRACT

Maritime safety in a vast archipelagic state like Indonesia presents structurally heterogeneous risks across fleets and operating environments. This study develops an empirical safety risk profile using 1,634 maritime accident records (2018-2021) and links the risk mapping to operational response capability using National Search and Rescue (BASARNAS) sea-incident handling timestamps (reporting–dispatch–arrival) to support actionable interventions. A quantitative approach combined descriptive statistics, spatio-temporal hotspot mapping, and frequency–severity risk matrices, supplemented by hypothesis-driven association testing and response-time performance metrics (dispatch delay, travel time, end-to-end time). The maritime risk landscape is dominated by catastrophic events, with capsizing and sinking accounting for 47.7% of incidents, and two extreme-risk scenarios fishing-vessel and passenger-ship capsizing/sinking were identified. Risk is geographically concentrated, with the Java Sea emerging as a major multi-vessel hotspot, while inland river systems exhibit distinct accident–response patterns. The findings indicate that a uniform safety policy is inadequate and support a differentiated, risk-based framework aligned with applicable international safety obligations in the Indonesian context) and cost-aware prioritization of prevention and SAR readiness. Key limitations include reliance on secondary reports and a bounded analysis period; therefore, the framework is intended for periodic updating as new accident and SAR-performance data become available.

1. INTRODUCTION

Maritime safety in archipelagic states is shaped by fragmented geography, uneven oversight capacity, and highly variable operating conditions, which together create non-uniform risk across vessel classes and routes. Indonesia's thousands of islands generate complex navigation and logistics demands that require robust governance and infrastructure [1]. The Indonesian maritime domain, covering approximately 3.25 million km², is not merely a transit route but the primary artery for economic activity, inter-island connectivity, and resource extraction. However, the capacity to enforce maritime laws and maintain safety standards across such an expansive area is often strained, a challenge common to many developing archipelagic states [2, 3].

These geographic challenges are compounded by security and governance stressors (e.g., illegal fishing, piracy, and smuggling) that complicate enforcement and safety management. At the same time, rising dependence on maritime transport for trade and mobility increases traffic density, which can elevate accident exposure and operational pressures [4]. In Southeast Asia, this coupling of traffic growth and uneven compliance capacity has been associated with persistent safety problems, making risk differentiation (by fleet and operating area) more informative than aggregate national statistics.

The research problem arises from the persistence of accidents that appear patterned rather than random, indicating gaps in prevention and response. Prior studies link incidents to human factors, adverse weather, and infrastructural shortcomings [5], while high-density corridors such as the Sunda Strait are repeatedly identified as hotspots where frequent ferry movements amplify risk [6]. This evidence implies that both upstream prevention (seaworthiness, training, compliance) and downstream mitigation (search-and-rescue timeliness) should be evaluated to prioritize interventions that are realistically implementable.

Consequently, a reactive "one-size-fits-all" approach is unlikely to control risk effectively in an archipelagic setting where fleets differ in design, oversight, and operating environments. A proactive, data-driven safety strategy requires identifying which vessel–accident–location combinations produce disproportionate harm and where response performance may further shape outcomes. Such a foundation enables evidence-based prevention and operational planning that can be prioritized under limited resources [7].

Established risk assessment frameworks provide systematic ways to translate incident data into control options. Formal Safety Assessment (FSA), for example, structures hazard identification, risk evaluation, and selection of risk control measures using empirical evidence [8]. In the Indonesian context, FSA-style logic is most useful when it is operationalized into differentiated priorities (e.g., by fleet type and operating area) rather than applied as a generic national checklist.

Goerlandt and Montewka [9] emphasized combining quantitative and qualitative reasoning to tailor maritime risk analysis to sector-specific conditions. Similarly, the Multi-State Maritime Transportation System Risk Assessment framework offers a more granular analysis by considering partial failure scenarios, which provides a more robust evaluation of operational vulnerabilities [10]. Building on these foundations, this study positions risk profiling as a decision-support instrument: not only characterizing accident patterns but also informing where prevention and response capacity (SAR) should be strengthened first.

Prior literature consistently highlights human factors and adverse weather as dominant contributors to marine incidents. Human reliability studies identify miscommunication, decision errors, and monitoring failures as recurring mechanisms [11, 12], while weather-related hazards motivate integrating forecasting into operational planning [5, 11]. A second, policy-relevant layer is regulatory applicability and compliance: international instruments (e.g., SOLAS, STCW, and the ISM Code) and their national transposition can produce different compliance realities between fleets—particularly between smaller fishing vessels and more regulated passenger/cargo operations. Despite this, a gap remains in combining (i) large-scale accident evidence, (ii) fleet- and geography-specific prioritization, and (iii) operational response performance (SAR timeliness) into a single decision-support profile for an archipelagic state [13].

