Equivalent: Jurnal Ilmiah Sosial Teknik
Volume 8, Issue 6, 2521-2535
e_ISSN: 2775-0833
https://jurnalequivalent.id/index.php/jequi/index
DOI: doi.org/10.59261/jequi.v8i6.484

Maritime Accident Patterns and Contributing Factors in Indonesia: Evidence from KNKT Investigation Reports, 2022–2025

Dwi Haryanto
Politeknik Pelayaran Sorong, Indonesia

Ryan Puby Sumarta
Politeknik Pelayaran Sorong, Indonesia

Muji Setiyono
Politeknik Pelayaran Sorong, Indonesia

***Corresponding author:**
Dwi Haryanto, Politeknik Pelayaran Sorong, Indonesia. ✉dwiharyanto75@gmail.com

Article Info :

Article history:
Received: September 22, 2026
Revised: November 09, 2026
Accepted: November 13, 2026
Available Online: November 24, 2026

Keywords:
Contributing Factors;
Indonesia;
KNKT;
Maritime Accident Patterns;

This is an open access article under the CC BY-SA license.

Copyright © 2026 by Author. Published by Politeknik Siber Cerdika International

Abstract

Background: Maritime accidents remain a significant safety concern because their occurrence may result from interactions among technical, operational, human, organizational, and environmental conditions.
Objective: This study examines maritime accident patterns in Indonesia and the contributing factors documented in Komite Nasional Keselamatan Transportasi (KNKT) investigation reports during 2022–2025.
Methods: A descriptive quantitative approach was employed using secondary data from the KNKT maritime investigation database and corresponding Final Reports. The study covered 35 accident cases recorded by year of occurrence. Accident patterns were analyzed using frequencies and percentages, while contributing factors in 13 available Final Reports were examined through a researcher-developed multi-label coding framework comprising five categories: technical, operational, human, organizational or management, and environmental factors.
Results: The results show that fires were the most frequent accident category, accounting for 17 cases (48.6%), followed by sinkings with 13 cases (37.1%). Together, they represented 85.7% of the 35 cases. Fires predominated in 2023 and 2024, whereas sinkings were most frequent in 2025. Among the 13 Final Reports, technical and operational factors were each identified in 9 reports (69.2%), followed by human factors in 5 reports (38.5%). Organizational or management and environmental factors each appeared in 3 reports (23.1%).
Conclusion: The findings indicate that maritime accidents involve interacting safety conditions rather than isolated contributing factors. The equal prominence of technical and operational factors highlights the need to address vessel conditions alongside operational practices and safety procedures. This study provides case-based evidence to support maritime safety improvement and further accident investigation.

To cite this article: Author 1., & Author 2. (2026). Maritime Accident Patterns and Contributing Factors in Indonesia: Evidence from KNKT Investigation Reports, 2022–2025. *Equivalent: Jurnal Ilmiah Sosial Teknik*, 8 (6), 2521-2535. https://doi.org/10.59261/jequi.v8i6.484

INTRODUCTION

Maritime transportation plays a vital role in the movement of people and goods, particularly in countries where sea transport is central to national connectivity. In Indonesia, an archipelagic country, maritime transportation is essential for connecting regions and supporting economic activities. However, maritime operations involve interactions among vessels, crews, operational procedures, environmental conditions, and safety management systems. Failures or weaknesses in any of these areas may contribute to accidents that affect human life, vessels, cargo, the marine environment, and the continuity of transportation services. Understanding maritime accident patterns and the factors associated with their occurrence is therefore an important part of maritime safety management and accident prevention (Jiang et al., 2024; Zhou et al., 2024).

Maritime accident investigations provide an important source of knowledge for improving safety. By reconstructing the sequence of events and examining the circumstances surrounding

an accident, investigators can identify the conditions and contributing factors associated with its occurrence. The International Maritime Organization (IMO) emphasizes that marine safety investigations should establish the circumstances of casualties and incidents and identify the factors contributing to them, with the broader purpose of preventing similar occurrences in the future (International Maritime Organization, 2008). Investigation reports consequently serve a purpose beyond documenting individual accidents. They provide empirical evidence that can be examined to understand recurring safety problems and weaknesses in maritime operations and management.

The analysis of maritime accidents, however, should not rely exclusively on the number of occurrences. Accident frequency describes the distribution of events within a particular dataset, whereas risk assessment also requires consideration of the likelihood of an event and the severity of its potential consequences. An accident category that occurs frequently is not necessarily associated with the greatest level of risk. Conversely, an event with relatively few occurrences may have serious consequences and warrant considerable safety attention (Kaptan & Bayazit, 2024; Zhou et al., 2024). Examining accident characteristics and consequences alongside contributing factors therefore provides a broader basis for understanding maritime safety than frequency distributions alone (International Maritime Organization, 2024).

Recent research has increasingly employed data-driven approaches to investigate maritime accident patterns and the factors associated with maritime casualties. Large-scale accident databases enable researchers to examine relationships among accident characteristics and risk-influencing factors across different cases. One example is the development of a data-driven Bayesian Network model using 55,469 global maritime accident records from 2002 to 2022 to quantify relationships among risk-influencing factors and maritime accidents (Jiang et al., 2024). Data-driven risk modelling has also been applied to examine global maritime casualty patterns and investigate factors associated with accident consequences (Zhou et al., 2024). Such approaches demonstrate the value of systematic accident database analysis in identifying relationships and patterns that may not be apparent through descriptive statistics alone.

Human factors represent another important dimension of maritime accident analysis. Decision-making, compliance with procedures, communication, supervision, competence, and working conditions may interact with technical and environmental conditions in the development of unsafe situations. Their contribution may differ according to the type and circumstances of an accident. An analysis integrating the Human Factors Analysis and Classification System (HFACS), association rule mining, and Bayesian Network modelling has demonstrated that human-factor contributions vary across different types of maritime accidents (Ma et al., 2024). This suggests that contributing factors should be examined in relation to the characteristics of individual accidents rather than assuming that all maritime accidents follow the same pattern.

