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Ship Operation Safety: Study of Human Factors, Fatigue, and Safety Culture

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Abstract: Ship Operational Safety: Human Factors, Fatigue, and Safety Culture is a literature review article. The objective of this article is to formulate hypotheses regarding the relationships between variables to be used in future research. The study draws upon resources from online libraries, Google Scholar, Mendeley, and other academic online platforms. The research methodology employs a library research approach, utilizing e-books and open-access e-journals. The findings of this article address: 1) the influence of Human Factors on Ship Operational Safety; 2) the influence of Fatigue on Ship Operational Safety; and 3) the influence of Safety Culture on Ship Operational Safety.

Keywords: Human Factors, Fatigue, Safety Culture, and Ship Operational Safety

INTRODUCTION

Ship operational safety is a fundamental aspect of maritime transportation, as it directly relates to the protection of human life, the safety of the vessel, the security of the cargo, and the sustainability of shipping operations (Joseph & Dalaklis, 2021). The complexity of the shipboard working environment, the nature of 24-hour operations, dynamic weather and sea conditions, and the need for precise decision-making mean that the safety of vessel operations depends not only on the ship's technical condition but also on human and organizational factors (Adumene et al., 2022). Therefore, enhancing ship operational safety requires an approach that considers the interrelationships between technical, human, and organizational aspects in an integrated manner.

Human factors constitute a crucial component of ship operational safety, as humans play a central role in operation, supervision, maintenance, and decision-making during a voyage (Ma et al., 2022). Competence, experience, communication, coordination, leadership, decision-making, and the crew's ability to respond to both normal and emergency conditions can influence the level of operational safety (Fan & Yang, 2023). Limitations in these aspects can increase the likelihood of human error and ultimately contribute to maritime accidents or incidents. Therefore, a human factors study is necessary to understand how individual characteristics and the work environment interact to influence the behavior and safety performance of ship crew members (Faturachman & Abdurrachman, 2026).

One of the human factors that significantly influences the safety of ship operations is fatigue (Nittari et al., 2022). Shipboard work patterns—involving watch systems, long hours, limited rest, work pressure, and less-than-ideal environmental conditions—can increase the risk of fatigue among crew members. Fatigue can impair alertness, concentration, cognitive abilities, response times, and the quality of decision-making. This situation becomes particularly critical when crew members must perform tasks requiring a high level of attention, such as navigation, vessel maneuvering, machinery monitoring, cargo handling, and emergency response (Rüpke & Athanassiou, 2024). Therefore, fatigue management is a crucial component of efforts to maintain human performance and prevent operational errors.

In addition to human factors and fatigue, the safety of ship operations is also influenced by the safety culture that develops within a shipping organization. Safety culture reflects the values, attitudes, beliefs, perceptions, and behaviors that indicate the extent to which safety is viewed as a priority in the execution of operational activities (Xi et al., 2025). A strong safety culture can foster adherence to procedures, open safety communication, the reporting of unsafe conditions, and learning from incidents, as well as commitment to safety from both management and the crew. Conversely, a weak safety culture can lead to safety procedures being disregarded, unsafe work practices becoming habitual, and operational risks not being adequately addressed (Teperi et al., 2019).

Human factors, fatigue, and safety culture are basically interrelated aspects in shaping the safety of ship operations. Human factors can determine how crew members carry out their duties and make decisions, while fatigue can influence the physical and cognitive conditions required to carry out these duties (Rajapakse & Emad, 2025). At the same time, an organization's safety culture determines how fatigue risks are managed, how safety procedures are implemented, and how crew members are encouraged to adopt safe behaviors. Consequently, the safety of vessel operations cannot be understood by looking at a single factor in isolation; rather, it requires analysis of the interrelationships between individual factors, working conditions, and the organizational environment.

Although various studies have addressed human factors, fatigue, and safety culture within the context of maritime safety, a study that comprehensively integrates these three aspects is still needed (Corrigan et al., 2019). Some studies tend to treat fatigue as an individual issue, human factors as the cause of human error, or safety culture as an organizational characteristic in isolation. However, in ship operations, these three elements can interact and reinforce one another in influencing safety performance. Therefore, there is a need for research that provides a more comprehensive understanding of how human factors, fatigue, and safety culture contribute to the safety of ship operations.