Therefore, this study evaluates maritime safety risk by vessel type, accident category, and location using Indonesian accident records (2018-2021), and extends the analysis to operational mitigation capacity by summarizing BASARNAS handling times (reporting → dispatch → arrival) to contextualize risk prioritization. The contribution is a differentiated risk-and-response profile that supports targeted regulation and enforcement rather than generalized assumptions. The study tests the hypotheses that (H1) accident categories differ significantly across vessel types and (H2) sea-water and inland-water environments exhibit distinct risk profiles, and uses the resulting evidence to propose risk-based, regulation-aligned, and resource-aware intervention priorities. To maintain interpretability and avoid over-claiming causality, the approach focuses on empirically observable associations and provides a basis for phased implementation planning and periodic updating as new data become available.

2. METHOD

This section describes the datasets and analytical procedures used to (i) characterize accident patterns by vessel type, accident category, and location, and (ii) contextualize risk prioritization with search-and-rescue (SAR) response-time performance (reporting–dispatch–arrival). The study is observational and analytical (not causal), and all inferential results are reported with the corresponding test statistics in the Results Section.

2.1 Research design

This study uses a quantitative, retrospective observational design within a national case study of Indonesia to evaluate maritime accident risk heterogeneity across fleets and operating environments. The case-study framing supports context-specific interpretation (archipelagic geography, fleet composition, and operational corridors) while enabling cautious comparison with other archipelagic settings. To address concerns of purely descriptive reporting, the design includes hypothesis-driven association testing: H1: accident-category distributions differ by vessel type; H2: sea-water and inland-water environments exhibit distinct accident profiles. In addition, to strengthen operational relevance, the accident risk profile is complemented by SAR performance indicators derived from BASARNAS operational timestamps (reporting–dispatch–arrival), allowing the discussion to distinguish between risk concentration and response capability.

2.2 Data source and collection

The primary dataset comprises 1,634 secondary accident records covering maritime incidents in Indonesian waters (2018–2021). Each record includes incident date, vessel type, accident category, and location, and all eligible records were compiled into a structured analytical table for quantitative processing. To address reviewer concerns regarding rescue performance, a supplementary BASARNAS operational dataset of sea-incident handling records (n = 846) was incorporated to quantify response performance using standardized time stamps: report received, resource dispatched, actual arrival, and outcome counts (survivors, fatalities, missing).

2.3 Data analysis technique

The analysis followed four stages to evaluate maritime safety risk and operational implications.

Stage 1 (Descriptive profiling): frequency distributions were computed for accident categories and vessel types to provide a baseline overview. Where relevant, results are reported as counts and percentages and interpreted as unadjusted patterns (not exposure-normalized rates).

Stage 2 (Spatial and temporal patterning): incident locations were grouped by major sea-water and inland-water areas to identify hotspots, and incident timing was summarized to examine broad temporal patterns. Spatial outputs were visualized using density-based mapping to highlight concentration zones.

Stage 3 (Inferential verification and effect size): to move beyond purely descriptive reporting, association testing was conducted to evaluate whether observed differences are statistically supported. Specifically, Chi-square tests of independence were used for vessel type × accident category and environment (sea vs. inland) × accident category, accompanied by effect size to quantify practical magnitude.

Stage 4 (Risk stratification + SAR performance): two risk matrices were constructed as decision-support tools. For the Risk Scenario Matrix, incident frequency over the four-year period was categorized as Rare (<10), Occasional (10–49), Frequent (50–100), and Very Frequent (>100). For the Location-Based Risk Matrix, vessel-specific concentration within a location was categorized as Low (<10), Medium (10–19), High (20–49), and Extreme (>50). In parallel, SAR operational performance metrics were computed from BASARNAS timestamps.

3. RESULTS AND DISCUSSIONS

The results are presented in three parts: accident-type distribution, vessel-type distribution, and spatial concentration (sea-water vs. inland-water). A separate subsection reports SAR response-time performance metrics to support operational implications without implying causality.

The analysis of 1,634 recorded incidents indicates a persistent national safety challenge. Accident categories were first summarized descriptively (Figure 1). Capsizing/Sinking is the dominant category (779 incidents; 47.7%), followed by Fire/Explosion (235; 14.4%) and Collision/Allision (205; 12.5%). Additional categories include Grounding (7.9%), Fatality/Workplace Injury/Person Overboard (7.6%), and Machinery/Equipment/Structural Damage (6.6%).