In Indonesia, the Komite Nasional Keselamatan Transportasi (KNKT), or National Transportation Safety Committee, conducts safety investigations into transportation accidents, including maritime accidents, and issues safety recommendations based on its findings. Its maritime investigation database provides information on investigated cases, including the year of occurrence, vessel, location, type of area, and investigation status (Komite Nasional Keselamatan Transportasi, 2026d). The corresponding investigation reports contain more detailed accounts of individual accidents, including the circumstances identified during the investigation and the contributing factors documented by investigators. The database and investigation reports therefore provide complementary sources for examining the distribution of investigated cases and the factors identified in individual investigations (Komite Nasional Keselamatan Transportasi, 2026d).

KNKT records illustrate that the distribution and characteristics of investigated maritime accidents can vary across years. In 2023, KNKT recorded seven maritime investigations, six of which involved vessel fires. Its review of final investigation reports covering the 2020–2023 period also identified technical factors as the predominant causal factor in the maritime accidents examined during that period (Komite Nasional Keselamatan Transportasi, 2024b). In 2025, KNKT recorded eight maritime investigations, comprising six sinking cases, one fire, and one collision. Seven of these eight cases were classified as very serious marine casualties (Komite Nasional Keselamatan Transportasi, 2026c). These differences in accident categories and annual

distributions indicate that the characteristics of investigated maritime accidents may change over time. Examining records across several years can therefore provide a broader picture than relying on a single year's distribution.

Using occurrence-year filtering of the KNKT maritime investigation database, the present study identified 35 investigated maritime accident cases from 2022 to 2025. These comprised 14 cases in 2022, seven in 2023, six in 2024, and eight in 2025. The records provide the basis for examining the annual distribution and characteristics of maritime accidents investigated by KNKT during the study period. The scope of this dataset must, however, be distinguished from the total incidence of maritime accidents in Indonesia. The 35 cases represent records included in the KNKT investigation database and should not be interpreted as a complete account of all maritime accidents that occurred nationally during 2022–2025.

Although international studies have used large accident databases to develop data-driven models of maritime risk, national investigation reports offer a different analytical contribution. Large international datasets support the examination of statistical relationships across extensive collections of cases, while national investigation reports provide case-specific information grounded in a particular institutional and operational context (Jiang et al., 2024; Zhou et al., 2024). An examination of KNKT reports can complement existing international research by documenting the characteristics and contributing factors identified in Indonesian maritime accident investigations. Distinguishing between the analysis of accident records and the detailed examination of final investigation reports is important for clarifying the scope of the evidence and avoiding conclusions that extend beyond the cases examined.

Against this background, the present study examines KNKT maritime accident records for the period 2022–2025 through two related levels of analysis. The first uses 35 investigated cases to describe the annual distribution and characteristics of maritime accidents. The second examines 13 KNKT Final Reports to identify and classify the contributing factors documented in the investigations. These factors are organized into five analytical categories: technical, operational, human, organizational or management, and environmental. The two datasets serve different but complementary purposes: the 35 cases provide the basis for describing accident patterns, while the 13 Final Reports provide the documentary evidence for the detailed analysis of contributing factors.

Accordingly, this study aims to analyse maritime accident patterns in Indonesia based on KNKT investigation records from 2022 to 2025. Specifically, it seeks to describe the annual distribution and characteristics of the 35 investigated cases and examine the contributing factors documented in 13 KNKT Final Reports using five analytical categories: technical, operational, human, organizational or management, and environmental factors. By distinguishing between the broader accident dataset and the reports selected for detailed analysis, the study seeks to provide a context-specific account of investigated maritime accidents in Indonesia without assuming that findings from the selected reports represent all maritime accidents nationally.

METHOD

This study employed a descriptive quantitative research design to examine maritime accident patterns and contributing factors based on investigation records published by the Komite Nasional Keselamatan Transportasi (KNKT). Secondary data were obtained from the KNKT maritime investigation database and the corresponding investigation reports for accidents with occurrence years between 2022 and 2025. The unit of analysis for the accident-pattern analysis was each maritime accident case recorded as an investigated event in the KNKT database. Applying the occurrence-year filter identified 35 cases, comprising 14 cases in 2022, seven in 2023, six in 2024, and eight in 2025. These cases constituted a purposive census of the maritime investigation records available in the KNKT database within the specified period. The term purposive census refers to the inclusion of all records meeting the study's defined criteria, rather than a sample drawn to represent the entire population of maritime accidents in Indonesia.

Data collection involved reviewing the information available in the KNKT database and examining the associated investigation documents. For the 35 cases, the extracted information included the year of occurrence, vessel name, accident type, location or area of occurrence, investigation status, and reported accident consequences where available. Accident types were

classified according to the terminology used by KNKT. Information that was not available in the database or corresponding records was treated as unavailable rather than inferred by the researchers.

A more detailed examination of contributing factors was conducted using 13 KNKT Final Reports. These reports provided the documentary basis for identifying factors explicitly discussed in the investigation findings. The identified factors were classified into five analytical categories: technical, operational, human, organizational or management, and environmental. The categories were developed to organize the information reported in the documents and to examine the different dimensions associated with the investigated accidents. As an accident could involve more than one contributing factor, the coding categories were treated as non-mutually exclusive. Factors were assigned only when supported by information in the relevant report; information that was not documented was not inferred or coded as an established contributing factor.

The collected information was organized into a case-level database and analysed descriptively using frequency and percentage distributions. The percentage of each accident category was calculated using the following formula:

$$P = \frac{f}{N} \times 100\%$$

where P represents the percentage, f the frequency of a particular category, and N the total number of investigated cases. For the annual distribution, N was 35. For the analysis of contributing factors, the denominator was based on the 13 Final Reports examined. Because multiple contributing factors could be identified in a single report, the percentages for the five factor categories were not expected to total 100%.

Cross-tabulations were used to examine the distribution of accident types across years and other relevant characteristics. Where the available information permitted, accident categories were also examined in relation to reported consequences. The contributing-factor analysis was conducted separately using the 13 Final Reports. This distinction maintained the difference between the database-level description of 35 investigated cases and the report-level examination of contributing factors. Accident frequency was interpreted as a description of the distribution of investigated cases, not as a direct measure of accident risk. Risk assessment requires consideration of both the likelihood of an event and its potential consequences (International Maritime Organization, 2024; Kaptan & Bayazit, 2024).

