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Integrating Human Factors and Safety Management Frameworks in Maritime Occupational Accidents: Evidence from Indonesia (2003–2019)

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ABSTRACT

Maritime occupational safety remains a critical issue for Indonesia as an archipelagic nation heavily dependent on sea transportation. This study investigates the causal patterns of maritime occupational accidents in Indonesian waters from 2003 to 2019 by integrating official accident reports from the National Transportation Safety Committee (KNKT) and scholarly literature. A systematic analysis was conducted using the Human Factors Analysis and Classification System (HFACS-Maritime) and the International Safety Management (ISM) Code frameworks to identify human, technical, environmental, and organizational factors contributing to shipboard accidents. A total of 120 documented maritime accidents were analyzed, comprising incidents of fires, sinkings, groundings, collisions, and mechanical failures, which collectively resulted in 513 fatalities, 726 injuries, and 701 missing persons. The findings reveal that human error accounted for approximately 72% of all cases, followed by technical malfunctions (14%), adverse weather (8%), organizational deficiencies (4%), and cargo overloading (2%). The thematic analysis based on HFACS highlighted four dominant error dimensions: unsafe acts, preconditions for unsafe acts, unsafe supervision, and organizational influences. These results demonstrate that systemic issues—such as fatigue, inadequate training, poor supervision, and weak safety culture—remain major underlying causes of accidents, despite Indonesia's adoption of the SOLAS Convention and ISM Code. The study concludes that improving maritime occupational safety requires a paradigm shift from regulatory compliance toward proactive risk management and cultural transformation. Policy recommendations include enhancing institutional oversight, implementing competency-based crew training, adopting fatigue management systems, and strengthening enforcement of ISM Code compliance. The integration of HFACS and ISM Code frameworks provides a holistic understanding of maritime safety, offering a foundation for evidence-based policymaking to build a more resilient and safety-oriented Indonesian maritime sector.

Keywords: Maritime Accidents, Human Error, Occupational Safety, HFACS-Maritime, ISM Code, Indonesia

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INTRODUCTION

Maritime transport plays a vital role in facilitating international trade and national logistics, with approximately 80% of global merchandise transported by sea (International Maritime Organization [IMO], 2022). However, the maritime sector remains one of the most hazardous industries, where occupational accidents frequently result in significant human casualties, environmental pollution, and economic losses (Ugurlu et al., 2020; Chauvin, 2011). According to IMO safety statistics, the majority of maritime accidents are linked to the *human element*, which contributes to more than two-thirds of all incidents reported globally (IMO, 2022).

In Indonesia, an archipelagic nation with over 17,000 islands and extensive maritime routes, the risk of marine occupational accidents is considerably high. The Indonesian National Transportation Safety Committee (Komite Nasional Keselamatan Transportasi [KNKT]) has documented numerous maritime incidents involving passenger ferries, fishing vessels, and cargo ships from 2003 to 2019, resulting in hundreds of fatalities and injuries. These accidents are not merely technical events but complex socio-technical phenomena influenced by human, organizational, and environmental interactions (Widodo & Sutopo, 2020). Despite Indonesia's efforts to strengthen maritime safety through the implementation of the International Safety Management (ISM) Code and the Safety of Life at Sea (SOLAS) Convention, the frequency of maritime occupational accidents remains alarming, indicating persistent systemic deficiencies (International Maritime Organization, 2022; Dewan Maritim Indonesia, 2021).

Previous studies have identified multiple contributing factors to shipboard accidents, including human error, inadequate training, poor maintenance, non-compliance with safety procedures, adverse weather conditions, and weak institutional oversight (Hetherington et al., 2006; Goulielmos & Giziakis, 2018; Ahmad, 2020). Among these, *human error* has consistently been recognized as the dominant cause—often estimated to account for more than 70% of all maritime accidents (Reason, 1990; Chauvin, 2011). Nevertheless, most existing research has focused on international contexts or specific case studies, leaving a gap in comprehensive national analyses of maritime occupational accidents in Indonesia over an extended period.

