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SUBMARINE OPERATIONAL RISK MANAGEMENT DESIGN IN SUPPORTING TNI AL'S DUTIES

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ABSTRACT

This research discusses risk management faced by submarines and their crews. One of the risks that can occur is that the submarine cannot surface because the steering and propulsion system is not functioning properly. With the submarine unable to surface, it will cause the ship to sit on the seabed. A submarine that experiences an emergency so that it cannot surface is called a Distressed Submarine (DISSUB). Through the FMEA method the author identifies risks and aims to prioritize different causes based on their priority. FMEA itself is a systematic method, so it can find out the root of the problem that actually occurs. By knowing how urgent the priority is, the author can focus on problems that have a big impact on ship operational risks. It is hoped that the research results can be used as recommendations for mitigating risks that occur on submarines, providing a risk management framework for submarines.

Keywords: Risk, Distressed Submarine (DISSUB). Failure Mode and Effects Analysis (FMEA)

1. INTRODUCTION

Submarines, as strategic weapon systems, are designed to operate both on and below the sea surface, facing significant risks, including the inability to surface due to malfunctioning steering and propulsion systems. When a submarine cannot surface and sits on the seabed, it is termed a Distressed Submarine (DISSUB). There are two primary rescue methods: the rescue method, relying on external rescue forces, and the escape method, which depends on the crew's knowledge and decision-making abilities. Critical factors influencing the waiting time in a DISSUB include carbon dioxide (CO2) levels, pressure, and oxygen (O2) levels (KOARMADA II Submarine Unit Standing Procedure Book, 2020).

If the escape method is chosen, two techniques are used: Rush or Compartment Escape and Tower Escape, both employing Submarine Escape Immersion Equipment (SEIE). Post-escape, the crew must survive on the surface while awaiting rescue. The development of escape capabilities, mastery of safety equipment, and rigorous training are essential for crew preparedness and submarine safety.

Geographically, Indonesia, an archipelagic country with 17,504 islands and a coastline of 108,000 km, covers a land area of 1.9 million km² and a water area of 6.4 million km². The enactment of the United Nations Convention on the Law of the Sea (UNCLOS) 1982 further defines these areas (Kasal Decree No Kep-503-V-2018, May 22, 2018, Concerning Indonesian Navy Submarines, No. 302, 2018).

Indonesia's strategic maritime territory stretches between the Asian and Australian continents and lies between the Indian and Pacific Oceans, making it a key international shipping route (Wiranto, 2020). This positioning provides significant benefits and poses sovereignty threats. Indonesia's waters vary from shallow seas to depths of thousands of meters, encompassing seas, straits, and bays with diverse seabeds like mud, sand, rocks, and coral.

The territorial waters include deep regions like the Banda Sea, Flores Sea, Makassar Strait, Maluku Sea, and parts of the Arafuru Sea, and shallow regions such as the Java Sea, Karimata Strait, and Sunda Strait. Indonesia’s maritime defense must cover internal waters, archipelagic waters, and outer jurisdictions, requiring robust naval power and comprehensive sea power to control international trade and marine resources, implement sea control, sea denial, blockades, and power projection.

Indonesia's marine area is divided into five zones: littoral, epineritic, neritic, batial (200-2,000 meters deep), and abisal (over 2,000 meters deep) (Marsetio, 2015). Effective maritime defense strategy, supported by reliable sea and air power, is crucial for Indonesia to protect its territory, control outer islands, landing beaches, strategic sea funnels, and airspace, thereby ensuring national security.

Figure 1.1.
Indonesian Archipelago Sea Lanes
Source: www.ruangguru.com (2023)

The TNI AL's capabilities can be realized through planning and building within the framework of an Integrated Fleet Weapons System (SSAT). Submarines, as part of the SSAT component, have reconnaissance and infiltration capabilities with low detection levels by opponents, as well as ambush and high destructive power, providing the necessary deterrence effect. To maximize this effect and uphold sovereignty, it is essential to develop submarine strength and deployment patterns supported by advanced infrastructure and base facilities tailored to the Submarine Operating Area (SOA) (Defense White Paper, Indonesian Ministry of Defense, Jakarta, 2015). This aligns with the Indonesian National Army (TNI) Commander's Regulation No. 26/V/2008, which emphasizes national defense at sea as part of the Archipelago Maritime Defense Strategy (SPLN). This strategy ensures the sovereignty and law enforcement within Indonesia's national jurisdiction through sea control and various maritime operations (TNI Commander Regulation No. 26/V/2008).

The Indonesian Navy relies on the SSAT, consisting of Ships, Aircraft, Marines, and Bases, to conduct maritime operations. Submarines play a vital role, with the current fleet including the Cakra class and the Nagapasa class. The Cakra class, specifically Cakra-401, was built in Germany in 1980, while the Nagapasa class includes three units made in South Korea as part of a technology transfer cooperation. Both classes are based on the German Type 209 submarine design, ensuring similar capabilities and dimensions. Type 209 submarines, diesel-electric models from HDW Germany, have been in service since 1971, with 61 units operated by 13 countries. Their mission has evolved from traditional blue water operations to littoral operations, reflecting the changing strategic environment post-Cold War.

The Cakra class features a length of 59.9m, a surface displacement of 1300 tons, and a diving capability up to 300m, with an endurance of 53 days. The Nagapasa class is slightly larger, with a length of 61.3m, a surface displacement of 1442 tons, and similar endurance. The Nanggala-402, another Type 209 submarine, tragically sank on April 21, 2021, in Bali waters, highlighting the risks associated with submarine operations. This incident underscores the importance of risk management in submarine operations to prevent such losses.

Operational risks, divided into financial and operational risks, must be managed. Financial risks involve economic factors, while operational risks stem from human error, natural, and technological factors. Submarines face emergencies due to various causes, such as loss of propulsion, steering gear malfunction, and fire hazards. Understanding these risks and implementing preventive measures are crucial for maintaining buoyancy and operational stability (Kountur, 2004). The stability of a submarine relies on the center of gravity, center of buoyancy, and metacenter. Factors like loss of propulsion, steering gear issues, and fire hazards can compromise stability. Effective risk management involves addressing these factors to ensure submarine safety and operational readiness.