Based on the foregoing, this study aims to examine the roles of human factors, fatigue, and safety culture in supporting the safety of ship operations. This study is expected to make an academic contribution by enhancing the understanding of human and organizational factors in maritime safety, while also offering practical implications for shipping companies to develop strategies for crew management, fatigue control, competency enhancement, and the strengthening of safety culture, thereby achieving safer, more effective, and sustainable ship operations.

Various studies have addressed human factors, fatigue, and safety culture within the context of ship operational safety. However, a study that comprehensively integrates these aspects is still needed to gain a more systematic understanding of the relationship between human factors and ship operational safety. Therefore, this article aims to conduct a Systematic Literature Review (SLR) of prior research regarding the roles of these factors: 1) Do human factors influence ship operational safety? 2) Does fatigue influence ship operational safety? 3) Does safety culture influence ship operational safety? This study is expected to identify key themes, relationships between variables, research gaps, and future research directions for developing strategies to enhance ship operational safety.

METHOD

This literature review article was prepared using library research and Systematic Literature Review (SLR) methods, analyzed qualitatively, drawing on sources from online platforms such as Google Scholar, Scopus, Mendeley, and other academic applications. A Systematic Literature Review (SLR) is defined as a series of steps to identify, evaluate, and interpret all available research evidence to answer specific research questions (Resnawita & Karmanita, 2024).

In qualitative studies, literature research must be conducted consistently with established methodological principles. One reason for undertaking qualitative analysis is the exploratory nature of the research (Safarudin et al., 2023).

RESULTS AND DISCUSSION

Based on the background, objectives, and methods, the results of this article are as follows:

Ship Operational Safety

Ship operational safety refers to the capacity of the vessel, the crew, the shipping company, and the operational systems to manage risks during voyage activities, thereby preventing accidents, incidents, vessel damage, and pollution, as well as harm to people and the environment (Aydin, 2025). This reflects the fact that the safety of vessel operations depends not only on the technical condition and seaworthiness of the vessel but also encompasses crew competence, physical and psychological condition, fatigue, communication, decision-making, adherence to procedures, safety culture, risk management, emergency preparedness, and compliance with maritime safety regulations and standards. Typical indicators of vessel operational safety include adherence to safety procedures, crew competence, vessel seaworthiness, emergency preparedness, and risk management (Xi et al., 2025).

The indicators or dimensions comprising Ship Operational Safety include: 1) Adherence to Safety Procedures: Compliance with SOPs, the ISM Code, checklists, the use of PPE, and safe work procedures; 2) Crew Competence: Knowledge, skills, certification, experience, and the ability to perform duties; 3) Emergency Preparedness: Drills, emergency response, firefighting, abandon-ship procedures, and the ability to handle emergencies; 4) Ship Seaworthiness: Condition of machinery, structure, navigation equipment, LSA/FFA, and ship certificates; 5) Risk Management: Hazard identification, risk assessment, risk control, and monitoring (Xi et al., 2025)

Human Factors

Human factors can be understood as the various elements influencing human behavior in the work environment, encompassing environmental and organizational aspects, job characteristics, as well as individual conditions and characteristics that affect health and safety (Chowdhury et al., 2024). Meanwhile, human error refers to human actions or decisions that do not align with established plans, procedures, rules, or limitations. Typical indicators of human factors include crew competence, fatigue, and safety culture (Faturachman & Abdurrachman, 2026)

The indicators or dimensions comprising the Human Factors variable include: 1) Competence: The knowledge, skills, certifications, experience, and ability of the crew to perform tasks safely; 2) Fatigue: A state of physical and mental exhaustion resulting from long working hours, shift work or watchkeeping, sleep deprivation, and workload; 3) Communication: The ability to convey and receive information clearly, accurately, and effectively, both among crew members and with shore-based personnel (Andrei et al., 2020).

Human factors have been studied by several researchers, including (Hasanain, 2024; Shanty et al. 2020 ; Ma et al. 2022, Brcko et al. 2023, & Pseftelis et al. 2021).