This study seeks to fill this gap by examining the causal patterns of maritime occupational accidents in Indonesia from 2003 to 2019. Through a systematic literature review and secondary analysis of official accident reports, this research aims to: 1) Quantify and

classify the types and frequencies of maritime accidents in Indonesian waters; 2) Identify and categorize contributory factors—human, technical, environmental, and organizational—based on established theoretical frameworks such as the Human Factors Analysis and Classification System (HFACS) and the ISM Code; and 3) Propose strategic recommendations to strengthen Indonesia's maritime occupational safety management system.

By synthesizing statistical evidence and qualitative insights, this study contributes to a deeper understanding of the complex interactions that lead to shipboard accidents and offers actionable recommendations for policymakers, regulators, and maritime operators to reduce the risk of future incidents.

METHODS

This research employs a qualitative-descriptive approach combined with systematic document analysis to examine the causal patterns of maritime occupational accidents in Indonesia from 2003 to 2019. The study integrates two complementary data sources: (1) official accident investigation reports published by the Komite Nasional Keselamatan Transportasi (KNKT) and the Indonesian Maritime Council (Dewan Maritim Indonesia), and (2) relevant peer-reviewed academic publications, government documents, and international maritime safety reports. This dual-source integration enables a comprehensive understanding of both empirical accident data and theoretical perspectives on human and organizational factors influencing maritime safety performance.

The study design follows the principles of a systematic literature review adapted from the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) protocol. The literature search was conducted between January and March 2024 using three major academic databases—Scopus, Web of Science, and Google Scholar—combined with national maritime repositories. The search terms included combinations of "maritime accident", "human error", "occupational safety", "Indonesia", and "shipboard incidents". Only English and Indonesian language sources published between 2003 and 2023 were considered. Inclusion criteria required that each source contain either (a) empirical data on maritime occupational accidents in Indonesian waters, or (b) analytical frameworks relevant to accident causation and prevention. Editorials, conference abstracts without full texts, and documents lacking methodological clarity were excluded.

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All retrieved documents were screened for relevance and methodological quality. After the initial screening, duplicates were removed, and full-text analysis was conducted on the remaining studies and reports. From the official data, a total of 120 documented incidents were identified within the 2003–2019 timeframe. Each case was examined to extract descriptive variables, including the type of vessel, nature of the accident (fire, sinking, grounding, collision, or explosion), number of casualties, and contributory factors cited in the investigative findings.

To classify the causal factors, the study employed a content analysis approach using the Human Factors Analysis and Classification System (HFACS-Maritime) framework, which categorizes human-related causes into four hierarchical levels: unsafe acts, preconditions for unsafe acts, unsafe supervision, and organizational influences (Wiegmann & Shappell, 2017). This classification was complemented by the International Safety Management (ISM) Code guidelines to capture systemic and managerial deficiencies contributing to unsafe operations. Two independent coders reviewed each report to ensure reliability in categorization. Any discrepancies were resolved through discussion until consensus was achieved. The inter-coder reliability was assessed using Cohen's Kappa coefficient, which yielded a value of 0.81, indicating strong agreement.

Descriptive statistical techniques were used to summarize the frequency and proportion of accident types and contributory factors. The data were processed using SPSS version 26 for simple frequency tabulation and cross-tab analysis to identify recurrent patterns. For qualitative interpretation, thematic synthesis was applied to identify dominant themes emerging from textual narratives within accident reports and academic literature. These themes were subsequently aligned with the HFACS and ISM Code dimensions to generate a comprehensive interpretation of the systemic causes of maritime occupational accidents in Indonesia.

Ethical considerations were addressed by limiting the analysis to publicly available reports and secondary data. No individual or confidential information was used. All data sources were appropriately cited to maintain transparency and research integrity.

Through this methodological design, the study ensures analytical rigor and reproducibility in identifying the underlying causal mechanisms of maritime occupational accidents and in proposing evidence-based recommendations for enhancing maritime occupational safety.