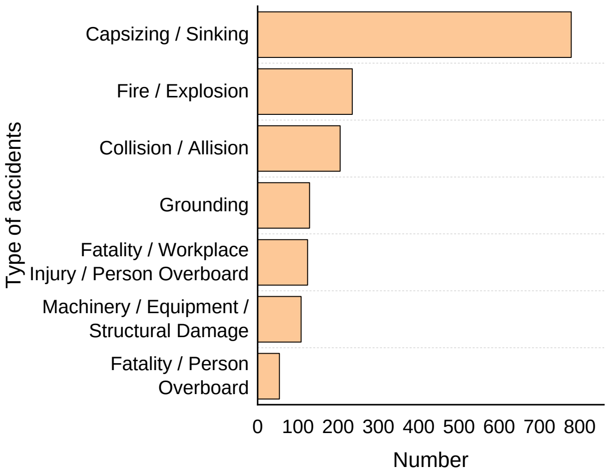

Figure 1. Distribution of maritime accident types in Indonesia (2018-2021)

Compared with contexts where collisions dominate in high-traffic lanes [14], the Indonesian distribution emphasizes catastrophic outcomes (capsizing/sinking) as the leading category. While collisions remain relevant, the predominance of capsizing/sinking points to vulnerabilities linked to seaworthiness and operating conditions, consistent with literature on vessel stability and severe weather exposure in the region [15]. Fire/explosion incidents further reinforce the need for onboard prevention and preparedness measures highlighted in global safety work [16]. These descriptive patterns are complemented by association testing to verify whether category distributions differ systematically across fleets and environments.

Accident involvement differs across vessel types (Figure 2). Fishing vessels represent the largest share (555 incidents; 34%), followed by general cargo ships (205; 12.5%) and passenger ships (187; 11.4%). Other categories include specialized vessels, tugboats, and speedboats. This stratification motivates fleet-specific control measures and provides the basis for the vessel-type × accident-category association tests described in Section 2.3.

The prominence of fishing vessels is consistent with evidence from developing contexts where smaller craft, offshore exposure, and uneven safety compliance contribute to higher incident burdens [17]. The involvement of general cargo and passenger ships indicates risks in core domestic transport sectors. Passenger-ship incidents warrant particular attention because consequence severity can be high even when frequency is below that of fishing vessels [18]. Accordingly, subsequent sections interpret "priority" using both frequency-based risk concentration and SAR response capability (dispatch and arrival performance), rather than frequency alone.

Incidents are spatially concentrated and exhibit distinct patterns between sea waters and inland waters. In sea waters (Figure 3), the Java Sea is the primary hotspot (274 incidents), followed by the South China Sea (192), Makassar Strait (121), East Indian Ocean (108), and Molucca Sea (84). In inland waters (Figure 4), the Mahakam River (41), Musi River (35), and Barito River (28) show the highest counts. These location groupings are used to construct the Location-Based Risk Matrix and to support environment-specific association testing.

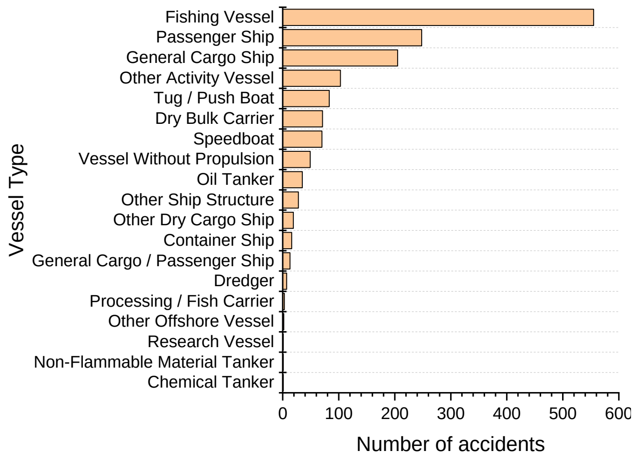

Figure 2. Distribution of maritime accident based on the types of ship in Indonesia (2018-2021)