Fatigue

Fatigue is a significant factor that can affect the safety and performance of ship crew members in carrying out maritime operational activities (Fan & Yang, 2024). This indicates that fatigue is not solely related to the physical condition of the crew but can also impair concentration, decision-making ability, alertness, and the response to emergency situations, thereby potentially increasing the risk of human error and maritime accidents. Typical indicators of fatigue include workload, working hours, sleep quality, and psychological condition (Mansyur et al., 2021). The indicators or dimensions comprising the fatigue variable include: 1) Workload: heavy task load, high volume of work, job demands; 2) Working hours: long working hours, overtime, work extending beyond normal hours; 3) Sleep quality: insufficient sleep, interrupted sleep, difficulty obtaining quality sleep; 4) Psychological conditions: work pressure, stress, mental burden, work-family conflict (Staab et al. 2026).

Fatigue has been studied by several researchers, including: (Lützhöft et al., 2011; López-López et al., 2024; Fan & Yang, 2024; Crestelo Moreno et al., 2026 & Crestelo Moreno et al., 2023).

Safety Culture

Safety culture is a key factor determining the behavior, compliance, and commitment of ship crew members regarding the implementation of safety measures during maritime operations (Adikwu et al., 2024). This reflects the fact that safety culture is not merely about understanding safety regulations; it also encompasses management commitment, safety communication, adherence to procedures, and crew involvement in creating a safe working environment. Typical indicators of safety culture include management safety commitment, safety communication, and safety compliance (Barasa et al., 2025).

The indicators or dimensions comprising the safety culture variable are: 1) Management Commitment to Safety: safety priority, resource support, and management attention to safety; 2) Safety Communication: dissemination of hazard information, crew communication, and safety briefings; 3) Adherence to Procedures: compliance with SOPs, the ISM Code, and safety regulations, as well as the use of PPE (Ajmal et al., 2022)

Safety culture has been studied by several researchers, including: (Adikwu et al., 2024; Bairamova, 2025; Ekawati, 2024; & Andrei et al., 2020).

Table 1. Results of Relevant Research

No	Author (Year)	Previous Research Findings	Similarities to This Article	Differences from This Article
1	(Fransiska et al., 2024)	Research findings indicate that the implementation of the Safety Management System is crucial for supporting ship safety and operational efficiency; however, it is not yet optimal due to a lack of understanding and discipline among the crew regarding its execution.	Safety of Ship Operations	Focusing on the implementation of the Safety Management System to support smooth operations

2	(Malik et al., 2025)	Human factors encompassing skills, personnel, stress, and communication significantly impact maritime safety; therefore, they require proper attention and management by shipping companies.	The Influence of Human Factors on Shipping Safety on Ships	The influence of human factors on passenger ship safety
3	(Widarbowo, 2020)	The research results show that the use of crew members' rest time is not optimal due to additional workload and boredom, thereby increasing fatigue, which has the potential to trigger human error and maritime transportation accidents.	Examining crew fatigue as a factor that can affect the safety of vessel operations	Utilization of rest periods, workload, and fatigue (exhaustion) as causes of crew fatigue and their impact on maritime accidents.
4	(Santoso et al., 2020)	The research results indicate that safety culture, safety leadership, and the ISM Code have a positive effect on work safety motivation.	Examining safety culture as a factor influencing ship operational safety	Focuses on safety culture, safety leadership, and the ISM Code on work safety motivation

Source: Processed by the Author

Discussion

Based on the theoretical review, the discussion in this literature review article involves examining relevant articles, evaluating the influence between variables, and conceptually designing the research.

Based on the research findings, the discussion in this article involves reviewing relevant articles:

The Influence of Human Factors Studies on the Safety of Ship Operations

Human factors analysis examines the human elements that influence the performance, behavior, decision-making, and capabilities of ship crew members in safely carrying out their duties during maritime operations.

Human factors assessments influence the safety of ship operations; when conducted accurately and comprehensively, they enhance the accuracy and reliability of operational safety. This can be explained as follows: 1) Crew competence and capabilities: Human factors assessments ensure that the crew's competence, knowledge, skills, experience, and abilities align with the demands of their tasks and operational responsibilities on board; 2) Fatigue and physical/psychological conditions: These assessments consider factors such as fatigue levels, workload, working hours, rest periods, and the physical and psychological states of the crew—all of which can impact concentration, alertness, cognitive ability, and decision-making; 3) Communication, decision-making, and safety behavior: Human factors assessments evaluate the effectiveness of crew communication, decision-making capabilities, situational awareness, adherence to procedures, and crew behavior when managing risks during ship operations; 4) Safety culture and organizational environment: These assessments also encompass safety culture, management commitment, leadership, the reporting of hazards, procedural compliance, and crew involvement in fostering a safe working environment; 5) Human interaction with technology, procedures, and the work environment: Human factors

assessments consider how the crew interacts with navigation equipment, safety systems, work procedures, navigational environmental conditions, and the technology utilized in operations; 6) Prevention of human error and enhancement of operational safety: Analyzing various human factors enables companies and crews to identify potential human errors and implement preventive and risk-control measures, thereby improving the safety and reliability of ship operations.