The analysis focused on identifying patterns within the KNKT records and examining the contributing factors documented in the selected Final Reports. The observed patterns were considered in relation to previous maritime safety research to assess areas of similarity and difference between the Indonesian investigation records and findings reported in other contexts (Jiang et al., 2024; Ma et al., 2024; Zhou et al., 2024). Since the dataset comprised cases investigated and recorded by KNKT rather than the complete population of maritime accidents in Indonesia, the interpretation of the findings was restricted to the scope of the available investigation records for the 2022–2025 period.

RESULTS AND DISCUSSION

Annual Distribution of KNKT-Investigated Maritime Accidents

The KNKT maritime investigation database records investigated maritime casualties according to several characteristics, including occurrence year, vessel, location, and investigation status. Applying the occurrence-year filter for 2022–2025 identified 35 maritime accident cases for analysis. The annual distribution comprised 14 cases in 2022, seven in 2023, six in 2024, and eight in 2025. These records represent cases investigated by KNKT and should not be interpreted as a complete census of all maritime accidents occurring in Indonesia during the study period. The database also distinguishes cases according to their reporting status, including those with Final Reports and those that have not yet reached the final reporting stage (Komite Nasional Keselamatan Transportasi, 2026d).

Table 1

Distribution of KNKT-investigated maritime accident cases by year

Year	Number of Cases	Percentage (%)

2022	14	40.0
2023	7	20.0
2024	6	17.1
2025	8	22.9
Total	35	100.0

The annual distribution indicates that the number of investigated cases varied throughout the observation period. The highest number was recorded in 2022, accounting for 14 cases (40.0%). This was followed by seven cases in 2023 (20.0%) and six in 2024 (17.1%), before the number increased to eight in 2025 (22.9%). The pattern shows a decline between 2022 and 2024, followed by a moderate increase in the final year.

This variation should not be interpreted as evidence of a corresponding decline or increase in the overall incidence of maritime accidents in Indonesia. The dataset contains cases selected for investigation by KNKT, rather than all accidents reported or occurring nationally. KNKT investigations are intended to establish the circumstances of accidents, identify safety lessons, and formulate recommendations to prevent recurrence. The resulting database therefore provides evidence of investigated cases, not a comprehensive measure of national accident incidence (Komite Nasional Keselamatan Transportasi, 2026d).

Distribution of Maritime Accident Types

Classification of the 35 cases according to the accident descriptions in the KNKT database resulted in five analytical categories: fire, sinking, grounding, collision, and a fumigation-related occupational fatality. Fire was the most frequently recorded category, with 17 cases (48.6%), followed by sinking with 13 cases (37.1%). Grounding and collision each accounted for two cases (5.7%), while one case involved a fumigation-related occupational fatality (2.9%).

Table 2

Distribution of maritime accident types, 2022–2025

Accident Type	Number of Cases	Percentage (%)
Fire	17	48.6
Sinking	13	37.1
Grounding	2	5.7
Collision	2	5.7
Fumigation-related occupational fatality	1	2.9
Total	35	100

Fire and sinking together accounted for 30 of the 35 investigated cases, representing 85.7% of the dataset. The prominence of fire is consistent with KNKT's official review of maritime investigations in 2023, in which six of the seven cases investigated that year involved vessel fires (Komite Nasional Keselamatan Transportasi, 2024b). This similarity provides context for the high proportion of fire cases in the present dataset, although the annual review and the four-year dataset cover different observation periods.

The frequency distribution does not, however, establish that fire represents the highest maritime safety risk. Accident frequency describes how often a particular category appears in the dataset, whereas risk assessment also requires consideration of the likelihood of occurrence and the severity of potential consequences. The present results therefore identify fire as the most frequently investigated accident category, not necessarily the category associated with the highest overall risk (International Maritime Organization, 2024; Kaptan & Bayazit, 2024).

A breakdown by occurrence year provides further insight into the distribution of accident types and reveals differences that are not immediately apparent from the aggregated figures.

Table 3

Accident type by occurrence year

Year	Fire	Sinking	Grounding	Collision	Fumigation-related occupational	Total

					fatality	
2022	5	5	2	1	1	14
2023	6	1	0	0	0	7
2024	5	1	0	0	0	6
2025	1	6	0	1	0	8
Total	17	13	2	2	1	35

The fumigation-related occupational fatality was classified separately because it involved a fatal occupational incident associated with fumigation rather than a conventional vessel accident category such as fire, sinking, grounding, or collision. Although it accounted for only one case, its inclusion preserves the completeness of the KNKT investigation records examined in this study.

The annual breakdown reveals a change in the dominant accident category during the observation period. In 2022, fire and sinking occurred in equal numbers, with five cases each. Fire became the dominant category in 2023, accounting for six of the seven investigated cases (85.7%). A similar pattern appeared in 2024, when five of the six cases (83.3%) involved fire. In 2025, however, sinking became the predominant category, with six of the eight cases (75.0%). Fire and collision each accounted for one case in that year. This distribution is consistent with KNKT's official 2025 performance report, which recorded six sinking cases, one fire, and one collision among the eight maritime investigations conducted during the year (Komite Nasional Keselamatan Transportasi, 2026c).

The shift observed in 2025 demonstrates that the dominant accident category was not consistent throughout the four-year period. Aggregating all cases into a single frequency distribution provides an overall description but conceals differences between individual years. Previous maritime accident studies have shown that accident patterns are associated with combinations of vessel characteristics, operational conditions, human factors, and environmental conditions. Different combinations of these factors may be associated with different accident categories (Jiang et al., 2024; Zhou et al., 2024). Examining the annual distribution alongside the overall frequency therefore provides a more informative description of the investigated cases.

The predominance of fire in 2023 and 2024 should also not be taken to mean that all fire incidents followed the same causal mechanism. Fires may arise from different combinations of machinery conditions, fuel or oil leakage, electrical systems, cargo characteristics, ignition sources, fire detection arrangements, and emergency response procedures (Aydin et al., 2024; Sarıalioğlu et al., 2020). The KNKT Final Reports examined in this study provide case-specific evidence of this variation. The contributing factors documented in individual fire investigations differed, indicating that the same accident classification may encompass substantially different accident mechanisms.

