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Risk Assessment of Safety Management System Implementation on the Training Ship Barombong Using the House of Risk Method

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Abstract

Background: The importance of the *Safety Management System* (SMS) in ensuring the safety of crew, passengers, vessels, and operational continuity is increasingly recognized due to the high operational risks faced by the shipping industry. The *Barombong Training Ship*, as a learning platform and one of the first training vessels in the country, is potentially exposed to risk factors that can affect SMS effectiveness.
Objective: This study intends to identify and prioritize the risks associated with SMS implementation on the *Barombong Training Ship* using the *House of Risk* (HOR) method and to develop evidence-based mitigation strategies for the highest-ranked operational safety risks.
Methods: A descriptive analytical method with the two-phase HOR framework was used in this study. Phase I identified risk events and risk agents, which were scored by five purposively selected crew respondents using RPN = P × I based on probability and impact. Phase II aggregated the risk agents and proposed proactive mitigation actions. This process included conducting field observations, semi-structured interviews with crew members, and reviewing documentation of SMS reports and safety records.
Results: Fifteen non-conformities were identified. Non-compliance with SOP/SMS procedures (RPN = 20) and fuel leakage in the engine room (RPN = 15) posed the greatest risks, indicating gaps between documented procedures and field implementation.
Conclusion: The HOR framework can be utilized to facilitate risk prioritization and mitigation planning for SMS implementation, thereby contributing to the improvement of the maritime safety culture aboard the *Barombong Training Ship*.

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INTRODUCTION

The shipping industry is one of the strategic sectors supporting global connectivity and the economic growth of a nation. More than 80% of world trade is conducted by sea, making shipping safety a critical factor in ensuring the continuity of maritime transport activities. However, this sector also has a high level of operational risk due to various factors such as marine environmental conditions, human factors, and the complexity of ship operational systems. Various international reports indicate that maritime accidents still frequently occur in different parts of the world. Data from international shipping safety reports show that maritime incidents are still dominated by failures in safety management systems and human error in ship operations. This indicates that an effective safety management system is one of the main factors in preventing accidents and enhancing ship operational safety (IMO) (Mardiana et al., 2026; Organization, 2018). Furthermore, global shipping safety reports also indicate that the Southeast Asian region is among those with relatively high shipping risk levels due to intense maritime transport activity and the complexity of congested shipping lanes.

Several interrelated key factors contribute to the emergence of various shipping safety issues (Moreno et al., 2022; Yercan et al., 2026). The weakest determinant remains the effectiveness of safety management system implementation on board, including operational procedures, safety oversight, and crew training. Furthermore, maritime accidents are sometimes caused by inadequate human resource competencies, insufficient knowledge of safety procedures, and other factors such as non-compliance with operational procedures. The second factor is that the risk identification and assessment process in ship operations is often neither timely nor efficient. In the absence of systematic identification of potential hazards, risk mitigation actions may be delayed. Mathematically, this condition indicates that unstructured risk management increases the number of accidents and reduces the effectiveness of integrated ship safety systems.

These various factors can have serious consequences for shipping safety. In addition to material losses, ship accidents may also lead to loss of life, marine environmental damage, and disruption of the maritime transport system. Safety risks can also affect the education and training process for cadets undertaking practical sea training on board training ships. Additionally, shipping accidents may reduce public confidence in ship management institutions and may also affect maritime educational institutions associated with them. Thus, enhancing the safety management system and applying a systematic risk analysis method are among the primary ways to reduce shipping accidents.

The Safety Management System (SMS) is one of the predominant methods used to enhance ship operational safety. A Safety Management System (SMS) is a systematic approach to managing operational safety based on integrated policies, procedures, and risk management processes. It is designed to identify hazards, assess accident risks, and implement appropriate controls to reduce those risks. The SMS in maritime risk management is mandated for all ship owners and is embodied in the International Safety Management Code (ISM Code), which requires every ship operator to implement a systematic safety management system. The SMS contains components essential to the effective management of safety within a vessel's operational environment, including but not limited to safety policy, risk management, evaluation, and the promotion of a safety culture. SMS implementation is not merely about having written procedures, but also about the effective application of those procedures by all crewmembers, supported by a system that enables continuous monitoring and evaluation of compliance.

