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Determination of Ship Accident Risk in Indonesia: Contribution of Crew Member Competence and Job Stress Through Safety Culture Moderated by Communication Effectivity and Supervision

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***Abstract*—** Indonesia, as the largest archipelagic nation, continues to face high rates of maritime accidents despite compliance with international conventions such as SOLAS, STCW, and the ISM Code. Human factors remain the dominant cause of casualties. This study investigates the role of crew competence and job stress in shaping safety culture, with communication effectiveness and supervision as moderators, and their collective impact on ship accident risk. Using accident data from KNKT (2020–2025) and a quantitative survey of Indonesian seafarers, Partial Least Squares–Structural Equation Modelling (PLS-SEM) was applied to test direct, indirect, and moderating effects. Results confirm that competence enhances safety culture, job stress weakens it, communication strengthens competence–culture links, supervision reinforces culture–risk reduction, and safety culture significantly lowers accident risk. The study contributes theoretically by integrating HFACS-Maritime and safety culture perspectives into a comprehensive framework tailored to Indonesia, and practically by offering evidence-based recommendations for regulators and shipping companies to prioritize training, stress management, communication systems, and supervisory practices.

Keywords—crew performance, human error, maritime safety management, risk perception, safety behavior

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I. INTRODUCTION

Indonesia, as the world's largest archipelagic state with more than 17,000 islands, relies heavily on maritime transport for passenger mobility and cargo distribution. The continuous growth in fleet capacity and cargo throughput has made shipping a vital component of national logistics and economic development [10,11]. However, accident reports from the National Transportation Safety Committee (KNKT) and the International Maritime Organization (IMO) reveal that serious incidents such as fires, sinkings, and collisions continue to occur [2,8]. Between 2020 and 2024, KNKT investigated 57 marine accidents, resulting in 678 casualties [2]. KNKT's 2025 performance report further confirms that human factors remain the dominant cause of accidents [8,9].

International studies consistently indicate that 70–80% of marine accidents are associated with human error [4,5, 20]. An integrative study of Indonesian maritime occupational accidents found that 72% of 120 analysed cases involved human error [6]. Despite the implementation of international conventions such as SOLAS, STCW, and the ISM Code, accident rates remain high, suggesting that compliance alone is insufficient to reduce risk [1].

Existing research has examined crew competence, communication, supervision, and stress as determinants of safety behaviour [3,14]. However, most studies treat these variables in isolation, without integrating them into a comprehensive framework that explains accident risk in Indonesian domestic shipping. Furthermore, the moderating roles of communication effectiveness and supervision remain underexplored in the Indonesian context, where multilingual crews, uneven training standards, and diverse supervisory practices complicate safety management [16, 22, 23]. This gap limits the ability of policymakers and shipping companies to design targeted interventions that address the root causes of accidents.

This study introduces a multidimensional structural model that integrates crew competence and job stress with safety culture as a mediating variable, while incorporating communication effectiveness and supervision as moderators. The novelty lies in:

1. Integration of accident data and crew perception surveys—combining KNKT accident reports with quantitative data from Indonesian seafarers [2,6,20].
2. Contextualization for archipelagic shipping—tailoring the model to Indonesia's unique maritime environment, where inter-island ferries and cargo vessels face distinct operational challenges [24].

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3. Empirical testing of moderating effects—examining how communication and supervision strengthen or weaken the relationship between safety culture and accident risk, an area rarely addressed in Indonesian maritime safety research [22,23].

This study aims to:

1. Analyse the direct effects of crew member competence (X1) and job stress (X2) on safety culture (Z).
2. Examine the mediating role of safety culture (Z) in reducing ship accident risk (Y).
3. Investigate the moderating effects of communication effectiveness (M1) and supervision (M2) on the relationship between safety culture and ship accident risk.
4. Provide empirical evidence from Indonesian domestic shipping to strengthen maritime safety management frameworks.

Academically, the study enriches maritime safety literature by integrating human factors into a comprehensive conceptual model [7,16,17,18]. Practically, the results will inform policymakers, shipping companies, and training institutions in designing competence-based training, stress management programs, communication systems, and supervisory practices that foster a proactive safety culture, ultimately reducing accident risks in Indonesian waters [21,22,23,24].

II. METHOD

Indonesia, as the largest archipelagic country, depends heavily on maritime transport for both passenger mobility and cargo distribution [10,11]. KNKT reported 57 shipping accidents between 2020–2024, resulting in 678 casualties [2]. Despite international conventions such as STCW and ISM Code [1], accident rates remain high, with human factors consistently identified as the dominant cause [8,9]. This indicates that regulatory compliance alone is insufficient, and deeper analysis of human factors is required to reduce accident risk.