Contributing Factors Identified in the KNKT Final Reports

A more detailed examination of contributing factors was conducted using 13 Final Reports identified among the 35 cases. This distinction is important because the analysis of contributing factors relies on completed investigation findings. The KNKT database identifies cases according to their reporting status, including Final Reports and reports that have not reached the final stage (Komite Nasional Keselamatan Transportasi, 2026d). For example, Tunu Pratama Jaya is listed as a Final Report, whereas Port Link III is identified as a Preliminary Report. Accordingly, all 35 cases were included in the accident-pattern analysis, while the detailed examination of contributing factors was restricted to the 13 cases for which Final Reports were available.

The 13 Final Reports examined were China Express, Permata Asia, Trisila Bhakti II–Gerbang Samudera 2, Sabuk Nusantara 91, Young Yong, Mutiara Timur I, LIT Enterprise, Ladang Pertiwi 02, Royce I, Kurnia Jaya, Labuan Bajo 1, Umsini, and Tunu Pratama Jaya. The reports documented different circumstances and contributing conditions, often involving more than one dimension of the accident process.

To organize the findings, a multi-label analytical coding procedure was applied using five categories: technical, operational, human, organizational or management, and environmental factors. The coding was conducted by the researcher through a systematic examination of the contributing factors and relevant investigation findings documented in the 13 KNKT Final

Reports. Information explicitly identified as contributing factors by KNKT was distinguished from other investigation findings before being assigned to one or more analytical categories according to its substantive characteristics and relevance to the study's analytical framework. The five categories were developed by the researcher and do not represent an official KNKT classification system. Since an individual accident could involve several contributing factors, more than one category could be assigned to a single report.

Table 4
Analytical coding of contributing factors in 13 KNKT Final Reports

Case	Accident Type	Technical	Operational	Human	Organizational	Environmental
China Express	Fumigation-related fatality	✓	–	✓	–	–
Permata Asia	Sinking	✓	–	–	–	–
Trisila Bhakti II–Gerbang Samudera 2	Collision	–	✓	✓	–	✓
Sabuk Nusantara 91	Fire	✓	✓	–	–	–
Young Yong	Grounding	–	✓	✓	–	–
Mutiara Timur I	Fire	✓	✓	✓	✓	–
LIT Enterprise	Fire	✓	–	–	✓	–
Ladang Pertiwi 02	Sinking	✓	✓	–	–	–
Royce I	Fire	–	✓	✓	–	–
Kurnia Jaya	Fire	–	✓	–	✓	✓
Labuan Bajo 1	Fire/Explosion	✓	–	–	–	–
Umsini	Fire	✓	✓	–	–	–
Tunu Pratama Jaya	Sinking	✓	✓	–	–	✓

Note: A check mark (✓) indicates that the corresponding category was assigned by the researcher based on the contributing factors and relevant investigation findings documented in the KNKT Final Reports. The five categories represent a researcher-developed analytical framework and are non-mutually exclusive; therefore, more than one category could be assigned to a single report.

The distribution of the coded contributing factors across the 13 Final Reports is presented in Table 5.

Table 5
Distribution of analytically coded contributing factors

Contributing Factor	Number of Cases	Percentage (%)
Technical	9	69.2
Operational	9	69.2
Human	5	38.5
Organizational/Management	3	23.1
Environmental	3	23.1

Technical and operational factors were each identified in nine of the 13 Final Reports (69.2%), making them the most frequently represented categories. Human factors appeared in five reports (38.5%), while organizational or management factors and environmental factors each

appeared in three reports (23.1%). Because the coding procedure allowed multiple categories to be assigned to one report, these percentages are not expected to total 100%. They represent the proportion of reports in which each category was identified, rather than mutually exclusive shares of accident causation.

The representation of technical factors in the present analysis is consistent with KNKT's review of maritime investigations for the 2020–2023 period, which identified technical factors as the predominant causal factor in the Final Reports examined during that period (Komite Nasional Keselamatan Transportasi, 2024b). The present analysis provides a more case-specific perspective by examining the circumstances documented in individual investigations. At the same time, the equal frequency of technical and operational factors in the current dataset indicates that accident development cannot be understood solely through equipment or vessel-related conditions. Operational practices and the implementation of safety procedures also feature prominently in the investigated cases.

In the Permata Asia case, the formal contributing factor identified by KNKT was the deterioration and perforation of the engine-room bilge-well plate due to corrosion, which made the plate unable to withstand water pressure (Komite Nasional Keselamatan Transportasi, 2024a). The report also documented weaknesses in the availability of information concerning the condition of the bilge well and the absence of relevant inspection records. However, these were reported as investigation findings rather than as the formal contributing factor itself. Maintaining this distinction is important because not every observation or deficiency documented in an investigation report should automatically be classified as a contributing factor. Within the analytical framework of this study, the case was therefore classified as a technical factor.

A different combination of technical and operational conditions was identified in the Umsini case. KNKT found that oil escaped from the cylinder-head area of Auxiliary Engine No. 3 because its cover was not properly secured. The oil subsequently reached a hot surface of the exhaust gas manifold, resulting in ignition. The investigation also identified that the crew's response to the emergency did not comply with the vessel's Safety Management System (SMS) procedures for firefighting and the operation of the fixed CO_2 fire-extinguishing system (Komite Nasional Keselamatan Transportasi, 2026a). These two contributing factors represent distinct aspects of the accident: the machinery-related condition that initiated the fire and the operational deficiencies in the implementation of emergency response procedures. Accordingly, the case was classified under both technical and operational factors.

The LIT Enterprise investigation also documented the importance of machinery condition and maintenance arrangements. The report identified the small-end bearing of a connecting rod as the source of a hot spot associated with the engine-room fire. It also documented the absence of historical data and maintenance records for the component, an increase in oil mist concentration that was not detected, and the failure of the oil mist detection device to provide a warning as the concentration increased (Komite Nasional Keselamatan Transportasi, 2025a). These findings indicate that the accident involved both a machinery-related ignition source and weaknesses in maintenance documentation and technical detection arrangements. Within this study's analytical framework, these conditions were classified as technical and organizational or management factors.