To improve the effectiveness of SMS implementation, a risk analysis method is required to systematically identify and prioritize each potential threat or risk. One method that can be utilized is the House of Risk (HOR). This method is a risk assessment approach that combines hazard identification, risk source analysis, and the prioritization of mitigation actions based on risk severity levels. House of Risk enables researchers to identify the relationships between risk-causing factors and their impacts, thereby determining the most appropriate control measures. One advantage of the HOR approach over conventional risk analysis methods is its ability to establish relationships between sources of risk and appropriate mitigation actions. Consequently, this technique can assist organizations in developing safer policies based on prioritized risks.

The novelty of this research lies in integrating Safety Management System (SMS) implementation with the House of Risk method to analyze safety performance on training ship operations using a technical ratio approach. Most previous studies have generally examined safety management systems or risk analysis separately, whereas this study integrates both approaches to develop a more comprehensive risk analysis model. Moreover, this research is conducted as a case study on a training ship, which has operational characteristics different from commercial vessels due to the presence of cadet education and onboard training activities. The integration of the House of Risk method and SMS is expected to enable more effective risk identification and the development of appropriate mitigation strategies to improve training ship operational safety.

Considering the increasing importance of training ships in educating and training human resources directly involved in the shipping industry, this research has become increasingly important. Training ships are not only used as educational facilities for cadets but also function as maritime transport vessels, including pioneer vessels. This dual function creates relatively high operational complexity on training ships and increases the need for an effective safety management system. In the absence of an effective risk analysis system, hazards arising from operational activities may directly threaten the safety of crew members, cadets, and passengers. Therefore, research aimed at optimizing risk assessment in the implementation of the Safety Management System is essential for improving safety performance effectiveness on training ships and supporting the establishment of a safety culture within the maritime education environment.

Based on this background, this study aims to assess the risks arising from the implementation of the Safety Management System (SMS) on the Training Ship Barombong, analyze the dominant causal factors contributing to those risks, and formulate risk mitigation strategies using the House of Risk method. Through this approach, it is expected that a more comprehensive overview of the potential risks generated by ship operations in maritime training activities and the corresponding control measures can be obtained to improve shipping safety.

The findings of this research are expected to provide both theoretical and practical implications. Theoretically, this research contributes to the development of knowledge regarding the application of the House of Risk method in maritime risk management, specifically in shipping safety management systems. Practically, this research is expected to serve as a reference for maritime educational institutions, training ship operators, and regulators in improving the effective implementation of Safety Management Systems and safety risk management on board ships. Moreover, this research may also contribute to improving the quality of seafarer training systems through the implementation of a stronger safety culture integrated into the maritime education environment.

METHOD

Research Design and Approach

This descriptive analytical study utilized a combination of qualitative field investigation and quantitative risk prioritization using the House of Risk (HOR) framework. This combination was chosen because, while the research required an in-depth understanding of operational safety conditions, risk severities also had to be quantified to enable objective comparisons. Consistent with Pujawan and Geraldin (2009), the HOR framework was conducted in two consecutive phases: Phase I consisted of risk event identification, analysis of risk agents (human and environmental factors), scoring of probability and impact on a scale from 1 to 5 by a panel of expert respondents, and calculation of the Risk Priority Number (RPN = P × I); Phase II consisted of Aggregate Risk Potential (ARP) calculation and the formulation of proactive mitigation actions (Bubicz et al., 2026). The HOR approach consisted of two phases, expanding upon a simple Failure Mode and Effects Analysis (FMEA)-style RPN matrix and making it distinctive to the HOR methodology. This research was conducted on the Training Ship of the Barombong Shipping Polytechnic, which was utilized as a practical training facility for cadets and also supported shipping education activities and pioneer transport services. The research was conducted while the ship was in operation, enabling the researchers to observe various safety procedures in practice.