Figure 1.2 Causes of Fire

Solid fuel, when exposed to sufficient heat, produces vapors that are easily ignitable. The position of the solid fuel affects the combustion rate. Liquid fuel vaporizes when heated, producing flammable gas. It has a fire point, flash point, and auto-ignition temperature. The fire point is the minimum temperature at which fuel vapors ignite and burn for at least five seconds when exposed to an external source. The flash point is the minimum temperature at which fuel vapors continuously ignite with an external source. The auto-ignition temperature is the minimum temperature at which the fuel ignites spontaneously in normal atmospheric conditions without an external source. When liquid fuel absorbs heat, it reaches the flash point and burns continuously if an external flame is present. At the auto-ignition temperature, the fuel ignites on its own.

Gas fuels are the most dangerous due to their natural ignitability. Submarine air contains various substances (oxygen, hydrogen, carbon, arsenic, water particles, etc.). Oxygen concentration is about 21%, but only 16% is needed to start a fire. Heat is energy transferred due to a temperature difference, while temperature measures how hot or cold something is. Common heat sources on a ship include open flames and electrical currents.

Fire classification by the National Fire Protection Association (NFPA) in America helps determine effective firefighting methods and safety levels based on the fire's source. Leakage in submarines can increase weight, reduce buoyancy, and risk sinking. Quick actions are essential to maintain buoyancy, such as using high-pressure air systems. Toxic gas poisoning, especially from lead-acid batteries in diesel-electric submarines, is a critical concern. These batteries contain sulfuric acid, producing flammable hydrogen gas during charging. Submarine operations include various roles and activities like warming up systems, preparing for sailing and combat, conducting watertight tests, steering trials, navigating underwater, responding to alarms, and surfacing.

Operational risk management is essential for achieving organizational objectives, identifying potential obstacles, and ensuring successful assignments. It involves recognizing losses from operational failures, internal factors, personnel errors, system failures, external events, and violations (Kaho, 2018). Effective operational risk management ensures the achievement of objectives, job security, and minimizes losses. The risk management process includes risk identification, analysis, evaluation, handling, monitoring, and review. Risk identification uses brainstorming, analysis with a risk matrix, evaluation with Failure Mode and Effect Analysis (FMEA), and risk treatment through manual recommendations. The House of Risk (HOR) method, developed by Pujawan and Geraldin in 2011, is relevant for designing submarine risk management. HOR combines FMEA and the House of Quality (HOQ) methods to prioritize risk triggers and select effective actions. HOR's two stages are risk identification, which develops HOQ based on Indonesia's maritime needs, and risk treatment, which uses FMEA to reduce risk events.

The risk identification step involves identifying, measuring, and prioritizing risk events and triggers, calculating their correlation. The risk handling step selects high-priority risk agents and formulates actions based on preventive action relationships. The final stage designs preventive activities for risk mitigation. Based on the explanation above, it is necessary to design operational risk management for submarines to support the duties of the Indonesian Navy. Therefore, the author will conduct research with the title "Submarine Operational Risk Management Design in Supporting the Tasks of the Indonesian Navy". The objectives of this research are to identify operational risks on submarines in supporting the Indonesian Navy's missions, assess and evaluate risk events on submarines in supporting the Indonesian Navy's missions, and determine risk mitigation or management strategies to support the Indonesian Navy's missions.

2. MATERIAL AND METHOD

2.1. Understanding Risk

Risk is defined as "the adverse impact on probability of several distinct sources of uncertainty". Risk is defined as uncertainty caused by change. Risk is a deviation from something that is expected (Joel Bessis, 2010).

2.2. Operational Risk

Chrouhy, Galai and Mark (2001) define operational risk as the risk of operating a business. This risk is divided into two components, namely operational failure risk and operational strategic risk. Operational failure risk arises from potential failures in people, processes or technology in business units that can cause losses to the company. Operational strategic risk arises from environmental factors such as the presence of new competitors. Marshall (1964) stated that operational risks are all possibilities that cause disruption to the company's operational processes. Operational risks can arise due to errors or negligence in all operational activities within the company and lack of accuracy or lack of control of the employees involved.

2.3. Risk management

Risk management is defined as directed and coordinated organizational activities related to the risks that exist in the organization. Risk management has several components consisting of principles, frameworks and processes. These components are inseparable from one another and inherent in an organization. Principles are the main reference that guides the implementation of risk management in all areas of the organization. The framework is the foundation and organization of the organization. Meanwhile, the risk management process is a series of risk management activities that handle risks one by one and in groups according to the type of target affected. Thus, the risk management process is the core of overall risk management (Kaho, 2018).

2.4. Risk management

Risk management or risk mitigation requires planning and consideration of various alternative solutions in order to obtain effective and efficient mitigation results.

2.5. Monitoring and Review

Monitoring and review are carried out on all risk management activities including the context (organization, strategy, stakeholders, environment, processes, etc.). Monitoring results records are then stored as reports that the activities have been implemented and as input for the existing Risk Management Framework.

2.6. Failure Mode and Effects Analysis (FMEA)

FMEA is a method for identifying the risk of failure and carrying out calculations to obtain the Risk Priority Number (RPN) as the main factor for the risk of failure. The aim is to identify risks of failure that have undesirable impacts by identifying each form of failure from a sequence of events related to the risk. How it works is by identifying problems and collecting data in the field, calculating the scale of each Severity, Occurrence, Detection table to get the highest RPN value. Activities that have the highest RPN values are the main failure risks that must be provided with solutions to reduce the possibility of risks arising during the work process. FMEA can be used in various fields, from systems, product design, work processes, etc. (Idham & Fahmi, 2014).

2.7. Main Duties of the Indonesian Navy

Internal reform within the TNI, namely to reorganize the TNI according to its new paradigm, is consistently outlined in TNI Law No. 34 and was enacted in 2004. This law regulates all duties, functions and roles of the TNI in the future, including the TNI AL. The TNI AL is an integral part of the TNI which participates in determining the success of Defense and Security efforts, and in itself cannot be separated from the demand for a Defense and Security system that is able to ward off and overcome all threats, especially the threat of maritime terrorism with the available national strength and potential. It is clearly written that the TNI AL, as one of the main components of the TNI, has the main task of supporting Indonesia's foreign policy as a political decision as outlined in the law.