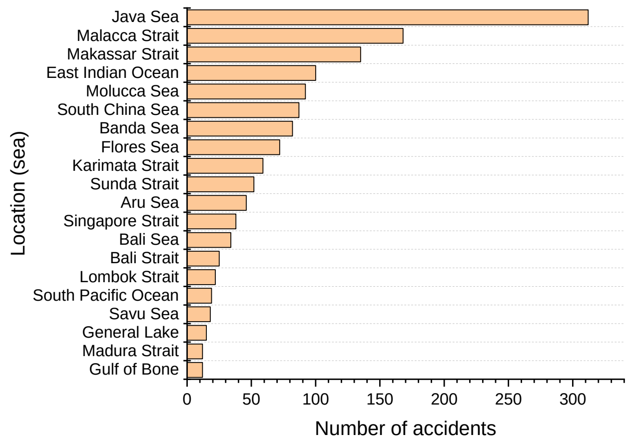

Figure 3. Ship accident based on the location in sea water

The clustering in the Java Sea and major straits is consistent with evidence that high traffic density and navigational complexity elevate risk in key corridors [19]. The East Indian Ocean hotspot aligns with the operational exposure of fishing vessels in offshore environments. In contrast, concentration in rivers such as Mahakam and Musi suggests a different risk dynamic that likely reflects congestion from industrial river traffic (e.g., tugs and barges) and small passenger craft operations. A visual summary of these primary hotspots is presented in Figure 5.

Synthesizing the findings on frequency, vulnerability, and location, a comprehensive risk profile was developed using two risk matrices. The Risk Scenario Matrix (Table 1) categorizes the scenario of Fishing Vessel for Sinking/Capsizing as an Extreme risk. This is justified by its exceptionally high frequency and severe outcomes, often involving total loss of vessel and life. This aligns with literature that emphasizes human and environmental factors as dominant causes of accidents [20]. Other scenarios, such as Passenger Ship - Sinking/Capsizing and General Cargo - Collision, are classified as High risk due to a combination of significant frequency and high-severity consequences.

The Location-Based Risk Matrix (Table 2) adds geographic resolution, identifying the Java Sea as a multi-vessel hotspot with High/Extreme risk levels across fishing, general cargo, and passenger ships. The Makassar Strait and South China Sea show concentrated risk, particularly for fishing and (to a lesser extent) cargo vessels, while the Mahakam and Musi Rivers exhibit a distinct inland profile dominated by tug/push-boat–barge and speedboat activity.