Population, Sample, and Research Data Sources

The population in this study consisted of the entire crew and all parties involved in managing operational safety on the Training Ship of the Barombong Shipping Polytechnic. This included the master, ship officers, deck crew, engine crew, and all other personnel responsible for implementing the Safety Management System (SMS). A research sample was then selected from this population based on specific criteria related to experience and responsibility in managing ship operational risks. This study utilized purposive sampling to identify five respondents who had direct responsibility for ship safety operations: (1) Master/Captain, (2) Chief Officer, (3) Chief Engineer, (4) Deck Officer (responsible officer), and (5) Safety Officer/SMS Coordinator, as presented in the following table. These positions were selected primarily because their operational roles provided the most relevant experience in assessing the probability and impact scores for each identified risk event. Pujawan and Geraldin (2009) illustrated this method, in which respondents rated probability (P) and severity (I) on a scale of 1–5, and the scores were averaged across respondents to generate consensus RPN values (Bubicz et al., 2026). The selected respondents possessed the knowledge, experience, and responsibility necessary to implement the ship's safety system, ensuring that the resulting data reflected actual risk management conditions on board.

This research utilized two types of data sources: primary and secondary data. The primary data were obtained through onboard observations, field observations, and interviews with the ship's crew and related parties regarding safety procedures. Secondary data consisted of supporting documents such as ship safety records, Safety Management System audit reports, ship operational manuals, and shipping activity reports related to occupational safety on board. Through the utilization of both primary and secondary data, the researchers analyzed and evaluated gaps in the implementation of the safety management system and developed a comprehensive understanding of the potential risks that could arise during operational activities on board the training ship.

Data Collection Techniques and Research Instruments

Data collection methods in this study were conducted through several complementary stages to obtain comprehensive and in-depth information regarding ship safety management conditions. The first stage was based on observations of ship operational activities related to occupational safety procedures and the use of personal protective equipment (PPE) by crew members while performing potentially hazardous activities. During the systematic observation process, the researchers observed various situations that could potentially affect ship operational safety, enabling the identification and recognition of different types of hazards that might arise during operations.

The next phase involved interviews with crew members responsible for implementing the safety system. Semi-structured interviews were conducted to enable the researchers to explore more deeply the experiences, perceptions, and practices of the crew related to operational risk management on board the ship. This study also employed documentation techniques to collect various documents related to the implementation of the Safety Management System, such as safety procedures, inspection reports (checklists), records of safety training and improvement programs, and risk evaluation reports.

The research instruments used for data collection included interview guides, observation sheets, and documentation recording formats prepared according to the research needs. The collected data were then analyzed descriptively to identify risk patterns arising from ship operational activities and to evaluate the potential application of the risk assessment process in supporting the effective implementation of the Safety Management System on the Training Ship of the Barombong Shipping Polytechnic.

RESULTS AND DISCUSSION

The application of HOR in this research resulted in applicable mitigation strategies for the Training Ship Barombong. This strategy not only emphasizes handling risks after they occur but also focuses on prevention so that risks can be minimized from the outset. With this approach, efforts to improve safety and foster a work culture oriented toward the Safety Management System (SMS) will be more sustainably ensured.

Table 1. Findings and risk calculations (Training Ship Barombong), 2025

No.	NC Code	Risk Description	Probability Description	P	Impact Description	I	RPN
1	NC1	Inconsistent SOP/SMS compliance in the field	Deviation risk remains high in daily practice despite the availability and validity of SOP and	4	Procedural violations may trigger serious incidents and operational	5	20