The Sabuk Nusantara 91 investigation provides another example of the interaction between technical and operational conditions. KNKT identified a heat source that ignited a foam mattress and its covering in the central passenger space on Deck 1. The investigation also identified insufficient safety and fire patrol activities in the passenger accommodation area while the vessel was berthed (Komite Nasional Keselamatan Transportasi, 2023c). The first factor concerns the physical conditions associated with fire ignition, whereas the second concerns the implementation of onboard safety monitoring and fire-prevention activities. Accordingly, the case was classified under technical and operational factors.

A related mechanism was documented in the Labuan Bajo 1 case. The investigation identified an accumulation of fuel vapour and oxygen in a space beneath the vessel's floor, extending towards the aft wall. The mixture was within the lower and upper explosive limits (LEL–UEL) and was subsequently ignited by a heat source (Komite Nasional Keselamatan Transportasi, 2025b). This case draws attention to the formation of a flammable atmosphere in

an enclosed vessel space and the presence of an ignition source. Within the analytical framework of this study, the condition was classified as a technical factor.

Human factors were also evident in the reports, although they were not consistently expressed as simple operator error. In the Young Yong grounding, KNKT identified inadequate situational awareness on the bridge and indicated that the Electronic Chart Display and Information System (ECDIS) was unlikely to have been optimised by the Navigation Officers on Watch during navigation (National Transportation Safety Committee, 2024). These findings indicate an interaction between human performance and the operational use of navigational technology. The case was therefore classified under human and operational factors rather than as a technical equipment failure. The role of the human element must be considered in relation to the information, equipment, and operational conditions within which navigational decisions are made (Ma et al., 2024).

The China Express case provides another example of the relationship between human understanding and technical protection. KNKT's investigation described how a helper entered a cargo hold without authorisation or appropriate protective equipment to retrieve a gas detector during the aeration process. A fumigator subsequently entered the hold in an attempt to rescue the helper but used respiratory protection that was unsuitable for exposure to high concentrations of toxic gas. Both individuals died from methyl bromide poisoning. The investigation highlighted the helper's underestimation of the hazard despite having received brief training, as well as the inadequacy of the respiratory protection used during the rescue attempt (Komite Nasional Keselamatan Transportasi, 2022). These circumstances represent two distinct safety concerns: human understanding and decision-making in a hazardous environment, and the suitability of protective equipment for the exposure involved. Accordingly, the case was classified under human and technical factors.

The Mutiara Timur I investigation illustrates how hazardous cargo characteristics, human awareness, operational procedures, and organizational arrangements can interact in a maritime accident. KNKT identified contributing conditions associated with the carriage of 50% hydrogen peroxide in a truck, insufficient awareness among the ship's crew of the hazards and characteristics of the cargo, the absence of a detection and inspection system for dangerous goods transported by road vehicles on passenger ro-ro vessels, and inadequate understanding of dangerous goods handling among freight forwarding companies (Komite Nasional Keselamatan Transportasi, 2026b). These conditions indicate that the accident was not limited to the chemical properties of the cargo itself but also involved human knowledge, operational controls, and organizational preparedness for the transportation of hazardous materials. The case was consequently classified under technical, operational, human, and organizational or management factors.

Operational and organizational conditions were particularly evident in cases involving port activities. In the Kurnia Jaya investigation, KNKT identified three formal contributing conditions: the fire occurred on a fishing vessel within a group of mutually moored vessels; the shallow port basin made it difficult to move other vessels away from the fire; and supervision of activities on fishing vessels in the port was weak (Komite Nasional Keselamatan Transportasi, 2023a). The investigation also documented broader conditions, including inadequate firefighting facilities, a number of fishing vessels exceeding the port's original design capacity, and activities such as welding or repairs taking place outside periods of effective supervision (Komite Nasional Keselamatan Transportasi, 2023a). These conditions illustrate how port characteristics, vessel arrangements, and supervision can affect the ability to contain a fire and limit its consequences. In the analytical coding, the case was classified under operational, organizational or management, and environmental factors.

The Trisila Bhakti II–Gerbang Samudera 2 collision also demonstrates the relevance of human, operational, and environmental conditions. Both vessels were manoeuvring to leave their respective berths within a relatively short time interval. During the manoeuvre, the northward current affected the movement of Gerbang Samudera 2 by pushing the vessel towards the MB1 berth. Communication between the two vessels was also ineffective, as the radio call from Trisila Bhakti II received no response from Gerbang Samudera 2. As the distance between the vessels decreased, both masters made manoeuvring decisions in an attempt to avoid contact, but the

available space and timing limited their options. These circumstances indicate that the collision involved operational coordination, human actions and decision-making, and environmental conditions during manoeuvring in a confined port area (Komite Nasional Keselamatan Transportasi, 2023d). The investigation's recommendations concerning communication with the Local Port Service and other vessels, as well as procedures for vessel departures and berthing, further emphasize the importance of coordination and traffic management in confined port environments.

The Ladang Pertiwi 02 investigation identified an interaction between technical deficiencies and operational conditions. KNKT identified four contributing factors: engine failure that caused the vessel to lose propulsion; the design of the engine-room ventilation openings without watertight closures, which allowed seawater to enter the engine room; the use of a fishing vessel to transport passengers and cargo despite limitations in safety equipment; and the inability of portable suction pumps to operate optimally in reducing incoming seawater (Komite Nasional Keselamatan Transportasi, 2025c). These factors indicate that the sinking involved vessel-related technical conditions, including machinery, ventilation, and pumping arrangements, as well as operational limitations associated with the vessel's use for passenger and cargo transportation. The case was therefore classified under technical and operational factors.

The Royce I investigation highlights the role of human and operational factors in the detection and response to an onboard fire. KNKT identified two contributing factors: the initial outbreak of fire in Bus A was not detected by the crew, and the fire inside the bus could not be extinguished effectively (Komite Nasional Keselamatan Transportasi, 2025d). The investigation findings also described the initial use of foam fire extinguishers and the activation of the sprinkler system. However, the crew did not use firefighting clothing and hydrants for further firefighting efforts. These findings indicate limitations in early fire detection and the effectiveness of the onboard firefighting response. Within this study's analytical framework, the case was classified under human and operational factors.