Globally, human error accounts for 70–80% of maritime accidents [4,15,16]. In Indonesia, Fitrianggraeni and Avianti [6] found that 72% of occupational accidents were linked to human error. Stress, fatigue, poor communication, and inadequate supervision are recurring contributors [14]. The Human Factors Analysis and Classification System (HFACS) has been widely applied in aviation and maritime contexts to categorize unsafe acts, but its integration with safety culture perspectives in Indonesian shipping remains limited.

Competence encompasses knowledge, technical skills, discipline, and professional attitudes. Chandra et al. [3] emphasized competence as a determinant of seafarers' safety behaviour, while Celik et al. [13] highlighted maritime English competence as essential for operational safety, particularly in multinational crews. Kim, Park, Lee [12] further showed that individual characteristics perceived collision risk, while Kim [5] explained how competence deficiencies contribute to human error in collision encounters. Inadequate competence leads to misinterpretation of procedures, poor decision-making, and increased accident probability. Flin et al. [17] identified competence as a foundation for safety climate, and Ship Crew Behavior [18] linked competence directly to safety culture outcomes. For Indonesia, where domestic crews often face uneven training standards, competence is a critical determinant of safety culture.

Job stress arises from workload, pressure, and fatigue. Oldenburg and Jensen [14] showed that stress levels vary across occupational groups, influencing safety outcomes. Anderson et al. [21] further confirmed that fatigue undermines safety culture in shipping operations, while Kim [5] explained how stress contributes to human error in collision encounters. Kim, Park, and Lee [12] highlighted that individual characteristics interact with stress to shape perceived risk, and Zhou et al. [20] identified stress as a recurring contributor in their systematic review of human factors in maritime accidents. Stress impairs cognitive performance, reduces situational awareness, and increases accident probability. In Indonesian domestic shipping, long inter-island voyages, irregular work-rest schedules, and high passenger demands exacerbate stress, making it a significant risk factor for safety culture deterioration.

Safety culture reflects shared values, attitudes, and adherence to procedures. Xi et al. [7] demonstrated that safety culture significantly affects deck officers' safety behaviour, while Flin et al. [16], [17] identified safety climate as a predictor of organizational safety performance. Ship Crew Behaviour [18] further linked safety culture directly to operational outcomes in maritime organizations. A strong safety culture encourages proactive risk management, whereas a weak culture tolerates unsafe practices. In Indonesia, where compliance with international codes is often formal rather than substantive, strengthening safety culture is pivotal to reducing accident risk [24].

Effective communication ensures clarity, reduces misinterpretation, and enhances coordination. Choudhury and Chatterjee [4] noted that communication failures are a major source of maritime risk, while Slovic [19] emphasized that risk perception is strongly influenced by communication quality. Rahman et al. [22] highlighted communication breakdowns in Southeast Asian maritime accidents, underscoring the relevance for Indonesia's multilingual crews. Kim, Park, and Lee [12] also showed that individual characteristics interact with communication effectiveness in shaping safety behaviour, while Zhou et al. [20] identified communication as a recurring human factor in their systematic review of maritime accidents. In Indonesian shipping, multilingual crews and hierarchical communication structures often hinder effective dialogue, increasing the likelihood of errors. Communication effectiveness is therefore hypothesized to moderate the relationship between competence and safety culture.

Supervision involves monitoring, evaluation, and guidance. Strong supervisory practices reinforce safety culture and reduce unsafe acts [3]. Wiegmann and

Shappell [16] argued that supervision is a critical moderating factor in accident prevention. In Indonesia, supervisory practices vary widely across companies, with some emphasizing compliance checks while others lack systematic monitoring. Effective supervision is expected to moderate the relationship between safety culture and accident risk.

Synthesizing the literature, this study proposes the conceptual model illustrated in Figure 1. The hypotheses are:

- H1: Crew member competence (X1) positively influences safety culture (Z).
- H2: Job stress (X2) negatively influences safety culture (Z).
- H3: Communication effectiveness (M1) moderates the relationship between competence (X1) and safety culture (Z).
- H4: Supervision (M2) moderates the relationship between safety culture (Z) and ship accident risk (Y).
- H5: Safety culture (Z) negatively influences ship accident risk (Y).