No.	NC Code	Risk Description	Probability Description	P	Impact Description	I	RPN
			SMS documents.		disruptions.		
2	NC7	Fuel leakage in the engine room	Identified as a common hazard within the engine room environment.	3	Very high consequences, including fire or explosion, threatening life safety and operations.	5	15
3	NC2	Suboptimal Permit to Work (PTW) compliance for hazardous tasks	PTW is available, but non-compliance risks in confined space work, hot work, and work at height remain possible.	3	PTW failure may lead to severe or fatal accidents.	4	12
4	NC4	Uneven training and drills; need for strengthening SMS basics	Routine drills and training are available, but strengthening basic SMS exercises is still required.	3	Emergency preparedness is strongly determined by the quality and consistency of training.	4	12
5	NC8	Excessive machinery temperature or overheating	The hazard was highlighted by the Chief Engineer; controls are in place, but risks remain.	3	It may damage vital equipment and trigger safety incidents.	4	12
6	NC9	Rotating machinery hazards	One of the hazards frequently identified in the engine room.	3	It may cause serious injuries and equipment downtime.	4	12
7	NC10	Failure or unreliability of engine alarm and monitoring systems	Systems are in place and monitored, but technical failures remain possible.	2	Failure of early detection may lead to large-scale critical events.	5	10
8	NC11	Navigational risks: collision or grounding due to bad weather and human error	The risk is acknowledged in the navigation domain despite SOP mitigation and monitoring.	2	Very high impact on life safety, assets, and operations.	5	10
9	NC3	Gap in leadership understanding of HAZOP/FMEA risk identification and documentation	The Master mentioned "compliance with rules" without detail, indicating a gap in specific methods.	3	It affects supervision consistency and the quality of cross-departmental risk control.	3	9
10	NC6	Non-compliance or incomplete use of PPE	PPE is mandatory, but the risk of non-compliance in the field remains.	3	Moderate to severe injuries during deck or engine work are still possible.	3	9
11	NC12	Unclear distribution of risk reporting responsibilities	The general statement that "everyone has a role" is not supported by clear task descriptions.	3	Delayed escalation and handling may increase the risk level.	3	9
12	NC13	Risk assessments are not always updated immediately during	Update procedures exist, but they depend on implementation discipline during	3	Outdated risk assessments reduce mitigation effectiveness.	3	9

No.	NC Code	Risk Description	Probability Description	P	Impact Description	I	RPN
		changes	significant changes.				
13	NC5	Crew or cadet fatigue	Work-rest procedures exist, but watchkeeping loads and varying compliance may cause fatigue.	2	Fatigue increases the likelihood of human error affecting life safety and operations.	4	8
14	NC15	Inconsistent inspection and preventive maintenance compliance	Preventive maintenance exists, but variations in workload and conditions may affect consistency.	2	It may disrupt critical system functions and increase accident risk.	4	8
15	NC14	Delay or negligence in recording and reporting logbooks, risk registers, and training records	Documentation is formal but scattered, creating risks of delay or inconsistency across departments.	2	It hinders transparency, accountability, and follow-up improvements.	3	6

Source: Research data

Based on the full two-phase House of Risk (HOR) analysis (Phase I: risk event identification and RPN prioritization; Phase II: risk agent aggregation via Aggregate Risk Potential and proactive mitigation mapping per (Bubicz et al., 2026; Nyoman Pujawan & Geraldin, 2009), the most dominant findings representing the greatest risks in the implementation of the Safety Management System (SMS) on the Training Ship Barombong are non-compliance with SOP/SMK (RPN = 20) and the potential for fuel leakage in the engine room (RPN = 15). The first risk reflects that even when SMK documents and SOPs are fully available and used daily, field compliance remains inconsistently enforced. With the highest RPN value (20), the probability of deviation is high and its impact is very serious. This suggests a greater likelihood that operational accidents could lead to loss of life, material losses, and significant audit findings. This also poses a threat to the onboard safety culture because, if left unaddressed, minor infractions may escalate over time into major incidents with little or no warning.

On the other hand, the technical hazard of fuel leakage in the engine room has the second-highest RPN value (15). Eight potential hazards were identified in ship engine operations, including fuel leakage, which carries the highest risk because of its severe impact. Once leakage occurs, there is a high potential for fire or explosion, which is difficult to control without alarms, technical protection systems, or immediate corrective action. This risk affects not only crew safety but also operational continuity, the reputation of the managing institution, and the reliability of the main engine, potentially resulting in operational downtime. This study confirms that technical issues in the engine room should not be treated as routine problems, but rather as critical components of the mitigation strategy.

These two key findings the procedural danger of weak compliance and the engineering hazard of fuel leakage complement each other in describing the fundamental weaknesses of the ship's SMS. Both illustrate that the greatest threat lies not in the absence of a system, but rather in the gap between documentation and field implementation, as well as inadequate technical controls in high-risk areas. Both risks, if not properly controlled, could degrade the overall safety system and contribute to major incidents.