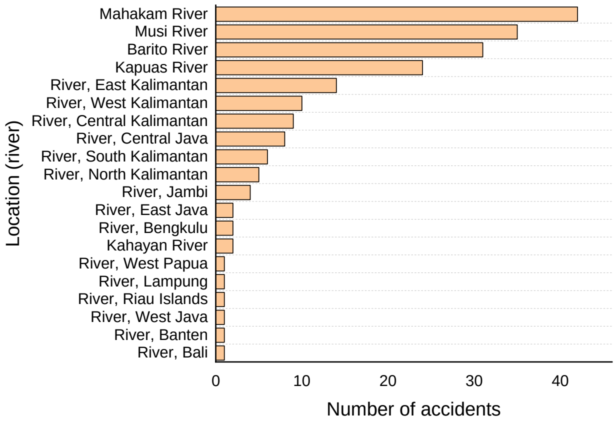

Figure 4. Ship accident based on the location inland water

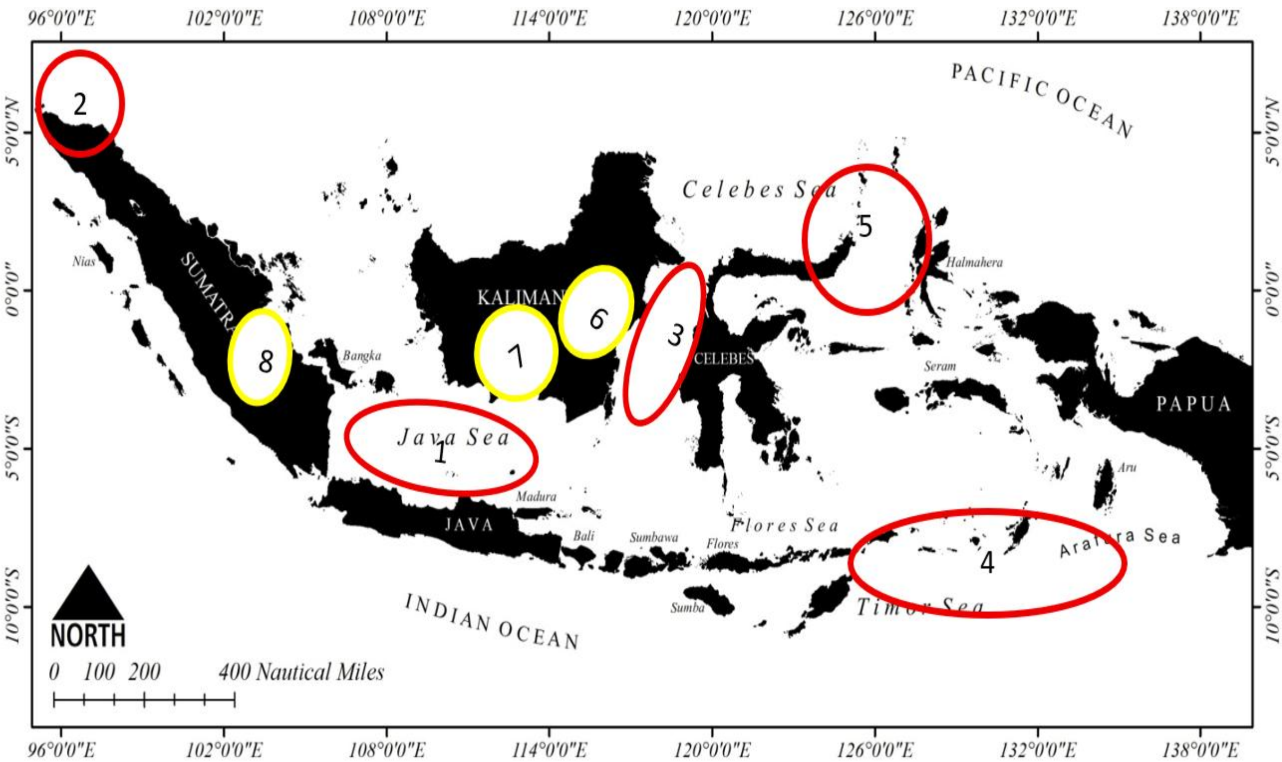

Figure 5. Summary of the highest-incident locations in sea waters (Java Sea, South China Sea, Makassar Strait, East Indian Ocean, Molucca Sea) and inland waters (Mahakam River, Musi River, Barito River), Indonesia (2018-2021)

Table 1. The Risk Scenario Matrix

Risk Scenario	Incident Count	Frequency Level	Severity Level	Calculated Risk Level
Fishing Vessel - Capsizing / Sinking	388	Very Frequent	High	EXTREME
Passenger Ship - Capsizing / Sinking	111	Very Frequent	High	EXTREME
Fishing Vessel - Collision / Allision	62	Frequent	Medium	High
General Cargo Ship - Collision / Allision	58	Frequent	Medium	High
Passenger Ship - Fire / Explosion	49	Occasional	High	High
General Cargo Ship - Grounding	45	Occasional	Medium	Medium
Tug / Push Boat - Collision / Allision	39	Occasional	Medium	Medium
Fishing Vessel - Fire / Explosion	38	Occasional	High	High
Ro-Ro / Passenger - Capsizing / Sinking	25	Occasional	High	High

Table 2. Location-Based Risk Matrix

Location	Fishing Vessel	General Cargo Ship	Passenger Ship	Tug / Push Boat & Barge	Speedboat	Dominant Risk Profile
Java Sea	Extreme (105 incidents)	High (41 incidents)	High (35 incidents)	Medium (15 incidents)	Low (6 incidents)	Multi-Vessel Hotspot
South China Sea	Extreme (118 incidents)	Medium (14 incidents)	Medium (11 incidents)	Low (5 incidents)	Low (1 incident)	Fishing Vessel Hotspot
Makassar Strait	Extreme (65 incidents)	Medium (17 incidents)	Low (8 incidents)	Medium (10 incidents)	Low (2 incidents)	Fishing & Cargo Hotspot
East Indian Ocean	Extreme (85 incidents)	Low (3 incidents)	Low (2 incidents)	Low (0 incidents)	Low (0 incidents)	Fishing Vessel Hotspot
Mahakam River	Low (1 incident)	Low (3 incidents)	Low (2 incidents)	High (25 incidents)	Medium (10 incidents)	Inland Industrial & Passenger Hotspot
Musi River	Low (1 incident)	Low (2 incidents)	Low (4 incidents)	Medium (11 incidents)	High (20 incidents)	Inland Passenger & Industrial Hotspot

The dominance of Capsizing/Sinking (47.7%) shifts attention beyond navigational conflicts to stability, seaworthiness, and operational integrity under adverse conditions. The two extreme scenarios Fishing Vessel for Capsizing/Sinking (388) and Passenger Ship with Capsizing/Sinking (111) indicate that these fleets warrant the highest priority for preventive controls. Rather than framing this as "unequivocal" causal proof, we interpret it as strong empirical prioritization evidence that a uniform regulatory approach is insufficient. This supports a differentiated framework that aligns controls with vessel characteristics and applicable safety governance mechanisms [21], including Indonesia's implementation of international obligations (SOLAS/STCW/ISM) where relevant and fleet-appropriate standards for fishing vessels where coverage differs.