The Tunu Pratama Jaya investigation provides a particularly clear example of an accident involving several interacting conditions. KNKT identified four formal contributing factors: excessive loading that caused an overdraft condition and allowed water to enter the vehicle deck through the freeing port; the accumulation of water on the vehicle deck and in the engine room; vehicle movement that increased the vessel's heel; and rolling resonance arising from the similarity between the vessel's natural rolling period and the incident wave period (Komite Nasional Keselamatan Transportasi, 2023b). These factors involve vessel loading and stability, operational practices, cargo movement, and environmental interaction. The case was therefore classified under technical, operational, and environmental factors.

The investigation further documented how these conditions developed into a sequence that progressively reduced the vessel's stability. The vessel departed with very low freeboard, allowing water to enter the vehicle deck as wave conditions increased. Water subsequently accumulated on the deck and entered the engine room, while vehicles shifted because they were not effectively restrained. The resulting increase in heel caused further vehicle movement, shifting the vessel's centre of gravity and reducing its stability. This sequence illustrates how loading condition, water ingress, cargo movement, and wave interaction can reinforce one another and progressively reduce a vessel's safety margin.

The Kurnia Jaya and Tunu Pratama Jaya cases offer complementary examples of accident development involving interacting conditions. In Kurnia Jaya, port characteristics, vessel mooring arrangements, supervision, and firefighting preparedness influenced the ability to control the spread of fire. In Tunu Pratama Jaya, loading condition, freeboard, water ingress, vehicle movement, and wave interaction contributed to a sequence leading to loss of stability. Both cases demonstrate that accident development may involve interacting conditions rather than a single isolated failure.

These case-level observations are consistent with international research indicating that maritime accidents are associated with interconnected risk-influencing factors rather than a single independent cause (Jiang et al., 2024; Zhou et al., 2024). Research on human factors has likewise shown that their contribution may vary according to accident type and scenario (Ma et al., 2024). Data-driven risk studies have also demonstrated that maritime accident outcomes can

be associated with combinations of operational, environmental, and vessel-related conditions (Cao et al., 2025; Kaptan & Bayazit, 2024).

An important distinction emerging from the analysis is that accident category and accident mechanism are not interchangeable. The 17 fire cases should not be regarded as a homogeneous group merely because they share the same classification. The Final Reports describe different mechanisms, including hazardous fumigation exposure, ignition of combustible materials, machinery-related fire, fuel or oil leakage, accumulated fuel vapour, and insufficient monitoring. Sinking cases may also involve different mechanisms, including structural deterioration, water ingress, stability failure, and loading conditions. Accident-type frequency therefore provides an initial description of the dataset, while the examination of Final Report findings offers a more detailed explanation of the circumstances documented in individual cases.

The distinction between investigation findings and contributing factors is also important for interpreting the coding results. The reports contain both formal contributing factors and broader observations concerning equipment condition, inspection, documentation, operational arrangements, and management practices. The Permata Asia case, for example, distinguishes the formal contributing factor concerning the corroded bilge-well plate from broader findings about inspection and documentation. The analytical coding in this study therefore prioritizes factors explicitly identified by KNKT, while other documented findings are used to explain the circumstances and mechanisms of the accidents. This distinction helps prevent every observation in an investigation report from being treated as an established contributing factor.

The equal representation of technical and operational factors indicates that the investigated accidents cannot be explained solely by technical deficiencies. Although both categories appeared in nine of the 13 Final Reports, human, organizational or management, and environmental factors also appeared in several cases. The distribution suggests that technical conditions may become hazardous within particular operational and organizational contexts. This interpretation is consistent with safety-management perspectives that consider accidents as outcomes of interactions among people, technology, procedures, management, and operating environments rather than failures of individual components alone (Sarıalioğlu et al., 2020; Uflaz et al., 2022).

From a safety-management perspective, preventive measures should be informed by the mechanisms documented in the investigations rather than determined solely by the frequency of accident categories. For fire-related cases, the reports point to issues involving machinery condition, hazardous materials, combustible materials, fire patrols, detection and response arrangements, and port firefighting facilities. For sinking cases, the documented mechanisms draw attention to structural integrity, loading and stability, water ingress, cargo securing, and environmental interaction. Such an approach is consistent with the preventive purpose of marine casualty investigations, which is to identify safety lessons and reduce the likelihood of similar occurrences (International Maritime Organization, 2008).

Taken together, the findings provide a case-based perspective on maritime accident patterns and contributing factors in Indonesia. Previous research has often relied on large international databases to examine statistical relationships and develop data-driven maritime risk models (Jiang et al., 2024; Zhou et al., 2024). The present study complements this work by combining the annual distribution of KNKT-investigated cases over four years with a detailed examination of completed Final Reports. This approach identifies both the accident categories most frequently represented in the database and the technical, operational, human, organizational, and environmental conditions documented in individual investigations.

The present study complements this work by combining the annual distribution of KNKT-investigated cases over four years with a detailed examination of completed Final Reports. This approach identifies both the accident categories most frequently represented in the database and the technical, operational, human, organizational, and environmental conditions documented in individual investigations.

Three principal findings emerge from the analysis. First, fire and sinking accounted for 85.7% of the 35 KNKT-investigated maritime accident cases recorded for occurrence years 2022–2025. Second, the dominant accident category varied over time: fire predominated in the investigated cases in 2023 and 2024, whereas sinking was the most frequent category in 2025.

Third, the analysis of 13 Final Reports identified technical and operational factors as the most frequently represented categories, each appearing in nine reports (69.2%). Human, organizational or management, and environmental factors were also identified in several cases. These findings indicate that frequency analysis alone provides an incomplete account of maritime accident development and that Final Reports offer important case-specific evidence for understanding the circumstances and contributing factors documented in investigated accidents.

CONCLUSION

This study examined maritime accident patterns documented in the KNKT database during the 2022–2025 period and analysed the contributing factors identified in 13 available Final Reports. The analysis of 35 KNKT-investigated cases showed that fire and sinking were the most frequently recorded accident categories, accounting for 17 cases (48.6%) and 13 cases (37.1%), respectively. Together, these two categories represented 85.7% of the cases examined. The annual distribution also revealed variations in accident patterns, with fire predominating in 2023 and 2024, while sinking was the most frequently recorded category in 2025.