This potential disruption may increase the risk of violating SOPs and SMK procedures; therefore, the most relevant mitigation measure is strengthening operational discipline, such as implementing safe navigation SOPs during transshipment operations, along with Permit to Work (PTW) implementation. Crew members, particularly cadets, must also become accustomed to complying with SOPs not merely understanding them, but consistently applying them in every task performed. Before work begins, toolbox meetings should be conducted to remind personnel of the importance of SOP compliance and the appropriate use of PPE according to the type of work being carried out. Although the primary responsibility rests with the master and deck officers, the effectiveness of this mitigation depends on the participation of all crew members and cadets.

Second, preventive maintenance and inspections should be conducted periodically to minimize the risk of fuel leakage in the engine room. The Chief Engineer and engine officers are responsible for checking the fuel system daily, not only for minor leakages but also for potential damage to pipes and tanks. Pressure and temperature data from automatic alarm systems should also be reviewed regularly, since reliable early detection depends on proper system testing. PTW is a prerequisite for maintenance work involving tanks and fuel systems, as it helps control the risk of fire or explosion more effectively.

Third, the Training Ship Barombong has established evaluation mechanisms, such as emergency drills and internal and external audits, to ensure the effectiveness of mitigation measures. Practical training is essential, and fire drills or abandon-ship drills should be conducted regularly and followed by debriefing sessions so that vulnerabilities can be identified and addressed immediately. In addition, the logbook documents the results of technical inspections in the engine room, including functional tests of firefighting equipment. These test results serve as the basis for updating SOPs when gaps are identified. In this regard, mitigation is not merely the enforcement of rules, but an evolving process based on continuous learning.

Fourth, supervisory practices and periodic reviews are critical for ensuring mitigation consistency. On deck, risks are monitored through bridge watch observations and logbook entries, which are then reviewed during weekly officer meetings. In the engine room, risks are monitored through alarm systems and daily inspection reports, which are evaluated monthly during technical review meetings. This approach ensures that every potential hazard is identified and corrected promptly upon detection.

Lastly, any major changes to ship operations such as new sailing routes, equipment replacement, or high-risk drills require revisions to the risk assessment. This can be supported through additional toolbox meetings and proper documentation in the risk assessment forms. As a result, the mitigation strategy remains current and does not lose its relevance by becoming merely a formality.

Mitigation efforts on the Training Ship Barombong must involve strict enforcement of SOP discipline, preventive engine maintenance, reliable engineering alarm systems, regular drill evaluations, and periodic reviews of risk assessments. If all these elements are implemented effectively by the master, chief engineer, officers, and crew, the two most dominant risks identified can be significantly reduced, thereby ensuring shipping safety and enhancing the effectiveness of the ship's SMS.

Correlation of the *House of Risk* (HOR) Method with the Elements of the *Safety Management System* (SMS)

Safety Policy → Hazard Identification (House of Risk Phase I)

In the safety policy element, the Safety Management System (SMS) emphasizes the importance of establishing standards and mechanisms for risk detection on board. Based on the research results, this process on the Training Ship Barombong is already underway through toolbox meetings before work begins, during which all crew members are actively involved in communicating potential hazards.

Field findings indicate that the Chief Officer explained that hazard identification is carried out participatively, while the Chief Engineer added that the process is complemented by a risk assessment form, which is standard practice in the engine room. The Master also mentioned that this process is carried out "according to applicable regulations," although it is not accompanied by comprehensive documentation.

House of Risk (HOR) Phase I: This identification process aligns with the stage of determining risk events and risk agents. The Training Ship Barombong has implemented this stage by identifying various potential risks, such as fuel leakage, engine overheating, Standard Operating Procedure (SOP) noncompliance, and human error.

HOR then converts these data into an initial list of potential hazards, which becomes the basis for quantitative assessment in the next stage. Thus, the safety policy implemented through toolbox meetings and routine inspections is directly applied as a hazard identification process in HOR.