Factors influencing human factors include: crew competence and experience; fatigue; physical and psychological conditions; communication; decision-making; situational awareness; safety culture; leadership; workload; work environment and operational conditions; and organizational procedures and systems.

Based on a review of the literature and relevant previous studies, it was found that the study of human factors has an impact on the safety of ship operations; this is in line with research conducted by (Shi et al., 2021; Hasanspahić et al., 2021; Wu et al., 2022).

The Influence of Fatigue on Ship Operational Safety

Fatigue is a state of physical and mental exhaustion that can affect alertness, concentration, cognitive abilities, decision-making, reaction times, and the ability of the crew to perform tasks safely during maritime operations.

Fatigue impacts the safety of ship operations; if crew fatigue is identified, controlled, and managed appropriately and comprehensively, the crew's ability to maintain vigilance, make decisions, and perform tasks safely is optimized, thereby enhancing the safety and reliability of ship operations. This can be explained as follows: 1) Enhanced vigilance and concentration: Effective fatigue management helps the crew maintain alertness and concentration while performing duties, particularly during tasks requiring close attention such as navigation, engine monitoring, maneuvering, and cargo handling; 2) Improved decision-making capabilities: Fatigue can impair cognitive function and slow down the decision-making process. Controlling fatigue helps the crew maintain their ability to think, assess situations, and determine appropriate actions when facing operational conditions or emergencies; 3) Improved reaction times and responses to operational conditions: Fatigue can slow down crew responses to changing situations. Proper fatigue management enables the crew to respond more quickly and accurately to potential hazards, changes in sailing conditions, or abnormal situations; 4) Reduced risk of human error: Fatigue increases the likelihood of human error resulting from diminished attention, coordination, vigilance, and cognitive ability. Therefore, controlling fatigue contributes to reducing errors during the execution of ship operational tasks; 5) Enhanced safety in task performance: Crew members who are in a sound physical and mental state are better able to follow work procedures, communicate, coordinate, and perform tasks in accordance with established safety standards; 6) Strengthened ship operational safety: Systematic fatigue management through the regulation of work and rest hours, monitoring of crew condition, workload management, and the implementation of fatigue management procedures creates safer working conditions and supports the continuous improvement of ship operational safety. Faktor-faktor yang mempengaruhi fatigue antara lain: jam kerja dan waktu istirahat, kualitas dan durasi tidur, beban kerja, sistem jaga/shift kerja, dan lingkungan kerja kapal, kondisi fisik dan kesehatan awak kapal, faktor psikologis dan sosial.

Based on a literature review and relevant prior studies, it has been found that fatigue affects the safety of ship operations; this aligns with research conducted by : (Fan & Yang, 2024; Jepsen et al., 2015; & Crestelo Moreno et al., 2026).

The Influence of Safety Culture on Ship Operational Safety

Safety culture encompasses the safety-related values, beliefs, attitudes, behaviors, and practices that develop within an organization, serving as the foundation for all crew members to understand, implement, and prioritize safety while conducting maritime operations.

Safety Culture influences the safety of ship operations; If a safety culture within the organization and on board the ship is built, implemented and developed consistently and comprehensively, then compliance with safety procedures, communication and coordination between crew, awareness of risks, reporting of unsafe conditions and safety behavior will be more optimal, so that the potential for accidents and operational errors can be minimized and the safety of ship operations can be improved and more reliable.