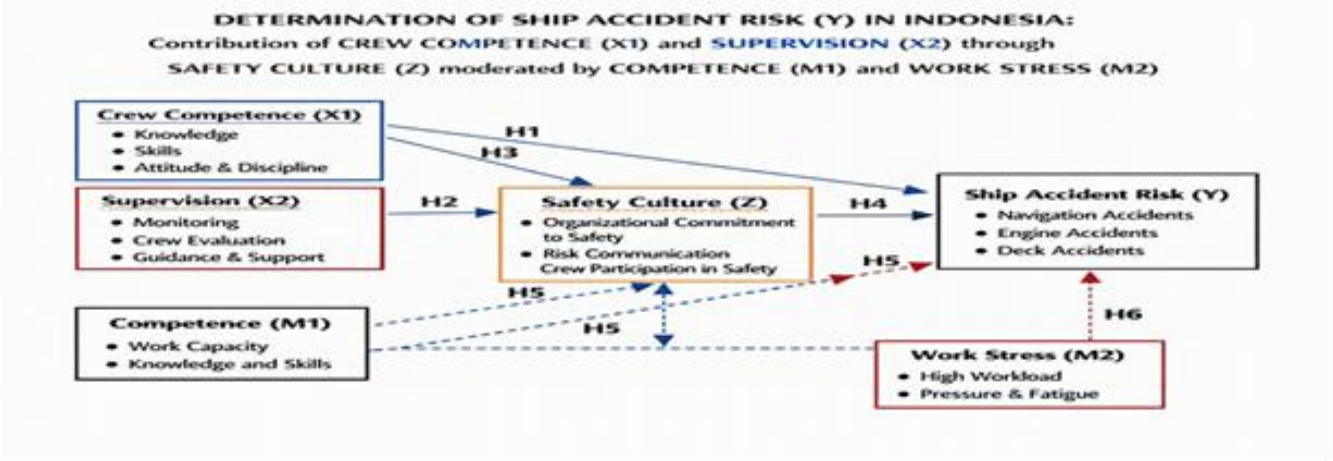

Figure 1. Conceptual Model of Human Factor Based Ship Accident Risk in Indonesian Shipping

Explanation of Figure 1**:** The conceptual model illustrates the determinants of ship accident risk (Y) in Indonesia's maritime sector. It integrates human factors (crew competence and supervision), organizational factors (safety culture), and psychological factors (work stress) to explain how these variables interact to influence accident risk. The model adopts a moderated mediation structure, where Competence (M1) and Work Stress (M2) act as moderators that shape the strength of relationships between safety culture and accident risk.

Direct Effects

- Crew Competence (X1) → Ship Accident Risk (Y) [H1] Competence directly affects accident risk through the crew's ability to perform tasks safely and efficiently. Higher competence reduces operational errors and enhances situational awareness.
- Supervision (X2) → Safety Culture (Z) [H2] Effective supervision fosters a strong safety culture by ensuring compliance, providing feedback, and reinforcing safety values among crew members.
- Crew Competence (X1) → Safety Culture (Z) [H3] Competent crew members contribute positively to safety culture by demonstrating safe behaviors and influencing peers through knowledge and discipline.
- Safety Culture (Z) → Ship Accident Risk (Y) [H4] A robust safety culture minimizes accident risk by promoting adherence to safety procedures, proactive hazard identification, and collective responsibility for safety.

Moderating Effects

- Competence (M1) and Work Stress (M2) → Moderation on Z → Y [H5] These variables moderate the relationship between safety culture and accident risk.
- When competence (M1) is high, the positive impact of safety culture on reducing accident risk becomes stronger.
- When work stress (M2) is high, the protective effect of safety culture weakens, as stress undermines attention and decision-making.

Additional Relationships

- Work Stress (M2) → Ship Accident Risk (Y) [H6] High stress levels increase accident risk by impairing concentration, reaction time, and communication effectiveness.
- Competence (M1) → Safety Culture (Z) [H7] Competence enhances safety culture by enabling crew members to internalize safety values and apply them consistently in operations.

Figure 2 further illustrates the conceptual framework of human-factor-based ship accident risk in Indonesian shipping. The model integrates crew member competence (X1) and job stress (X2) as predictors of safety culture (Z), moderated by communication effectiveness (M1) and supervision (M2), which collectively influence ship accident risk (Y). This framework emphasizes the interaction of individual and organizational factors in shaping maritime safety outcomes. This study adopts a quantitative explanatory design using Structural Equation Modelling (SEM) to test the relationships among competence, job stress,

safety culture, communication effectivity, supervision, and ship accident risk. The conceptual framework was developed based on previous studies [3,4,6,7,13,14]. The population
consists of Indonesian domestic shipping crew members. A purposive sampling technique was applied, targeting officers and crew with at least two years of sailing experience. The minimum sample size was determined using SEM requirements (≥200 respondents) [15]. Data were collected through structured questionnaires distributed to shipping companies in Merak, Bali, and Batam. The questionnaire items were adapted from validated scales on competence [3], job stress [14], safety culture [7,16], communication [13], and supervision [4].