The fishing sector's risk concentration supports targeted assessment and control selection using structured approaches such as FSA [22, 23]. The finding that passenger-ship capsizing/sinking is also Very Frequent in this dataset indicates that the issue is not limited to rare catastrophes and warrants urgent attention through measurable controls, such as mandatory stability verification, stricter inspection regimes, and crew competency reinforcement consistent with passenger-vessel safety expectations [24].

Location-based results distinguish open-sea and riverine risk landscapes. The Java Sea functions as the primary multi-vessel hotspot (High/Extreme across fishing, cargo, and passenger fleets), while the South China Sea and East Indian Ocean risk is concentrated primarily in fishing operations. In contrast, inland waterways (Mahakam and Musi) are dominated by tug/push-boat–barge and speedboat incidents, where congestion and navigational complexity may be more influential than meteorological exposure. This differentiation supports geographically tailored strategies: offshore fishing corridors require seaworthiness and weather-readiness controls, whereas inland waterways require traffic management and operational oversight appropriate to riverine conditions. The approach is potentially transferable to other archipelagic settings, but local fleet composition, governance capacity, and traffic patterns will shape the resulting prioritization [25].

Adverse weather is a plausible trigger for many capsizing events; however, the high frequency suggests it can also amplify underlying vulnerabilities (seaworthiness deficiencies, operational decision-making, and safety culture). The decision to operate in marginal conditions may reflect economic pressures, shifting the problem from purely environmental exposure to human and organizational factors [26] (This perspective is consistent with evidence that unsafe practices can arise from gaps in training, procedures, and safety culture [27].

The pattern of weather-associated losses highlights the need for interventions that address both information (forecasting/alerts) and behavior (decision-making and preparedness). Practical measures include targeted training, emergency drills, and safety management routines that improve readiness and reduce risk-taking under pressure [28], alongside stakeholder collaboration to strengthen safety culture and compliance incentives [29]. Where passenger and cargo fleets are subject to international safety expectations (e.g., STCW/ISM-related competency and management systems), enforcement should focus on demonstrable compliance; for fishing fleets, interventions should be adapted to fleet structure and capacity while maintaining measurable safety outcomes.

The risk matrices provide a basis for policy prioritization, supporting a shift from broad, uniform rules toward risk-based targeting. The identification of extreme/high-risk scenarios and locations enables strategic allocation under resource constraints. To strengthen operational justification, prioritization should integrate both accident concentration and BASARNAS response performance (dispatch delay and end-to-end arrival time) to identify where additional SAR readiness is likely to yield the greatest benefit. In practice, high-risk corridors such as the Java Sea warrant combined measures: prevention campaigns, compliance checks, and response-capability optimization. For vulnerable fishing fleets, improved storm-warning dissemination and real-time communication remain key preventive options [30].

For passenger vessels, the observed frequency of capsizing/sinking supports stronger inspection and competency assurance, consistent with international safety practice and national enforcement obligations. For inland waterways, interventions should emphasize traffic management, routing, and operational control suited to riverine congestion. To address feasibility and cost concerns, a simple multi-criteria prioritization (risk level × consequence proxy × SAR response-time performance × feasibility) can be used to select "quick wins" (0–6 months), mid-term actions (6–18 months), and regulatory refinements (18–36 months). Continuous monitoring is essential so that the prioritization remains valid as traffic patterns, fleet composition, and response capability evolve [31].

4. CONCLUSION

Maritime risk in Indonesia is dominated by catastrophic outcomes, with capsizing/sinking accounting for nearly half of recorded events. Two extreme scenarios for Fishing Vessel–Capsizing/Sinking and Passenger Ship–Capsizing/Sinking represent the most urgent safety priorities, and risk is geographically clustered, with the Java Sea functioning as a multi-vessel hotspot while major rivers show distinct inland profiles. The key implication is that a uniform regulatory approach is insufficient; instead, a differentiated framework is needed that aligns preventive controls with fleet characteristics and integrates operational readiness using SAR response-time performance indicators. This study contributes a replicable risk-and-response prioritization approach for archipelagic settings, while acknowledging limitations in exposure normalization and contributing-factor granularity. Future work should incorporate fleet-at-risk denominators (traffic/effort), richer causal fields (weather/stability/loading), and evaluate the effectiveness and cost-efficiency of targeted safety technologies and SAR resource allocation over time.

ACKNOWLEDGMENT

We would like to extend our sincere gratitude to the National Transportation Safety Committee (KNKT) and National Search and Rescue (BASARNAS) for providing the data that formed the basis of this research. This research was supported by Faculty of Marine and Fisheries, Universitas Brawijaya. We extend our deepest gratitude to the faculty for funding and facilitating this study.