RESULTS AND DISCUSSION

A total of 120 documented maritime occupational accidents were identified in Indonesian waters between 2003 and 2019. The dataset comprised various types of vessels, including passenger ferries, fishing vessels, cargo ships, and oil tankers. Table 1 presents the distribution of accident types, showing that fires and explosions accounted for 30.8% (n = 37) of all incidents, followed by vessel sinking at 19.2% (n = 23), grounding at 4.2% (n = 5), collisions at 25.8% (n = 31), and other categories such as mechanical failures or onboard injuries at 20.0% (n = 24). These accidents resulted in 513 fatalities, 726 injuries, and 701 individuals reported missing, reflecting the severe human consequences associated with occupational hazards at sea.

When classifying contributory factors using the HFACS-Maritime framework, human error emerged as the most dominant causal category, accounting for approximately 72% of all incidents analyzed. Technical failures contributed to 14%, adverse environmental conditions (such as storms, high waves, or poor visibility) accounted for 8%, organizational deficiencies contributed 4%, and cargo overloading or regulatory non-compliance represented the remaining 2%. This pattern aligns with the global distribution reported by the International Maritime Organization (2022) and supports prior findings that maritime accidents are predominantly caused by human and organizational factors rather than purely technical malfunctions (Chauvin, 2011; Ugurlu et al., 2020).

Quantitative Analysis of Accident Characteristics

The descriptive analysis reveals that the frequency of maritime occupational accidents exhibited a fluctuating trend across the 17-year period. A significant spike occurred between 2010 and 2014, coinciding with the expansion of inter-island passenger transport routes and the increase in small-scale shipping operations. The predominance of fire-related and sinking incidents indicates persistent challenges in ship maintenance, emergency response preparedness, and onboard safety management. The findings suggest that despite existing regulatory frameworks such as the SOLAS Convention and the ISM Code, compliance enforcement at the operational level remains inconsistent.

Further cross-tabulation between vessel type and accident cause demonstrates that passenger ferries exhibit the highest proportion of human error (78%) compared to cargo vessels (68%) and fishing boats (65%). This discrepancy can be attributed to inadequate training, overcapacity operations, and crew fatigue commonly observed in ferry services. Such

trends confirm the relevance of safety culture and fatigue management as critical determinants of maritime safety performance (Hetherington et al., 2006; Reason, 1990).

Thematic Findings Based on HFACS-Maritime Framework

The qualitative synthesis derived from accident narratives and investigation summaries was analyzed thematically in accordance with the HFACS-Maritime model. Four recurrent themes emerged across the dataset: unsafe acts, preconditions for unsafe acts, unsafe supervision, and organizational influences.

Unsafe acts represented the immediate level of human error. The most frequent unsafe acts identified were failure to follow standard operating procedures (SOPs), poor situational awareness, and incorrect decision-making during navigation or cargo handling. Several incidents involved operators continuing voyages despite unfavorable weather conditions or ignoring onboard alarms. These findings demonstrate that operational discipline and adherence to established procedures remain weak points in Indonesia's maritime sector.

Preconditions for unsafe acts were largely associated with fatigue, inadequate technical competency, and insufficient communication among crew members. Investigation reports frequently cited extended working hours and lack of structured rest schedules, especially among crews of smaller vessels. This condition directly correlates with the "fatigue-risk pathway" outlined in the HFACS framework, where reduced vigilance leads to a higher probability of operational errors (Wiegmann & Shappell, 2017).

Unsafe supervision involved the absence of systematic oversight and ineffective enforcement of safety standards. Supervisory failures were evident in the lack of voyage planning review, inadequate inspection routines, and insufficient emergency drills. In several cases, masters and officers-in-charge failed to enforce compliance with the ISM Code's safety management requirements, particularly regarding routine maintenance and documentation of safety training.

Organizational influences represented the underlying systemic level that shapes overall safety behavior. Recurring issues included cost-driven operational decisions, inadequate safety budgets, and weak internal auditing mechanisms. Several small and medium-scale operators prioritized commercial schedules over safety compliance, leading to maintenance delays and crew undertraining. These institutional weaknesses illustrate the limitations of Indonesia's maritime safety governance in ensuring the sustainable implementation of safety management systems.