Risk Management → Risk Analysis and Quantification (RPN Calculation in HOR)

The risk management element in the Safety Management System (SMS) includes a systematic process to assess the likelihood and impact of each identified hazard. In this study, the House of Risk (HOR) approach was used to transform the risk identification results into numerical values that describe handling priorities.

Field findings indicated that the ship's crew had implemented a risk assessment form to evaluate risks based on likelihood and consequence. The Chief Officer and Chief Engineer provided examples showing that risks such as fuel leakage, Standard Operating Procedure (SOP) violations, and crew fatigue were assessed using a risk matrix (low, medium, high).

HOR then strengthens this process through risk quantification using the Risk Priority Number (RPN = P × I).

From the research results, the highest RPN values were found in: NC1: non-compliance with SOP/Safety Management System (SMS) procedures (RPN = 20); NC7: fuel leakage in the engine room (RPN = 15); and NC2, NC4, NC8, and NC9, each with an RPN = 12.

This calculation makes the risk management process in the SMS more objective and data-driven, rather than being based solely on perception. Quantification using HOR ensures that each risk can be compared and prioritized appropriately, in accordance with the principle of risk-based decision-making regulated within the SMS.

Safety Assurance → Risk Prioritization (HOR Ranking Stage)

The safety assurance element focuses on ensuring that critical risks are identified and addressed immediately. The House of Risk (HOR) method makes a major contribution at this stage by mapping risks and determining the order of mitigation priorities based on the highest Risk Priority Number (RPN) values (Cicek, 2026; Tarigan & Mege, 2025; Zulfiadi et al., 2025).

Field Findings: Based on interviews, it was found that the ship has many operational risks, but two are the most dominant: noncompliance with Standard Operating Procedures (SOPs)/Safety Management System (SMS) procedures, even though complete documents are available and in use, and fuel leakage in the engine room, which is a typical risk with a high potential for fire and explosion.

Through HOR, these two risks are assigned the highest priority and therefore receive primary attention in safety assurance. HOR helps ship management determine that the focus of mitigation priorities should not only be on system documentation but also on implementation gaps in the field. For example, noncompliance with SOPs is not caused by the absence of procedures, but rather by weak implementation discipline, which constitutes the main risk agent. Thus, HOR functions as a quantitative internal audit tool, strengthening safety assurance through the identification of the most urgent risks requiring immediate corrective action.

Safety Promotion to Mitigation, Monitoring, and Evaluation (House of Risk Phase II)

The final element of SMS demands the formation of a safety culture through concrete actions, monitoring, and continuous evaluation. House of Risk (HOR) Phase II implements this by formulating mitigation strategies for each prioritized risk that has been identified.

Field findings indicate that various forms of mitigation have been implemented on the Training Ship Barombong, such as the enforcement of operational discipline through safe navigation SOPs and Permit to Work (PTW); preventive maintenance and routine inspection of the fuel system to prevent leaks; regular testing of automatic alarm systems and fire-fighting equipment; safety drills (fire drill, abandon ship drill); and internal inspections and external audits to verify system integrity.

House of Risk (HOR) Phase II translates the prioritized risks identified in Phase I into concrete and measurable mitigation action plans (Hasanah et al., 2025; Şentürk et al., 2026). For example, for NC1 (SOP non-compliance), HOR recommended improved supervision, training on work discipline, and toolbox meetings for field evaluation. For NC7 (fuel leakage), HOR recommended enhanced fuel system monitoring, daily pressure checks, and the implementation of PTW for high-risk work. HOR also supports the SMS monitoring, review, and improvement cycle. Data obtained from drill results and internal audit reviews are used to evaluate the effectiveness of mitigation measures and update strategies when weaknesses are identified. Thus, HOR becomes a central component in achieving continuous improvement and an adaptive safety culture.

The implementation of the Safety Management System (SMS), based on research integrating the House of Risk (HOR) method, produces a more measurable, adaptive, and prevention-oriented safety system.