Figure 2. Reducing Ship Accident Risk in Indonesia

III. Results and Discussion

The results of this study confirm that crew competence, job stress, communication effectiveness, and supervision collectively shape safety culture, which in turn reduces ship accident risk. While these findings align with international literature, their implications in the Indonesian archipelagic context reveal several unique insights and contributions.

Crew Competence and Safety Culture

The confirmation of H1 demonstrates that competence significantly enhances safety culture. This supports Chandra et al. [3] and Celik et al. [13], who emphasized knowledge, skills, and discipline as determinants of safety behavior. However, the novelty of this study lies in showing that competence is not only a direct determinant of safety culture but also interacts with communication effectiveness. In Indonesia, where multilingual crews and uneven training standards are common, competence alone is insufficient unless reinforced by effective communication systems. This highlights the need for integrated training programs that combine technical competence with communication skills.

Job Stress and Safety Culture

The support for **H2** confirms that job stress negatively affects safety culture. High workload and fatigue reduce compliance with safety procedures, consistent with Oldenburg and Jensen [14]. The novelty here is the contextualization: Indonesian domestic shipping crews often face long inter-island voyages, irregular schedules, and high passenger demands, which exacerbate stress levels. Unlike international fleets with stricter work-rest regulations, Indonesian crews operate under conditions that amplify fatigue-related risks. This finding underscores the urgent need for stress management and fatigue monitoring programs tailored to domestic shipping operations.

Communication Effectiveness as a Moderator

The confirmation of H3 shows that communication effectiveness strengthens the relationship between competence and safety culture. This finding extends the work of Choudhury and Chatterjee [4] and Slovic [19] by demonstrating that communication is not merely a direct factor but a moderator that amplifies the impact of competence. The novelty lies in identifying communication as a lever for maximizing competence outcomes. In practice, even highly competent crews may fail to uphold safety culture if communication systems are weak. This is particularly relevant in Indonesia, where crews often operate with mixed linguistic backgrounds and hierarchical communication structures.

Supervision as a Moderator

The support for H4 confirms that supervision positively moderates the relationship between safety culture and accident risk. This aligns with Wiegmann and Shappell [16], but the novelty lies in demonstrating that supervision is a critical reinforcement mechanism in the Indonesian context. Supervisory practices vary widely across domestic shipping companies, with some emphasizing compliance checks while others lack systematic monitoring. This study shows that strong supervision not only enforces safety procedures but also strengthens the protective role of safety culture against accidents.

Safety Culture as a Pivotal Variable

The confirmation of H5 establishes safety culture as the pivotal variable in reducing ship accident risk. This finding corroborates Xi et al. [7] and Flin et al. [16], but the novelty lies in integrating safety culture into a comprehensive human-factor-based framework tailored to Indonesia. By combining accident data from KNKT with crew perception surveys, this study bridges empirical evidence and theoretical models, offering a holistic explanation of accident risk.

Practical Implications and Novel Contributions

The novelty of this study can be summarized in three dimensions:

1. Integration of Variables: Unlike previous studies that examined competence, stress, communication, or supervision in isolation, this study integrates them into a single SEM-tested model.
2. Contextualization for Indonesia: The study highlights unique challenges in Indonesian domestic shipping, such as multilingual crews, uneven training standards, and irregular work-rest schedules.
3. Moderating Effects: By empirically testing communication and supervision as moderators, the study advances maritime safety literature and provides actionable insights for policymakers and shipping companies.

Policy Recommendations:

- Enhance crew competence through continuous training and certification programs.
- Implement stress management and fatigue monitoring systems tailored to inter-island operations.
- Develop multilingual communication protocols and onboard systems to reduce misinterpretation.
- Strengthen supervisory practices by standardizing monitoring, evaluation, and guidance across shipping companies.

IV. CONCLUSION

This study examined the determinants of ship accident risk in Indonesian shipping by integrating crew member competence, job stress, safety culture, communication effectivity, and supervision into a structural model. The results confirm that:

1. Crew member competence (X1) significantly enhances safety culture (Z), supporting the notion that knowledge, skills, and discipline are critical for safe operations.
2. Job stress (X2) negatively affects safety culture, indicating that high workload and fatigue reduce compliance with safety procedures.
3. Communication effectivity (M1) moderates the relationship between competence and safety culture, showing that clear information flow and effective dialogue strengthen safety values.
4. Supervision (M2) moderates the relationship between safety culture and ship accident risk, reinforcing the importance of monitoring and guidance in reducing unsafe acts.
5. Safety culture (Z) plays a pivotal role in reducing ship accident risk (Y), consistent with international findings that safety culture is a cornerstone of maritime safety.

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