The analysis of the 13 Final Reports identified technical and operational factors as the most frequently represented categories, each appearing in nine reports (69.2%). Human factors were identified in five reports (38.5%), while organizational or management factors and environmental factors each appeared in three reports (23.1%). These results demonstrate that maritime accidents documented in the investigated cases involved multiple contributing conditions. Technical deficiencies and operational practices were particularly prominent, but their interaction with human performance, organizational arrangements, and environmental circumstances was also evident in several investigations. The findings therefore suggest that accident prevention requires attention not only to vessel and equipment conditions but also to operational procedures, emergency preparedness, safety management, and the conditions in which maritime activities are conducted.

The findings have practical implications for maritime safety management. Preventive measures should be informed by the specific accident mechanisms documented in investigation reports rather than relying exclusively on accident-frequency statistics. Fire prevention requires attention to machinery maintenance, hazardous cargo management, fire detection, onboard patrols, firefighting procedures, and port safety arrangements. Similarly, the prevention of sinking incidents requires effective control of vessel loading, structural integrity, watertight arrangements, cargo securing, stability, and the effects of environmental conditions. Strengthening these areas may support more comprehensive safety practices among vessel operators, port authorities, and other stakeholders involved in maritime transportation.

Several limitations should be considered when interpreting the findings. First, the 35 cases represent maritime accidents investigated and recorded by KNKT during 2022–2025 and should not be interpreted as a complete record of all maritime accidents occurring in Indonesia. Second, the contributing-factor analysis was limited to 13 available Final Reports, rather than all 35 cases. Consequently, the identified factor distributions describe the reports examined and cannot be generalized to all maritime accidents in Indonesia. Third, the five analytical categories were developed by the researcher to organize the investigation findings and do not constitute an official KNKT classification. The multi-label coding approach also allowed a single report to be assigned to more than one category. Future research could examine a larger number of completed investigation reports, apply independent coding by multiple researchers, and compare KNKT findings with other maritime safety datasets to provide a broader understanding of accident mechanisms and contributing conditions.

Overall, this study provides a case-based account of maritime accident patterns and contributing factors documented in KNKT investigations during 2022–2025. By combining accident-frequency analysis with a detailed examination of completed investigation reports, it highlights the importance of understanding not only which accident categories occur most frequently but also the interacting conditions that contribute to individual accidents. This distinction provides a useful basis for developing more targeted maritime safety strategies and strengthening accident prevention in Indonesia.

ACKNOWLEDGEMENT

The authors would like to thank the Komite Nasional Keselamatan Transportasi (KNKT) for making its maritime accident investigation reports and database publicly accessible, which made this study possible, and Politeknik Pelayaran Sorong for its institutional support during the preparation of this research.

AUTHOR CONTRIBUTION STATEMENT

Dwi Haryanto: conceptualization, data collection, formal analysis, writing – original draft. Ryan Puby Sumarta: methodology, data curation, writing – review and editing. Muji Setiyono: supervision, validation, writing – review and editing. All authors read and approved the final manuscript.

REFERENCES

Aydin, M., Akyuz, E., & Boustras, G. (2024). A holistic safety assessment for cargo holds and decks fire & explosion risks under fuzzy Bayesian network approach. *Safety Science*, *176*(106555). https://doi.org/https://doi.org/10.1016/j.ssci.2024.106555

Cao, Y., Iulia, M., Majumdar, A., Feng, Y., Xin, X., Wang, X., Wang, H., & Yang, Z. (2025). Investigation of the risk influential factors of maritime accidents: A novel topology and robustness analytical framework. *Reliability Engineering and System Safety*, *254*(PB), 110636. https://doi.org/10.1016/j.ress.2024.110636

International Maritime Organization. (2008). *Code of the International Standards and Recommended Practices for a Safety Investigation into a Marine Casualty or Marine Incident (Casualty Investigation Code)*. https://wwwcdn.imo.org/localresources/en/KnowledgeCentre/IndexofIMOResolutions/MSCResolutions/MSC.255(84).pdf

International Maritime Organization. (2024). *Formal Safety Assessment (FSA)*. https://www.imo.org/en/ourwork/safety/pages/formalsafetyassessment.aspx

Jiang, H., Zhang, J., Wan, C., Zhang, M., & Soares, C. G. (2024). A data-driven bayesian network model for risk influencing factors quantification based on global maritime accident database. *Ocean & Coastal Management*, *259*, 107473. https://doi.org/https://doi.org/10.1016/j.ocecoaman.2024.107473

Kaptan, M., & Bayazit, O. (2024). Data-driven Bayesian risk assessment of factors influencing the severity of marine accidents in port areas. *Process Safety and Environmental Protection*, *192*, 1094–1109. https://doi.org/https://doi.org/10.1016/j.psep.2024.10.074

Komite Nasional Keselamatan Transportasi. (2022). *The fatality of fumigation team members on board the China Express at Balikpapan Port, East Kalimantan, Indonesia (Report No. KNKT.22.04.14.03)*. https://knkt.go.id/Repo/Files/Laporan/Pelayaran/2022/KNKT.22,04.14.03-Final-Report.pdf

Komite Nasional Keselamatan Transportasi. (2023a). *Laporan investigasi kecelakaan pelayaran: Kebakaran Kurnia Jaya di Pelabuhan Perikanan Pantai Tegalsari, Jawa Tengah, Republik Indonesia, 14 Agustus 2023 (Report No. KNKT.23.08.05.03)*. https://knkt.go.id/Repo/Files/Laporan/Pelayaran/2023/KNKT.23.08.05.03-Final-Report.pdf

Komite Nasional Keselamatan Transportasi. (2023b). *Laporan investigasi kecelakaan pelayaran: Tenggelamnya Tunu Pratama Jaya (IMO 8749432), Selat Bali, Republik Indonesia, 2 Juli 2025 (Report No. KNKT.25.07.06.03)*. https://knkt.go.id/Repo/Files/Laporan/Pelayaran/2025/KNKT.25.07.06.03-Final-Report.pdf

Komite Nasional Keselamatan Transportasi. (2023c). *Laporan investigasi kecelakaan pelayaran: Terbakarnya ruang penumpang Sabuk Nusantara 91 (IMO 9848065), Pelabuhan Masalembu, Republik Indonesia, 16 September 2022 (Report No. KNKT.22.09.08.03)*. https://knkt.go.id/Repo/Files/Laporan/Pelayaran/2022/KNKT.22.09.08.03-Final-Report.pdf