2.8. Submarine

A submarine is a ship that moves under the surface of the water, generally used for military purposes and purposes. Apart from being used for military purposes, submarines are also used for marine and freshwater science and for work at depths unsuitable for human divers. In supporting these maritime operations, the Indonesian Navy has prepared various forms of administration and logistics systems. One of the equipment owned by the Indonesian Navy is a submarine, which is a ship that moves below the surface of the water, generally used for military purposes and purposes. Apart from being used for military purposes, submarines are also used for marine and freshwater science and for work at depths unsuitable for human divers.

3. RESULTS AND DISCUSSION

The history of the Navy began with the formation of the People's Security Agency (BKR) at the PPKI session on 22 August 1945. The BKR then developed into several divisions, where the Marine BKR, one of the initial divisions, covered maritime/ocean areas. The formation of the Maritime People's Security Agency (BKR Laut) on 10 September 1945 by Soekarno's initial cabinet administration became an important milestone for the presence of the Navy in the Unitary State of the Republic of Indonesia which was proclaimed on 17 August 1945. The formation of the BKR Laut was spearheaded by veteran maritime figures who had served in the Koninklijke Marine ranks during the Dutch colonial period and was a Kaigun veteran during the Japanese occupation. Another factor that encouraged the formation of this agency was the potential to carry out Navy functions such as ships and bases, even though at that time the Indonesian Armed Forces had not yet been formed. The formation of the Indonesian military organization known as the People's Security Army (TKR) also spurred the existence of the Marine TKR, which was later better known as the Republic of Indonesia Navy (ALRI), with all the strength and capabilities it possessed.

3.1 Submarine Operational Risk Analysis using the FMEA Method

This FMEA method is carried out to analyze submarine operational risk planning and identify the causes and impacts that occur on each risk of submarine operational readiness. This FMEA method prioritizes completion based on level Severity (Impact), Occurance (Frequency of Events), and Detection (Detection Capability). Thus, the results allow controlling each basic cause of the failure.

When distributing the risk assessment questionnaire which was filled in by several respondents, the researcher included a risk assessment scale to assist respondents in assessing the risk in each variable of submarine operational readiness, namely: (1) Ship Losing Bouyancy, (2) Fire, (3) Leak, and (4) Noxious Gas Poisoning.

3.2 Analyzing Levels Severity (Impact)

Level Severity (Impact) aims to understand the impact of each risk that arises in submarine operations to support the duties of the Indonesian Navy. Severity This is evaluated based on the impact caused by each risk assessment in each submarine operational readiness variable, namely: (1) Ship Losing Bouyancy, (2) Fire, (3) Leak, and (4) Toxic Gas Poisoning. In the previous chapter, a severity scale from 1 to 10 was explained. However, to make it easier for respondents to fill out the questionnaire, in this chapter a scale is used. severity, as follows :

Table 1 Scale Severity

Skor Severity	1	2 - 3	4 - 5	6 – 7	8 - 9	10
Description	Very low	Low	Currently	Height	Very high	Extreme

Source: Data scores processed by the Author (2024)

Score Severity from the results of the assessment of 7 experts on each risk variable for submarine operational readiness, namely: (1) Ship Losing Bouyancy, (2) Fire, (3) Leaks, and (4) Toxic Gas Poisoning, can be seen in Table 4.4, as follows :

Table 2 Severity Score on Research Operational Risk Variables

Operational Risk	Sub Causes	Severity (S)	Information
Ship Loses Bouyancy	Thrust Stopped	7.80	Very high
	Steering Jammed	8.00	Very high
	Density of Sea Water	8.40	Very high
	Internal Solitary Wave	9.00	Very high
Fire	Class A fire	5.40	Currently
	Class B fire	4.70	Currently
	Class C fire	4.80	Currently
	Class D fire	4.40	Currently
	Class E fire	4.30	Currently
	Class K fire	4.50	Currently
Leakage	Water Pipe & Valve Systems	3.70	Currently
	Sea Water System Pump House	4.20	Currently
Toxic Gas Poisoning	Hydrogen	5.30	Currently
	Lead Acid Battery	6.00	Height

Source: Appendix 2 Expert Data Tabulation (2024)

Table 2 shows that the highest severity score is 9.00 for the operational risk of ship loss bouyancy sub cause internal solitary wave in the very high category, meaning that Loss of buoyancy on the submarine due to Internal Solitary Wave is an operational risk with a very high level of severity. Buoyancy is the ability of a submarine to float and control its depth in the water. Lost buoyancy occurs when a submarine cannot maintain a balance between the weight of the ship and the volume of water it displaces. ISW can cause sudden changes in the pressure distribution and water currents around the submarine, which can disrupt this balance. Here are some potential scenarios: (1) Sudden Depth Change: ISW can cause the submarine to move vertically without control from the crew. This could result in the submarine descending to dangerous depths or rising too quickly to the surface, risking structural damage or dangerous decompression for the crew; (2) Navigation System Disturbance: Strong currents and pressure fluctuations caused by ISW can disrupt a submarine's navigation and control systems. Hydraulic systems, sonar, and other navigation instruments may not function properly, increasing the risk of accidents; and (3) Structural Damage: Uneven water pressure can place excessive loads on the submarine's structure, causing cracks or damage to the hull. This is especially dangerous at greater depths where the water pressure is very high.

In risk assessment using FMEA, the severity level (Severity) describes the potential impact of failure on operations and safety. In the case of loss of buoyancy due to ISW, the severity level can be considered very high for the following reasons: (1) Personnel Safety: Sudden loss of buoyancy can result in an emergency situation that endangers the lives of the crew. The potential for sudden decompression, violent impact with the seabed, or even drowning, places this risk at the highest level of severity; (2) Material Loss: Damage to a submarine can be very expensive and take a long time to repair. This includes damage to the hull, navigation systems, and other equipment vital to submarine operations; (3) Mission Failure: Loss of buoyancy can disrupt or even derail the mission in progress. In military situations, this can mean loss of strategic initiative, failure to gather important intelligence, or inability to provide necessary support; and (4) Strategic Impact: Loss or damage to a submarine has broad strategic implications, including damage to naval power and diplomatic influence. This could also weaken the national defense and security position.

Therefore, it can be said that the impact on personnel safety, material losses, mission success and strategic position is very significant. So a comprehensive and proactive approach is needed to manage this risk. By implementing advanced detection technology, intensively training crews, improving navigation systems, implementing strict operational protocols, and collaborating with international institutions, the Indonesian Navy can increase the operational readiness of submarines and ensure effective support for its strategic tasks.