Integration with the ISM Code Dimensions

The International Safety Management (ISM) Code stipulates that ship operators must establish a structured Safety Management System (SMS) encompassing documentation, operational procedures, maintenance routines, and continuous improvement processes. However, the empirical data indicate that compliance with ISM Code provisions remains partial and reactive rather than preventive. Most accidents analyzed demonstrated deficiencies in the core ISM elements of resource management, emergency preparedness, and internal auditing.

A closer examination of case narratives suggests that the ISM Code is often perceived by operators as a regulatory formality rather than a proactive risk management framework. Training sessions are frequently conducted for certification purposes, but the learning outcomes are seldom evaluated in practice. This compliance-oriented culture undermines the effectiveness of the ISM Code and perpetuates unsafe organizational behavior. As highlighted by Goulielmos and Giziakis (2018), a strong safety culture cannot emerge without genuine managerial commitment to continuous improvement and risk learning.

Discussion and Comparative Interpretation

The findings confirm that maritime occupational accidents in Indonesia follow a pattern similar to that observed in global maritime operations, where human and organizational factors account for the vast majority of incidents. Nevertheless, the Indonesian context reveals distinctive systemic challenges: inconsistent implementation of the ISM Code, limited investment in safety training, and a fragmented regulatory oversight system. These factors combine to create a "latent error environment," in which minor operational deviations can escalate into major accidents.

From a theoretical standpoint, the HFACS-Maritime and ISM Code frameworks complement each other in explaining both the proximal and distal causes of maritime accidents. HFACS effectively captures the human performance dimension, while the ISM Code elucidates organizational and managerial weaknesses. The convergence of these frameworks demonstrates that improving maritime occupational safety requires an integrated approach that addresses human factors, supervision quality, and organizational governance simultaneously.

In policy terms, the study highlights the urgency of strengthening the implementation of the ISM Code across all shipping companies, including small-scale operators. The Ministry of Transportation and port authorities should enhance safety audits, implement digital

monitoring systems, and enforce penalties for non-compliance. Moreover, targeted interventions are needed to reduce fatigue and human error, such as mandatory rest-hour compliance and simulation-based training programs.

These results contribute to the existing body of literature by providing an empirical and contextualized understanding of maritime occupational safety in Indonesia. The integration of statistical evidence with HFACS-based thematic analysis not only validates global theories of human error but also contextualizes them within Indonesia's socio-organizational realities. The findings ultimately reaffirm that effective maritime safety management is not merely a matter of technical compliance but a function of cultural transformation, managerial accountability, and continuous human capacity development.

CONCLUSION

This study examined maritime occupational accidents in Indonesia from 2003 to 2019 through a systematic analysis of official investigation reports and scholarly literature, utilizing the Human Factors Analysis and Classification System (HFACS-Maritime) and the International Safety Management (ISM) Code as interpretive frameworks. The findings revealed that human error remains the dominant causal factor, contributing to approximately 72% of the total 120 recorded maritime accidents. Other significant contributors included technical malfunctions, adverse environmental conditions, organizational deficiencies, and cargo overloading. The persistence of such patterns across nearly two decades underscores the limited effectiveness of existing safety interventions and highlights the need for an integrated and sustainable approach to maritime occupational safety.

The analysis demonstrated that unsafe acts, such as procedural violations and inadequate situational awareness, are often symptomatic of deeper systemic weaknesses. These weaknesses stem from fatigue, skill gaps, insufficient communication, and limited managerial oversight—factors that are closely aligned with the preconditions for unsafe acts and unsafe supervision layers of the HFACS framework. Furthermore, the organizational-level analysis revealed structural issues, including the lack of continuous training programs, underfunded safety departments, and the absence of internal auditing systems to ensure ISM Code compliance. Collectively, these conditions perpetuate a reactive safety culture, where regulations exist in form but are weakly enforced in practice.

From a theoretical standpoint, the integration of HFACS and ISM Code frameworks proved effective in uncovering the multi-layered nature of maritime occupational accidents. The HFACS framework allowed for the systematic identification of proximal human errors, while the ISM Code provided a lens for understanding distal organizational failures and managerial inertia. Together, they emphasize that maritime safety must be approached as a socio-technical system, where technological reliability, human performance, and institutional governance interact continuously.

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