REFERENCES

[1] Kurniawan, M.H.S., Mahara, D.O. (2021). Survival analysis based on average response time of maritime search and rescue (SAR) incidents in 2019 using kaplan-meier method and log-rank test. Enthusiastic: International Journal of Applied Statistics and Data Science, 1(1): 7-12. https://doi.org/10.20885/enthusiastic.vol1.iss1.art2

[2] Susilo, A.K., Ciptomulyono, U., Putra, I.N., Ahmadi, A., Suharyo, O.S. (2019). Navy ability development strategy using SWOT analysis-interpretative structural modeling (ISM). Strategic Management-International Journal of Strategic Management and Decision Support Systems in Strategic Management, 24(1): 30-40. https://doi.org/10.5937/straman1901030s

[3] Afpriyanto, A., Putra, I.N., Jupriyanto, J., Sari, P. (2023). Critical role of maritime infrastructure in Indonesian defense logistics management towards the world maritime axis. International Journal of Humanities Education and Social Sciences, 3(3): 1215-1224. https://doi.org/10.55227/ijhess.v3i3.657

[4] Marsetio, M. (2017). Indonesian sea power and regional maritime security challenges. Journal of Maritime Studies and National Integration, 1(1): 34-46. https://doi.org/10.14710/jmsni.v1i1.1369

[5] Dhanistha, W.L., Frestiqauli, S., Akbar, R. (2025). Designing a neural network algorithm for predicting wave height on the surabaya-banjarmasin shipping route. In 12th International Seminar on Ocean and Coastal Engineering, Environmental and Natural Disaster Management, Surabaya, Indonesia, pp. 012025. https://doi.org/10.1088/1755-1315/1473/1/012025

[6] Priadi, A.A., Tjahjono, T. (2015). Implementation of traffic separation scheme for preventing accidents on the sunda strait. International Journal of Technology, 6(6): 990. https://doi.org/10.14716/ijtech.v6i6.1966

[7] Santospriadi, S., Tjahjono, T., Sunaryo, S. (2023). Safety improvement model in small multipurpose ports. International Journal of Safety & Security Engineering, 13(2): 289-299. https://doi.org/10.18280/ijsse.130211

[8] Marpaung, H.E., Suranta, N., Simarmata, D.F.F. (2023). Analysis of formal safety assessment (FSA) for ship accident risk assessment: A case study of work accident MV mandarin ocean at tanjung priok main port. ARRUS Journal of Social Sciences and Humanities, 3(4): 469-478. https://doi.org/10.35877/soshum1945

[9] Goerlandt, F., Montewka, J. (2015). Maritime transportation risk analysis: Review and analysis in light of some foundational issues. Reliability Engineering & System Safety, 138: 115-134. https://doi.org/10.1016/j.ress.2015.01.025

[10] Wang, S., Yin, J., Khan, R.U. (2020). The multi-state maritime transportation system risk assessment and safety analysis. Sustainability, 12(14): 5728. https://doi.org/10.3390/su12145728

[11] Bowo, L.P., Prilana, R.E., Furusho, M. (2021). Human error assessment of situation awareness in bridge operations: A case study of Indonesian maritime accidents. In the 5th International Conference on Marine Technology (SENTA 2020), Surabaya, Indonesia, pp. 012012. https://doi.org/10.1088/1757-899x/1052/1/012012

[12] Bowo, L.P., Furusho, M. (2018). Human error assessment and reduction technique for reducing the number of marine accidents in Indonesia. Applied Mechanics and Materials, 874: 199-206. https://doi.org/10.4028/www.scientific.net/amm.874.199

[13] Pfeiffer, L., Gratz, T. (2016). The effect of rights-based fisheries management on risk taking and fishing safety. Proceedings of the National Academy of Sciences, 113(10): 2615-2620. https://doi.org/10.1073/pnas.1509456113

[14] Kim, H., Koo, K., Lim, H., Kwon, S., Lee, Y. (2024). Analysis of fishing vessel accidents and suggestions for safety policy in South Korea from 2018 to 2022. Sustainability, 16(9): 3537. https://doi.org/10.3390/su16093537

[15] Coraddu, A., Oneto, L., de Maya, B.N., Kurt, R. (2020). Determining the most influential human factors in maritime accidents: A data-driven approach. Ocean Engineering, 211: 107588. https://doi.org/10.1016/j.oceaneng.2020.107588

[16] Liu, W., Hu, S., Xuan, S., Wang, J., Han, B., Chen, J. (2023). A spatial-temporal analysis approach to global maritime accidents with accident point density clustering. In Fourth International Conference on Computer Science and Communication Technology (ICCSCT 2023), pp. 429-437. https://doi.org/10.1117/12.3009392