3.3 Analyzing Levels Occurance (Frequency of Occurrence)

The frequency of events aims to determine how often failures occur in each operational risk faced by the submarine. This frequency level is based on each risk assessment variable for submarine operational readiness, namely: (1) Ship Loss Buoyancy, (2) Fire, (3) Leak, and (4) Toxic Gas Poisoning. In the previous chapter, a frequency scale from 1 to 10 was explained. However, in this chapter a scale is used Occurance in Table 4.5 to make it easier for respondents to fill out the questionnaire. The following are the frequency scale (occurrence) criteria for each risk of submarine operational incidents.

Table 3 Skala Occurance

Skor Occurrence	1	2 - 3	4 - 5	6 - 7	8 - 9	10
Description	Very rarely	Seldom	Currently	Often	Very often	Almost Sure

Source: Data scores processed by the Author (2024)

Score Occurance from the results of the assessment of 7 experts on each risk variable for submarine operational readiness, namely: (1) Ship Losing Bouyancy, (2) Fire, (3) Leaks, and (4) Toxic Gas Poisoning, can be seen in Table 4.6, as follows :

Table 4 Score Occurance on Research Operational Risk Variables

Operational Risk	**Sub Causes**	**Occurance (O)**	**Information**
Ship Loses Bouyancy	Thrust Stopped	3.70	Currently
	Steering Jammed	3.70	Currently
	Density of Sea Water	3.70	Currently
	Internal Solitary Wave	4.00	Currently
Fire	Class A fire	3.60	Currently
	Class B fire	3.60	Currently
	Class C fire	3.70	Currently
	Class D fire	3.50	Often
	Class E fire	3.40	Seldom
	Class K fire	2.70	Seldom
Leakage	Water Pipe & Valve Systems	3.60	Currently
	Sea Water System Pump House	3.40	netting
Toxic Gas Poisoning	Hydrogen	3.80	Currently
	Lead Acid Battery	3.20	Seldom

Source: Appendix 2 Expert Data Tabulation (2024)

Table 4 shows that score Occurance The highest is 4.00 on the operational risk of ship loss bouyancy sub cause internal solitary wave in the Medium category, meaning an occurrence score of 4.00 for the risk of loss of buoyancy due to internal solitary waves shows that even though this event is in the moderate category, the impact can be very dangerous and requires serious attention. In the FMEA analysis, this means that submarine operations must always be prepared to encounter ISW through constant monitoring, intensive training, and the implementation of advanced detection technology. In this way, the Indonesian Navy can minimize risks and ensure mission success and the safety of submarine crews.

3.4 Analyzing Levels Detection (Detection)

The level of ability to detect submarine operational risks aims to assess how well operational risks can be detected through various submarine operational readiness risk variables, namely: (1) Ship Losing Buoyancy, (2) Fire, (3) Leaks, and (4) Gas Poisoning Poisonous. In the previous chapter, the detection scale from 1 to 10 was explained. However, in this chapter a scale is used detection in Table 4.7 to make it easier for respondents to fill out the questionnaire. The following are the criteria for the detection ability scale (Detection) from any risk of submarine operational incidents.

Table 5 Scale Detection

Score Detection	1	2 - 3	4 - 5	6 - 7	8 - 9	10
Description	Very easy	Easy	Currently	Difficult	Very difficult	Almost impossible

Source: Data scores processed by the Author (2024)

Score Detection from the results of the assessment of 7 experts on each risk variable for submarine operational readiness, namely: (1) Ship Losing Bouyancy, (2) Fire, (3) Leaks, and (4) Toxic Gas Poisoning, can be seen in Table 4.8, as follows :

Table 6 Score Detection on Research Operational Risk Variables

Operational Risk	Sub Causes	Detection (D)	Information
Ship Loses Bouyancy	Thrust Stopped	3.80	Currently
	Steering Jammed	3.80	Currently
	Density of Sea Water	4.10	Currently
	Internal Solitary Wave	4.20	Currently
Fire	Class A fire	3.60	Currently
	Class B fire	3.40	Easy
	Class C fire	3.60	Currently
	Class D fire	3.30	Easy
	Class E fire	3.30	Easy
	Class K fire	3.00	Easy
Leakage	Water Pipe & Valve Systems	3.80	Currently
	Sea Water System Pump House	3.60	Currently
Toxic Gas Poisoning	Hydrogen	3.90	Currently
	Lead Acid Battery	3.90	Currently

Source: Appendix 2 Expert Data Tabulation (2024)

Table 7 shows that score Detection The highest is 4.00 on the operational risk of ship loss bouyancy sub cause internal solitary wave in the ability category detection moderate, meaning a detection score of 4.00 on the risk of buoyancy loss due to internal solitary waves indicates that even though there are detection systems and procedures, the detection capability is still at a moderate level and requires improvement, in other words that the ability to detect ISW is still at a moderate level . This means that although there are some detection systems available, they may not be effective enough to always provide the necessary early warning.

Linking this to the Standard Operational Procedures for Implementing Emergency Management for Nagapasa Class Submarines, it is important to improve detection technology, strengthen crew training and readiness, and revise SOPs to be more effective. With these steps, the Indonesian Navy can improve its risk detection and mitigation capabilities, thereby ensuring safer and more efficient submarine operations.

3.5 Analyzing RPN (Risk Priority Number) value calculations

Knowing the most critical risk level by paying attention to various risk scales can be done using the RPN (Risk Priority Number) method. The RPN value is obtained from multiplying the severity, occurrence and detection scales.

$$\boxed{\text{RPN} = \textit{severity x occurance x detection}}$$

The most critical RPN value will be identified as the source of the cause of each risk variable: (1) Ship Loses Buoyancy, (2) Fire, (3) Leak, and (4) Poisoning by Toxic Gas. The RPN value for each risk variable can be seen in Table 4.9 to Table 4.12 as follows:

Table 8 RPN of Ship Losing Bouyancy

Operational Risk	Sub Causes	Severity (S)	Occurance (O)	Detection (D)	RPN
Lost Ship *Bouyancy*	Thrust Stopped	7.80	3.70	3.80	109.7
	Steering Jammed	8.00	3.70	3.80	112.5
	Density of Sea Water	8.40	3.70	4.10	127.4
	Internal Solitary Wave	9.00	4.00	4.20	151.2
	Mean	**8.30**	**3.78**	**3.98**	**124.5**

Source: Appendix 2 Expert Data Tabulation (2024)

Based on Table 8 RPN of Lost Ship Bouyancy value can be known risk priority submarine lost buoyancy above, it is found that repair priorities must take precedence over the operational risk of losing the submarine Bouyancy is Internal Solitary Wave, this is due to the RPN value Internal Solitary Wave highest, compared to Stuck Thruster, Stuck Rudder, and Sea Water Density.