Table 2. The pressure of Safety Management System (SMS) is also related to Barombong training ship in which the implementation need House of Risk (HOR) method integration

SMS Element	HOR (Hazard & Operational Risk)	Findings / Activities
Safety Policy	Hazard Identification	Toolbox meetings, routine inspections, risk checklists.
Risk Management	Risk Analysis & Quantification	Likelihood-consequence matrix, RPN (Risk Priority Number) calculation.
Safety Assurance	Risk Prioritization	Determination of dominant risks: SOP non-compliance (RPN 20), fuel leakage (RPN 15).
Safety Promotion	Mitigation, Monitoring, & Evaluation	Safety drills, internal audits, risk assessment updates, SOP evaluations.

Source: Research data

Thus, House of Risk (HOR) strengthens the entire Safety Management System (SMS) cycle, from hazard identification → analysis → risk prioritization → mitigation and evaluation, so that the implementation of the SMS on the Training Ship Barombong is not merely formal but is based on real risk data and continuously improved through a systematic scientific approach.

Based on the research analysis results, where (1) non-compliance with Standard Operating Procedures (SOP)/Safety Management System (SMK) had the highest Risk Priority Number (RPN) and (2) potential fuel leakage in the engine room had the second-highest RPN, the findings strongly reflect the gap between system design (SMS documents exist) and field execution. Conceptually, the SMS in the International Safety Management (ISM) Code does indeed address this gap; it mandates that safe ship operation and pollution prevention be carried out using documented procedures, training, and continuous auditing. Without stability in safety culture, crew compliance with procedures during operations remains weak, and the SMS may not produce the expected outcomes. A robust safety culture is generally associated with systematic managerial efforts to ensure procedural compliance among deck officers. Accordingly, research studies indicate that, despite procedural documents being intended to provide solutions to operational issues, the central problem is organizational and behavioral rather than documentation-related (Xi et al., 2025). These findings correlate directly with the high RPN identified in NC1 of the present study; notwithstanding the complete SMS documentation on Barombong, deviations in field compliance remained possible, confirming the safety culture gap as the primary risk driver. Data from Port State Control (PSC) inspections conducted in the Paris Memorandum of Understanding (Paris MoU) region through October 2023 also highlight that ISM Code-related deficiencies remained among the most common non-conformities identified during ship inspections in 2024, further supporting the conclusion that compliance gaps in SMS implementation represent a systematic maritime safety challenge .

Risk 1, namely non-compliance with SOP/SMK, corresponds to broader shipping industry patterns identified in inspection findings and human factors research. Recent studies have demonstrated the significant role human factors play in maritime accidents, where failure to maintain procedural discipline rapidly increases the likelihood of operational deviations, with serious implications for safety. From an oversight perspective, recent PSC data suggest that ISM deficiencies continued to appear prominently in 2024 Paris MoU inspections, supporting the persistence of implementation gaps in shipboard SMS practices. Therefore, the highest RPN identified in this study can be interpreted as an indicator of systemic risk at both the compliance and organizational culture levels (Xi et al., 2025).

The second risk, namely fuel leakage in the engine room, is strongly supported by technical data because the engine room is widely recognized as a high-temperature fire-risk zone. Numerous experimental studies indicate that hot-surface ignition can occur rapidly when diesel fuel spills or sprays contact heated surfaces, although variables such as evaporation mode, ignition delay time, and flame behavior may influence the rate of fire development. Recent technical statistics further indicate that most shipboard fires originate in the engine room (76%) and are oil- or fuel-related (60%). Reports and International Maritime Organization (IMO) guidelines emphasize oil leak control, engine-room fire prevention, improvement of oil spill preparedness and response, protection of hot surfaces, and housekeeping compliance as key mitigation priorities (Wang et al., 2025).

The two most significant risks identified in this study are not "document failures" but rather "implementation failures," reflecting a combination of weak operational discipline and inadequate technical control in high-risk areas. This finding contextualizes comparisons with ISM/PSC deficiencies, which consistently identify ship operations, maintenance issues, and regulatory non-compliance as principal contributors to audit findings and maritime accidents. Therefore, improvement efforts should focus on behavior-based compliance and daily technical orderliness rather than merely adding more procedures (Baig et al., 2025; Supriatna et al., 2026).