[17] Nguyen, B.N., Nguyen, T.S., Tran, Q.C., Ho, V.H., Nguyen, H.H. (2024). Prevalence of accidents and injuries and related factors of fishermen fishing offshore in the north of Vietnam. International Journal of Occupational Safety and Health, 14(2): 228-236. https://doi.org/10.3126/ijosh.v14i2.56367

[18] Choiron, M.A., Setyarini, P.H., Nurwahyudy, A. (2024). Fishing vessel safety in Indonesia: A study of accident characteristics and prevention strategies. International Journal of Safety & Security Engineering, 14(2): 499-511. https://doi.org/10.18280/ijsse.140217
[19] Li, B., Li, J., Lu, J. (2019). Research on the coupled risk of key nodes in maritime transport based on improved catastrophe theory. Sustainability, 11(17): 4640. https://doi.org/10.3390/su11174640
[20] Erdem, P., Akyuz, E., Aydin, M., Celik, E., Arslan, O. (2024). Assessment of human error contribution to container loss risk under fault tree analysis and interval type-2 fuzzy logic-based SLIM approach. Journal of Engineering for the Maritime Environment, 238(3): 553-566. https://doi.org/10.1177/14750902231203074
[21] Hasibuan, M.T., Abdurachman, E., Marina, S., Tjipto, S. (2025). Analysis of the role of risk assessment, compliance with the Ism code, Isps code on risk and safety of shipping. The International Conference on Sustainable Economics Management and Accounting Proceeding, 1(1): 1261-1268. https://doi.org/10.32424/icsema.1.1.194
[22] Haapasaari, P., Helle, I., Lehikoinen, A., Lappalainen, J., Kuikka, S. (2015). A proactive approach for maritime safety policy making for the Gulf of Finland: Seeking best practices. Marine Policy, 60: 107-118. https://doi.org/10.1016/j.marpol.2015.06.003
[23] Nam, B.W., Lee, K.H., Lee, J.M., Kim, D.S., Ku, B.J., Li, R., Yu, S.S. (2015). A study on the estimation method of risk based area for jetty safety monitoring. Sustainability, 7(10): 13154-13168. https://doi.org/10.3390/su71013154
[24] Papanikolau, A., Hamann, R., Lee, B.S., Mains, C., et al. (2013). GOALDS–Goal based damage stability of passenger ships. SNAME Maritime Convention, D011S004R001. https://doi.org/10.5957/smc-2013-t04
[25] Sunardi, Choiron, M.A., Sugiarto, Setyarini, P.H. (2023). Development of fishing boat collision models in extreme weather using computer simulation. EUREKA: Physics and Engineering, 2: 149-159. https://doi.org/10.21303/2461-4262.2023.002601
[26] Kim, H., Koo, K., Lim, H., Kwon, S., Lee, Y. (2024). Analysis of fishing vessel accidents and suggestions for safety policy in South Korea from 2018 to 2022. Sustainability, 16(9): 3537. https://doi.org/10.3390/su16093537
[27] Fan, S., Yang, Z., Blanco-Davis, E., Zhang, J., Yan, X. (2020). Analysis of maritime transport accidents using Bayesian networks. Journal of Risk and Reliability, 234(3): 439-454. https://doi.org/10.1177/1748006x19900850
[28] Abođi, A.G., Živojinović, T.M., Kaplanović, S.M., Maraš, V.S. (2024). Overview and analysis of regulatory framework for the application of autonomous vessels. Tehnika, 79(1): 89-96. https://doi.org/10.5937/tehnika2401089a
[29] Shen, J., Ma, X., Qiao, W. (2022). A model to evaluate the effectiveness of the maritime shipping risk mitigation system by entropy-based capability degradation analysis. International Journal of Environmental Research and Public Health, 19(15): 9338. https://doi.org/10.3390/ijerph19159338
[30] Hebbar, A.A., Schröder-Hinrichs, J.U., Mejia, M.Q., Deggim, H., Pristrom, S. (2020). The IMO regulatory framework for Arctic shipping: Risk perspectives and goal-based pathways. In Governance of Arctic Shipping: Rethinking Risk, Human Impacts and Regulation, 229-247. https://doi.org/10.1007/978-3-030-44975-9_12
[31] Duong, P.A., Ryu, B.R., Jung, J., Kang, H. (2024). A comprehensive review of the establishment of safety zones and quantitative risk analysis during ship-to-ship LNG bunkering. Energies, 17(2): 512. https://doi.org/10.3390/en17020512