Table 9 Fire RPN

Operational Risk	Sub Causes	Severity (S)	Occurance (O)	Detection (D)	RPN
Fire	Class A fire	5.40	3.60	3.60	70.0
	Class B fire	4.70	3.60	3.40	57.5
	Class C fire	4.80	3.70	3.60	63.9
	Class D fire	4.40	3.50	3.30	50.8
	Class E fire	4.30	3.40	3.30	48.2
	Class K fire	4.50	2.70	3.00	36.5
	Mean	**4.68**	**3.42**	**3.37**	**53.9**

Source: Appendix 2 Expert Data Tabulation (2024)

Based on Table 9, the RPN for Fire values can be determined risk priority above from submarine fires, it was found that the repair priority that must come first from the operational risk of submarine fires is Class A fires, this is because the RPN value for class A fires is the highest, compared to Class B fires, Class C fires, Class D fires, Class A fires. E and Class K Fires.

Table 10 RPN Leaks

Operational Risk	Sub Causes	Severity (S)	Occurance (O)	Detection (D)	RPN
Leakage	Water Pipe & Valve Systems	3.70	3.60	3.80	50.6
	Sea Water System Pump House	4.20	3.40	3.60	51.4
	Mean	**3.95**	**3.50**	**3.70**	**51.2**

Source: Appendix 2 Expert Data Tabulation (2024)

Based on Table 10 RPN Leakage, the value can be determined risk priority Above, from submarine leaks, it was found that the repair priority that must come first from the operational risks of submarine leaks is the sea water system pump house, this is because the RPN value of the sea water system pump house is the highest, compared to pipe and water valve system leaks.

Table 11 RPN of Toxic Gas Poisoning

Operational Risk	Sub Causes	Severity (S)	Occurance (O)	Detection (D)	RPN
Toxic Gas Poisoning	Hydrogen	5.30	3.80	3.90	78.5
	Lead Acid Battery	6.00	3.20	3.90	74.9
	Mean	**3.95**	**5.65**	**3.50**	**3.90**

Source: Appendix 2 Expert Data Tabulation (2024)

Based on Table 11 RPN for Toxic Gas Poisoning, the value can be determined risk priority Above, from toxic gas poisoning in submarines, it was found that the priority for improvement that must first be the operational risk of Toxic Gas Poisoning in Submarines is the emergence of hydrogen gas (H2) from lead-acid batteries during processing. charging, this is due to the RPN value of the emergence of hydrogen gas (H2) from the lead-acid battery during the process charging highest, compared to the emergence of toxic gases from lead acid battery electrolyte materials.

Based on value risk priority it is found that repair priorities must come first from ship operational risks as long as the four causes are ship loss. Bouyancy RPN 124.5, compared to Toxic Gas Poisoning RPN 77.1, Fire RPN 53.9 and Leak RPN 51.2. This RPN value will be connected in the FTA method (Fault Tree Analysis)

3.6 Submarine Operational Risk Analysis using the FTA Method

Based on the Failure Mode and Effect Analysis (FMEA) carried out, the highest risk of a ship losing buoyancy is due to a phenomenon internal solitary wave. This phenomenon is explained by oceanography experts as strong underwater waves that can pull objects vertically. This internal solitary wave is produced by a combination of strong tidal interactions, temperature differences between warmer and colder sea layers, and underwater geographic conditions.

Furthermore, interviews with experts have identified 14 potential underlying causes (basic event) from the risk of loss of buoyancy in submarines due to internal solitary waves. These potential causes are divided based on human factors, environment and methods. Based on interviews with experts, there are 14 potential causes which are item basic, namely:

No.	Ship Incident Loss of Buoyancy	Item Basic Event
1	**Internal Solitary Wave**	**1. Lack of Crew Knowledge and Experience**: Lack of understanding of the internal solitary wave phenomenon and how to deal with it.
2		**2. Non-compliance with Operational Procedures**: Crew does not comply with

No.	Ship Incident Loss of Buoyancy	Item Basic Event
		established standard operating procedures.
3		**3. Fatigue and Stress**: Crew experiences fatigue or stress which can affect decisions taken.
4		**4. Poor Communication**: Lack of communication between crew in emergency situations.
5		**5. Inadequate Training**: The training provided is not sufficient to deal with critical situations such as internal solitary waves.
6		**6. Rapid Changes in Sea Conditions**: A sudden and unexpected change in sea conditions.
7		**7. Influence of Climate and Weather**: Extreme weather conditions that worsen the situation at sea.
8		**8. Diversity of Underwater Geography**: A complex underwater structure that amplifies the effects of internal solitary waves.
9		**9. Ocean Current Conditions**: Strong and unpredictable ocean currents.
10		**10. Errors in Navigation**: An error in navigation that causes a ship to enter a high-risk area.
11		**11. Deficiencies in the Detection and Monitoring System**: Detection and monitoring system that cannot detect internal solitary waves effectively.
12		**12. Ineffective Evacuation Procedures**: Evacuation procedures that cannot be carried out quickly and efficiently.
13		**13. Lack of Alarm and Early Warning Systems**: The absence or malfunction of an alarm system that can warn the crew of approaching danger.
14		**14. Obsolete Ship Technology**: Ship technology is outdated and unable to deal with extreme sea conditions.

Source: Interview with Expert (2024)

3.7 **Tree diagram** Proposed Improvements**Fault Tree Analysis (FTA)**

Tree diagram Fault Tree Analysis (FTA) for the event of a ship losing buoyancy due to the internal solitary wave phenomenon which has been discussed with experts. This diagram shows the flow from top events to intermediate events and then to basic events, using AND gate and OR gate symbols to describe the relationship between events.

Detailed explanation of Diagram 4.1 FTA, below:

Top Event: Ship Loses Buoyancy Due to Internal Solitary Wave

- OR Gate: Top event occurs if one of the intermediate events occurs.