Komite Nasional Keselamatan Transportasi. (2023d). *Laporan investigasi kecelakaan pelayaran: Tubrukan antara Gerbang Samudera 2 dengan Trisila Bhakti II, Pelabuhan Penyeberangan Ketapang, Banyuwangi, Jawa Timur, 13 Mei 2022 (Report No. KNKT.22.05.03.03)*. https://knkt.go.id/Repo/Files/Laporan/Pelayaran/2022/KNKT.22.05.03.03-Final-Report.pdf

Komite Nasional Keselamatan Transportasi. (2024a). *Laporan investigasi kecelakaan pelayaran: Tenggelamnya kapal Permata Asia, Timur-Laut Pulau Sangiang, Laut Flores, 07 Mei 2022 (Report No. KNKT.22.05.02.03)*. https://knkt.go.id/Repo/Files/Laporan/Pelayaran/2022/KNKT.22.05.02.03-Final-Report.pdf

Komite Nasional Keselamatan Transportasi. (2024b). *Rekapitulasi Investigasi Kecelakaan yang Terjadi Selama Tahun 2023*. 2024. https://knkt.go.id/news/read/rekapitulasi-investigasi-kecelakaan-yang-terjadi-selama-tahun-2023

Komite Nasional Keselamatan Transportasi. (2025a). *Laporan investigasi kecelakaan pelayaran: Kebakaran di kamar mesin LIT Enterprise, Pelabuhan Tanjung Perak, Surabaya, 13 Oktober 2022 (Report No. KNKT.22.10.09.03)*. https://knkt.go.id/Repo/Files/Laporan/Pelayaran/2022/KNKT.22.10.09.03-Final-Report.pdf

Komite Nasional Keselamatan Transportasi. (2025b). *Laporan investigasi kecelakaan pelayaran: Ledakan di Labuan Bajo #1, Perairan Pelabuhan Labuan Bajo, Republik Indonesia, 28 Desember 2023 (Report No. KNKT.23.12.07.03)*. https://knkt.go.id/Repo/Files/Laporan/Pelayaran/2023/KNKT.23.12.07.03-Final-Report.pdf

Komite Nasional Keselamatan Transportasi. (2025c). *Laporan investigasi kecelakaan pelayaran: Tenggelamnya Ladang Pertiwi 02 di Perairan Pulau Pamantauan, Selat Makassar, Sulawesi Selatan, Republik Indonesia, 26 Mei 2022 (Report No. KNKT.22.05.04.03)*. https://knkt.go.id/Repo/Files/Laporan/Pelayaran/2022/KNKT.22.05.04.03-Final-Report.pdf

Komite Nasional Keselamatan Transportasi. (2025d). *Laporan investigasi kecelakaan pelayaran: Terbakarnya kendaraan di Royce I, Selat Sunda, Republik Indonesia, 6 Mei 2023 (Report No. KNKT.23.05.04.03)*. https://knkt.go.id/Repo/Files/Laporan/Pelayaran/2023/KNKT.23.05.04.03-Final-Report.pdf

Komite Nasional Keselamatan Transportasi. (2026a). *Laporan investigasi kecelakaan pelayaran: Kebakaran di kamar mesin Umsini, Pelabuhan Soekarno Hatta, Makassar, Sulawesi Selatan, Republik Indonesia, 9 Juni 2024 (Report No. KNKT.24.06.01.03)*. https://knkt.go.id/Repo/Files/Laporan/Pelayaran/2024/KNKT.24.06.01.03-Final-Report.pdf

Komite Nasional Keselamatan Transportasi. (2026b). *Laporan investigasi kecelakaan pelayaran: Kebakaran kapal Ro-Ro penumpang Mutiara Timur I, Timur Laut Karangasem, Bali, Republik Indonesia, 16 November 2022 (Report No. KNKT.22.11.13.03)*. https://knkt.go.id/Repo/Files/Laporan/Pelayaran/2022/KNKT.22.11.13.03-Final-Report.pdf

Komite Nasional Keselamatan Transportasi. (2026c). *Capaian Kinerja Komite Nasional Keselamatan Transportasi Tahun 2025*. Komite Nasional Keselamatan Transportasi. https://knkt.go.id/news/read/capaian-kinerja-komite-nasional-keselamatan-transportasi-tahun-2025

Komite Nasional Keselamatan Transportasi. (2026d). *Database Investigasi Pelayaran*. Komite Nasional Keselamatan Transportasi. https://dev.knkt.go.id/investigasi/pelayaran

Ma, L., Ma, X., Wang, T., Zhao, Y., & Lan, H. (2024). A data-driven approach to determine the distinct contribution of human factors to different types of maritime accidents. *Ocean Engineering*, *295*, 116874. https://doi.org/https://doi.org/10.1016/j.oceaneng.2024.116874

National Transportation Safety Committee. (2024). *Marine accident investigation report: Grounding of Young Yong (IMO 9194127), Singapore Strait, Republic of Indonesia, 26 October 2022 (Report No. KNKT.22.10.12.03)*.

https://knkt.go.id/Repo/Files/Laporan/Pelayaran/2022/KNKT.22.10.12.03-Final-Report.pdf

Sarıalioğlu, S., Uğurlu, Ö., Aydın, M., Vardar, B., & Wang, J. (2020). A hybrid model for human-factor analysis of engine-room fires on ships: HFACS-PV&FFTA. *Ocean Engineering*, *217*, 107992. https://doi.org/https://doi.org/10.1016/j.oceaneng.2020.107992

Uflaz, E., Akyuz, E., Arslan, O., & Celik, E. (2022). A quantitative effectiveness analysis to improve the safety management system (SMS) implementation on-board ship. *Safety Science*, *156*, 105913. https://doi.org/https://doi.org/10.1016/j.ssci.2022.105913

Zhou, K., Xing, W., Wang, J., Li, H., & Yang, Z. (2024). A data-driven risk model for maritime casualty analysis: A global perspective. *Reliability Engineering and System Safety*, *244*(November 2023), 109925. https://doi.org/10.1016/j.ress.2023.109925