This can be explained as follows: 1) Compliance with safety procedures: Consistent application of safety rules, SOPs and provisions by all crew members in every operational activity; 2) Management commitment to safety: Management support and example in placing safety as a top priority through policies, provision of resources, supervision and evaluation of safety; 3) Communication and safety coordination: Creation of open, effective and coordinated communication between ship crew and between the ship and the company in conveying information, risks and operational conditions; 4) Risk awareness: The crew's ability to recognize dangers, assess risks, and take preventive action before the risk develops into an accident; 5) Reporting unsafe conditions and incidents: The existence of a culture that encourages ship crew to report dangers, near misses, errors, or unsafe conditions without fear of undue punishment; 6) Continuous learning and improvement: The organization's ability to use the results of evaluations, accident investigations, near misses, and operational experience as a basis for improving safety procedures and practices; 7) Crew safety behavior: Implementation of actions and behavior that are in accordance with safety principles in carrying out their duties, including the use of personal protective equipment, implementation of checklists, and compliance with work procedures.

Factors influencing the state of safety culture include management commitment and leadership regarding safety; safety policies and procedures; crew competence and training; safety communication and coordination; risk awareness and perception; reporting and learning from safety incidents; crew involvement and participation; workload and working conditions; safety supervision and evaluation; and reward systems and safety justice.

Based on a literature review and relevant prior studies, it was found that the state of safety culture influences ship operational safety; this aligns with research conducted by: (Andrei et al., 2020; Xi et al., 2025; Mudiyanto et al., 2026; & Putra et al., 2026).

Research Conceptual Framework

Based on the problem formulation, relevant research, and the discussion, the conceptual framework for this article was derived, as shown in Figure 1.

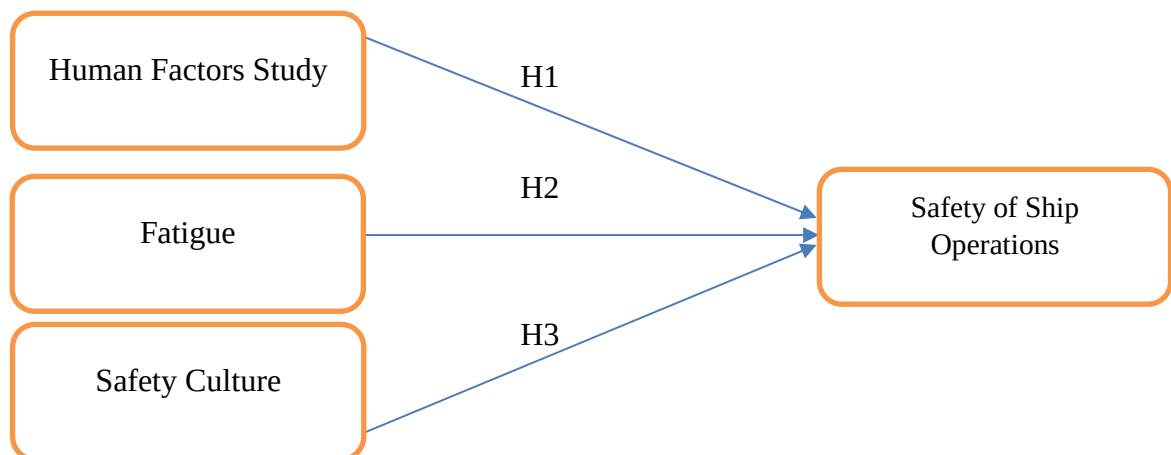


Figure 1: Conceptual Framework

Source: Prepared by the author

Based on the conceptual framework diagram above, the study examines the impact of human factors, fatigue, and safety culture on ship operational safety. Beyond the three exogenous variables influencing Y1, there are numerous other variables, including:

- 1) Leadership : (Fitriyana et al., 2024), (Anggoro, 2022), (Budiyo et al., 2022), (Majid et al., 2024), & (Rini et al., 2018).
- 2) Training and Familiarization : (Chae et al., 2021), (Kuber & Rashedi, 2024), (Mori & Manuel, 2023), & (Mori & Manuel, 2024).
- 3) Condition and Seaworthiness of the Ship : (J. Wu et al., 2023), (Putra Bimantara et al., 2024), (Wahid, 2025), & (Schinas & Metzger, 2023)

CONCLUSION

Based on the objectives, results, and discussion, the conclusion of this article is the formulation of hypotheses for future research, namely:

- 1) Human factors influence ship operational safety;
- 2) Fatigue influences ship operational safety; and
- 3) Safety culture influences ship operational safety.

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