Intermediate Event 1: Crew Not Ready to Face Internal Solitary Wave

- OR Gate: Intermediate Event 1 occurs if one of the following basic events occurs:

1. BE1: Lack of Crew Knowledge and Experience
2. BE2: Non-Compliance with Operational Procedures
3. BE3: Fatigue and Stress in Crew
4. BE4: Poor Communication between Crew
5. BE5: Inadequate Training

Intermediate Event 2: Extreme Marine Environmental Conditions

- OR Gate: Intermediate Event 2 occurs if one of the following basic events occurs:
    1. BE6: Rapid Changes in Ocean Conditions
    2. BE7: Effects of Climate and Extreme Weather
    3. BE8: Diversity of Undersea Geography
    4. BE9: Strong and Unpredictable Ocean Current Conditions

Intermediate Event 3: Errors or Deficiencies in Ship Methods and Systems

- OR Gate: Intermediate Event 3 occurs if one of the following basic events occurs:
    1. BE10: Error in Navigation
    2. BE11: Deficiencies in Detection and Monitoring Systems
    3. BE12: Ineffective Evacuation Procedures
    4. BE13: Lack of Alarm and Early Warning Systems
    5. BE14: Obsolete Ship Technology

3.8 Proposed Improvements

Enhance crew knowledge through regular training on internal solitary waves and emergency response. Enforce compliance with operational procedures, and provide support to reduce fatigue and stress. Improve communication and develop a comprehensive training curriculum. Upgrade navigation and detection systems with advanced technology. Implement effective evacuation procedures and maintain alarm and early warning systems. Modernize submarine technology to handle extreme conditions.

Utilize weather prediction and oceanography technology to monitor ocean conditions. Prepare contingency plans for extreme weather and adjust travel routes based on underwater geography and ocean currents. Conduct regular audits and inspections to ensure compliance and effectiveness. Collect feedback for continuous improvement and collaborate with research institutions and experts to enhance understanding and mitigation strategies.

3.9 Discussion of Research Findings

Based on Failure Mode and Effect Analysis (FMEA) and Fault Tree Analysis (FTA), this research identified that the main factor causing submarines to lose buoyancy is the internal solitary wave (ISW) phenomenon. In the FMEA analysis, ISW has the most dominant Risk Priority Number (RPN) value, indicating that this threat is a significant operational risk for submarines. The Fault Tree Analysis (FTA) diagram shows the flow relationship from top event, namely the ship losing buoyancy, to intermediate events and basic events, with the use of AND gates and OR gates to describe the relationship between events.

Study by Wang, et al. (2022) provide strong support for these findings by analyzing the characteristics and impacts of ISWs in the Bali Sea and linking them to the KRI Nanggala-402 accident. Some key points from the study of Wang et al. relevant to the findings from FMEA and FTA include the identification of active ISWs in the Bali Sea with a peak length of close to 200 km, which moves from the Lombok Strait to the northwest across the Bali deep sea basin. This analysis reinforces the finding that ISWs are a significant real threat to submarine navigation, especially in areas identified as high risk areas. In addition, the study of Wang et al. linked the KRI Nanggala-402 accident to ISWs that had large amplitudes and high propagation speeds in the area where the submarine sank, confirming that ISWs can cause sudden changes in buoyancy, which was identified as a major risk factor in the FMEA and described in the FTA as intermediate event that leads to loss of buoyancy.

Combining these findings provides a comprehensive understanding of the threat posed by ISWs to submarine operations in Indonesian territory, particularly in the Bali Sea. Some points of this integration include the theory of ISWs which explains that ISWs are non-linear internal waves that can move through layers of water at quite large speeds and amplitudes, capable of affecting the stability of submarines. Understanding these mechanisms helps develop effective mitigation strategies to reduce risk. Specific observations in the Indonesian region using data from satellite imagery enable real-time identification and monitoring of ISWs. Observations in the Bali Sea show that ISWs in this region have characteristics that can cause submarine accidents, such as what happened to the KRI Nanggala-402. The case study of KRI Nanggala-402 provides practical insight into how ISWs can cause buoyancy loss in submarines.

By combining theory about ISWs, specific observations in the Indonesian region, and analysis of the impact of ISWs on submarine navigation, this study provides a comprehensive understanding of the threat posed by ISWs to submarine operations in the Bali Sea. The findings from the FMEA and FTA analyzes indicating ISWs as a major risk factor were strengthened by an empirical study by Wang et al. (2022), provides a strong basis for the development of effective mitigation strategies in supporting the duties of the Indonesian Navy. This mitigation strategy includes increasing crew training and education, strengthening ship systems and technology, as well as comprehensively handling environmental factors. By implementing these mitigation measures, the risk of loss of buoyancy on submarines due to internal solitary waves can be minimized, thereby supporting the smooth and safe operation of the Indonesian Navy.

4. CONCLUSION

Based on the Failure Mode and Effect Analysis (FMEA) and Fault Tree Analysis (FTA) analysis, the following conclusions can be drawn Identification of operational risks on submarines can be done using the Failure Mode and Effect Analysis (FMEA) and Fault Tree Analysis (FTA) approaches. Through FMEA, various potential failures are identified and analyzed to determine the Risk Priority Number (RPN) value, which indicates the severity level, probability of occurrence, and detection ability of each risk. The internal solitary wave (ISW) phenomenon was identified as the main factor causing loss of buoyancy in submarines, having the most dominant RPN value. In FTA, this risk is analyzed further by describing the flow relationship from top event, intermediate event, to basic event, using AND gate and OR gate symbols to show how various factors contribute to this significant operational risk. The assessment and evaluation of risk events on submarines involves in-depth analysis using FMEA and FTA. In FMEA, each potential failure is scored based on severity, likelihood of occurrence, and detectability, resulting in an RPN value that helps identify priority risks that need to be addressed. The analysis results show that ISW is the main operational threat to submarines. FTA completes this evaluation by mapping the flow of events from top events (the ship loses buoyancy) through intermediate events (such as crew unpreparedness and extreme environmental conditions) to basic events (such as lack of crew knowledge and experience, rapid changes in sea conditions, and errors in navigation). . This allows a more comprehensive understanding of how and why these risks occur. Determining mitigation or handling of submarine risks requires a strategy based on findings from FMEA and FTA. By identifying ISW as a key risk factor, effective mitigation measures can be designed and implemented. Recommended mitigation strategies include increasing training and education for crew to deal with ISW, strengthening submarine systems and technology for real-time ISW detection and response, as well as developing better operational procedures. Apart from that, implementing an alarm and early warning system that can detect ISW effectively, as well as improving ship technology to be able to face extreme sea conditions, is also very important. This comprehensive approach aims to minimize the risk of loss of buoyancy on submarines, thereby supporting the Indonesian Navy's operational tasks more safely and effectively.