The proposed mitigation strategies are supported by both literature and regulations. One fundamental institutional practice widely recommended is strengthening operational discipline through safe navigation SOP, Permit to Work (PTW) systems, and routine toolbox meetings. Poor PTW quality is recognized as a significant contributor to PTW system failure, while inadequate documentation and insufficient understanding of safe work sequences are also contributing factors. Raising the minimum standard required for a completed PTW to function effectively as a "gateway" before maintenance or service interventions can help prevent procedural deviations that may lead to high-risk events. Toolbox meetings, conducted to reinforce hazard awareness, share lessons learned, and establish work-control agreements before tasks begin, have also been strongly advocated by Protection and Indemnity (P&I) organizations and professional maritime training institutions (Baig et al., 2025).

In the case of fuel leakage in the engine room, routine alarm and imaging-system functional testing, combined with preventive maintenance conducted at regular intervals, can significantly reduce risk. MSC.1/Circ.1432 establishes recommended testing frequencies for fire protection, detection, and alarm systems ranging from weekly to annual inspections, with compliance ensuring preparedness for early detection and emergency response when required. Results from the 2023 Concentrated Inspection Campaign (CIC) conducted by the Tokyo Memorandum of Understanding (Tokyo MoU) and Paris MoU reaffirmed that numerous deficiencies in fire protection systems continue to result in vessel detentions. These findings indicate that greater attention must be given to oil leak prevention and the reliability of detection and extinguishing systems, supported by daily to monthly engine-room inspections (International Maritime Organization (IMO) (Mardiana et al., 2026; Organization, 2018).

An important mechanism for continuous learning is the scheduled evaluation of drills through internal audits and external inspections. ISM audit handbooks issued by classification societies such as ClassNK stipulate that PSC/ISM findings must be closed through verified corrective action plans and documented follow-up procedures. Through the continuous drill–debrief–improvement cycle, the SMS evolves from mere "administrative compliance" toward genuine continuous improvement (Esad Demirci & Cicek, 2023; Singh & Raju, 2024).

The broader literature and regulatory data confirm that a combination of behavioral interventions (SOP adherence, PTW, and toolbox meetings), technical controls (daily inspections, preventive maintenance, and alarm testing), and evaluation cycles (drills, audits, and risk assessment updates) constitute the most effective strategic interventions for reducing the two major risks identified in this study (McKinnon, 2025; Oyekanmi & Onwumere, 2025).

CONCLUSION

This study concludes that the systematic application of the two-phase House of Risk (HOR) framework is effective in enhancing Safety Management System (SMS) implementation on the Training Ship Barombong. The monthly report identified a total of fifteen non-conformities, with SOP/SMS non-compliance (RPN = 20) and fuel leakage in the engine room (RPN = 15) identified as the two most severe risks. Both indicate implementation gaps between the systems defined on paper and their execution in real-world settings. Mitigation priorities derived from HOR disciplinary enforcement through PTW and toolbox meetings, structured PM/CM, and scheduled drill–debrief–improvement cycles are consistent with International Safety Management (ISM) Code requirements and are supported by numerous published maritime safety studies.

However, this study has several limitations. For example, a purposive sample of five respondents (Master, Chief Officer, Chief Engineer, Deck Officer, and Safety Officer) was considered sufficiently knowledgeable to assign scores based on the RPN. Although this composition ensures domain expertise, the limited sample size restricts the generalizability of the findings, and the research scope, which focused on only one training ship, implies that these findings cannot be generalized to all ships or other shipping institutions. Therefore, further research is expected to broaden the scope of the research object, involve more respondents, and combine qualitative and quantitative approaches so that the results can provide a more comprehensive picture of risk management in improving operational safety in the shipping sector.

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AUTHOR CONTRIBUTION STATEMENT

Rina Haryani contributed to the research conceptualization, data collection, analysis, and manuscript drafting. Sidrotul Muntaha supported the development of the methodological framework, risk identification, and House of Risk analysis. Yudi Satria contributed to field observation, documentation review, and interpretation of operational safety findings. Rachmat Tjahjanto contributed to manuscript supervision, critical review, and final refinement. All authors reviewed and approved the final version of the manuscript.

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