BIBLIOGRAPHY

Ahmad Hambali et al., “Pemanfaatan Citra *Planet Scope* Untuk Estimasi Batimetri (Studi Kasus Di Perairan Laut Dangkal Pulau Karimun Jawa Jepara Jawa Tengah),” Jurnal Hidropilar 7, no. 1 (2021)

Ahmad, dkk (2020) *Mitigation of Supply Chain Risk using HOR* Model at PT. Sumber Karya Indah doi:10.1088/1757-899X/847/1/012059

Alijoyo, A. (2006). *Enterprise Risk Management.* Jakarta: PT. Ray Indonesia.

Ardhiwirawan, D. S. (2018). Analisis Pelaksanaan Manajemen Risiko dengan Aplikasi *Enterprise Risk Management* Pada PT Bukit Asam Tbk .

Arimbo,Tunang. “Model Pemilihan KRI Alih Bina Untuk Mendukung Tugas Pokok Koarmada III Menggunakan Metode Integrasi MCDM”. Tesis Program S2, ASRO STTAL, 2020

Bekti, Harun. “Model Pemilihan Lokasi Home Base Kapal Selam Di Koarmada I Menggunakan Metode Dematel Dan ANP (*Analytical Network Process*).” Program S2, Seskoal, 2021.

Buku Putih Pertahanan, Kementrian Pertahanan RI, Jakarta, 2015

Creswell and Poth (2018) *Qualitative Inquiry and Research Design : Choosing Among Five Approaches. 4th edn.* UK-USA: *Sage Publication.*

Cohen L. (1995*). Quality Function Deployment, How to Make QFD Work for You. Massachussets: Addison-Wesley Publish Company*

COSO, T. C. (2017). Enterprise Risk Management. New Jersey

Dede Rusdiana et al., “Strategi Pembangunan Industri Pertahanan Pada Negara Kepulauan Guna Mendukung Pertahanan Negara,” Jurnal Academia Praja 4, no. 2 (2021)

Devi, R. S. (2016). Analisa Risiko Operasional PT.XYZ .

Diksono. (2018). Manajemen Risiko pada Pelaksanaan Tugas Operasi KRI Dalam Rangka Mendukung Program Zero Accident

Doktrin Jayamahe, Jalesveva. “Skep Kasal No Kep-503-V-2018 Tanggal 22 Mei 2018 Tentang Dokrin TNI Angkatan Laut,” no. 302 (2018)

Doktrin TNI AL “Eka Sasana Jaya”, Strategi Pertahanan Laut Nusantara, Mabesal, Jakarta, 2006

Fahmi I. (2010). Managemen Risiko (Teori, Kasus dan Solusi). Bandung: Alfabeta.

Franz-Stefan Gady, "Indonesia *Launches Thrid Nagapasa-Class Diesel Electric Attack Submarine," The Diplomat,* 11 April 2019, Indonesia *Submarine Capabilities - The Nuclear Threat Initiative (nti.org)* diakses 30 Maret 2022

Gibson, D. I. (1997). Efektifitas Organisasi Dan Manajemen. Wienna: Erlangga Jakarta.

Hutabarat, Dani. "Penentuan Prioritas Tipe Kapal Selam Sebagai Pertahanan Peperangan Kepulauan Dengan Metode Fuzzy AHP dan Analisis BCR" Tesis Program S2, ASRO STTAL, 2020

ISO. (2018). ISO 31000: 2018, *Risk Management-Guidelines. Genever: ISO*

Jalesveva Dokrin Jayamahe, “Skep Kasal No Kep-503-V-2018 Tanggal 22 Mei 2018 Tentang Dokrin TNI Angkatan Laut,” no. 302 (2018)

Joko Christanto. (2011).Gempa Bumi, Kerusakan Lingkungan, Kebijakan dan Strategi Pengelolaan.Yogyakarta: Liberty

Journal APEM. *Integration Of SWOT and ANP For Effectsive Strategic Planning in the Comestic Industry. Vol. 11 N0. 1*.

Junef, Muhar. “Implementasi Poros Maritim Dalam Prespektif Kebijakan.” Jurnal Penelitian Hukum De Jure 19, no. 3 (2019).

Kaho, L. J. (2018). Manajemen Risiko Berbasis ISO 31000: 2018, Panduan Untuk *Risk Leaders* Dan *Risk Practitioners*. Jakarta: PT. Gramedia Widiasarana Indonesia.

Kamus Besar Bahasa Indonesia (KBBI)

Kountur, R. (2004). Manajemen Risiko Operasional, Memahami Cara Mengelola Risiko Operasional Perusahaan. Jakarta : Penerbit PPM.

Krisnamurti Pius Herdasa. "Penetapan Negara Dikawasan Asia Tenggara Sebagai Prediktor Ancaman Bagi Indonesia, Mengunakan Metode *Profile Matching,* Delphi Dan Borda". Tesis Program S2, ASRO STTAL, 2020

Kurniasari, D. (2010). Aplikasi Model *House of Risk* (HOR) untuk mitigasi risiko proyek pembangunan jalan tol Gempol-Pasuruan. Prosiding Seminar Nasional Manajemen Teknologi XI, Program Studi MMT- Institut Teknologi Sepuluh Nopember

Kusnadi, C. (2014). Pengelolaan Risiko Pada *Supply Chain* Dengan Menggunakan Metode *House Of Risk* (Studi Kasus di PT . XYZ).

Liotta, P.H. & Lloyd, R.M. (Spring 2005). *From Here To There: The Strategy and Force Planning Framework. Naval War College Review, Vol.58, No.2*

Mabes TNI AL. "Perkasal no 5 tahun 2016 tentang kebijakan dasar pembangunan TNI Angkatan Laut menuju MEF *(Minimum Essensial Force),* Jakarta 2016

Marsetio, "Aktualisasi Peran Pengawasan Wilayah Laut Dalam Mendukung Pembangunan Indonesia Sebagai Negara Maritim Yang Tangguh" (Makalah Laksamana TNI Dr. Marsetio, pada acara kuliah umum di hadapan Civitas Akademika Universitas Sumatera Utara, di Medan, Januari 2015.

Marsetio, *Sea Power* Indonesia, Jakarta, 2014

Maulana, Victor. *"Choke Point'* Di Dunia, Tiga Ada Di Indonesia." Sindonews.com, 2021. Diakses pada 21 Maret 2022 https://international.sindonews.com/read/528566/40/choke-point-di-dunia-tiga-ada-di-indonesia-1630483787.

Mawanto, Andi. "Pengaruh Dukungan Logistik Terpadu Di Wilayah Natuna Terhadap Kesiapan Operasi KOGABWILHAN I." Jurnal Logistik Indonesia 4, no. 2 (2020).

Michael J. Mazzar*, "The Revolution in Military Affairs: A Framework for Defense Planning" (Monograph, Army War College, n.d.)*

Mulya, Lillyana. "Postur Maritim Indonesia: Pengukuran Melalui Teori Mahan." Lembaran Sejarah 10, no. 2 (2013).

Nainggolan, Poltak Partogi. "Indonesia Dan Ancaman Keamanan Di Alur Laut Kepulauan Indonesia (Alki) Security Threats To Indonesia ' S *Sea Lanes,"* 2015, 183–200.

Normaria M. Sirait, A. S. (2015). Analisa Risiko Operasional Berdasarkan Pendekatan *Enterprise Risk Management* (ERM) Pada Perusahaan Pembuatan Kardus di CV Mitra Dunia Palletindo

Notoatmodjo, S. (2003). Pengembangan Sumber Daya Manusia (5 ed.). Jakarta: PT Rineka Cipta.

Nugroho, Sigit Sutadi. "Implementasi Ketentuan Pasal 50 Unclos Di Wilayah Negara Kepulauan." *Jurnal Rechts Vinding*: Media Pembinaan Hukum Nasional 8, no. 2 (2019)

Okol Sri Suharyo, daftar Istilah d
alam "Model Penentuan Lokasi Pangkalan Angkatan Laut Berbasis Sustainabilitas" Doktor Pasca Sarjana,ITS, 2017.

Peraturan Panglima TNI Nomor 26/V/2008 Tentang Operasi Laut

Poetra. "KSAL: Semua Komando Armada Akan Memiliki Satuan Kapal Selam." airspace-review.com, diakses pada 15 Maret 2022, https://www.airspace-review.com/2022/02/08/ksal-semua-komando-armada-akan-memiliki-satuan-kapal-selam/

Pujawan, I. N., & Geraldin, L. H. (2009). *House of risk*: *a model for proactive supply chain risk management. Emerald: Business Process Management Journal , Vol. 15 No. 6, pp. 953-967*

Putra, I N (2016). Konsepsi Pembangunan Kekuatan dan kemampuan Teknologi Informasi TNI AL dalam mendukung Penyelenggaraan Strategi Pertahanan Laut Nusantara. Malang : Bintang Surabaya.

Putri Amelia, I. V. (2017). Analisa Risiko Operasional Pada Divisi Kapal Perang PT. PAL Indonesia dengan Metode *House Of Risk*.

Ramdhan, Taufik. "Analisis Penentuan Lokasi Pangkalan Kapal Selam di Wilayah Koarmada III Dalam Rangka Mendukung Tugas Pokok TNI AL" Tesis Program S2, ASRO STTAL, 2021

Ruben J.Paredes dan Maria T.Quintuna, *“Numerical Flow Characterization around a Type 209 Submarine Using Open FOAM †,” 2021, 1–23*

Rusdiana, Dede, Yusuf Ali, Suyono Thamrin, and Resmanto Widodo. *“Strategi Pembangunan Industri Pertahanan”*

S Wiranto, “Membangun Kembali Budaya Maritim Indonesia Melalui Kebijakan Kelautan Indonesia Dengan Strategi Pertahanan Maritim Indonesia: Perspektif Pertahanan Maritim,” Jurnal Maritim Indonesia 8, no. 2 (2020): 110–26, http://pusjianmar- seskoal.tnial.mil.id/index.php/IMJ/article/view/35.

Saaty, T*. "Decision Making with Dependence and Feedback: The Analytic Network Process". Second. Pittsburgh, USA: RWS. 2001*.

Saaty, T. "*The Analytic Hierarchy And Analytic Network Processes For The Measurement Of Intangible Criteria And For Decision-Making, Multiple Criteria Decision Analysis" Pittsburgh, USA, 2015.*

Santoso, Tri Budi, Endang Widjiati, Wirawan, and Gamantyo Hendrantoro. *“Ambient Noise Measurement and Characterization of Underwater Acoustic Channel in Surabaya Bay.” In APWiMob 2015 - IEEE Asia Pacific Conference on Wireless and Mobile, 2016.*

Setia Mulyawan, (2015). Manajemen Risiko. Bandung : Pustaka Setia. Siegel, J. G., & Sim, J. K. (1999). *Operations Management. Hauppauge, NY: Barron's Business Review*.

Silvana Maulidah, (2020) *Risk Mitigation of Tobacco Supply Chain: Business Process Model DOI: 10.21776/ub.habitat.2020.031.3.18*

Soewarso M.Sc, Laksamana Muda TNI, Kumpulan Karangan tentang Evolusi Pemikiran Masalah Keangkatanlautan, terbitan ke-2, Seskoal, 1986, hal 73

Sondang, S. P. (1998). Manajemen Strategi (3 ed.). Jakarta: Bumi Aksara. Soehatman Ramli, (2010). Manajemen Risiko, Pedoman Praktis dalam

Sutanto, S. (2012). *Desain Enterprise Risk Management* Berbasis ISO 31000 Bagi Duta Minimarker di Situbondo .

Stamatis, D. H. (1995). “*Failure Mode and Effect Analysis: FMEA from Theory to Execution*”. Penerbit: *ASQC Quality Press,* Milwaukee.

Wignjosoebroto, S. (2006). Pengantar Teknik dan Manajemen Industri.Surabaya: Guna Widya.

Wiranto, S. “Membangun Kembali Budaya Maritim Indonesia Melalui Kebijakan Kelautan Indonesia Dengan Strategi Pertahanan Maritim Indonesia: Perspektif Pertahanan Maritim.” Jurnal Maritim Indonesia 8, no. 2 (2020): 110–26.