Analysing the Impact of Human Factors on Marine Accidents

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ABSTRACT

Marine accidents remain a significant challenge for the maritime industry, with human factors identified as a leading cause. This study explores the most common human elements contributing to these incidents through descriptive and inferential analysis. Key factors include fatigue, which impairs decision-making; poor communication among crew and between ship and shore; and lack of situational awareness, often exacerbated by distractions or over-reliance on automation. Other critical contributors include inadequate training, decision-making errors, violations of procedures, substance use, and crew coordination issues. The findings underscore the complex interplay between individual behaviors, teamwork, and organizational practices in accident causation. Addressing these human factors through fatigue management, communication protocols, enhanced training, and adherence to safety procedures can significantly reduce risks. This study highlights the need for proactive interventions to improve maritime safety and minimize human error, reinforcing the importance of both organizational responsibility and individual accountability in high-stakes environments.

Keywords: Marine accidents, human factors, fatigue, communication breakdown, training

INTRODUCTION

Marine accidents remain a significant concern for the global maritime industry, with human factors being recognized as one of the most critical contributors to these incidents. Research consistently shows that human error accounts for 75% to 96% of marine accidents, making it a key focus for improving maritime safety (Mellahi & Wilkinson, 2020). Human factors include a wide array of influences, such as cognitive limitations, fatigue, poor communication, and decision-making errors, as well as broader organizational elements like leadership and safety culture (Bhattacharya, 2021). Despite the introduction of advanced navigation systems, automation, and strict regulatory frameworks, these human-related issues persist as major risks in maritime operations.

Human factors are often complex and multifaceted, interacting with environmental and technological variables in unpredictable ways. For example, automation, while designed to reduce human workload, can inadvertently increase risks by fostering over-reliance on systems, reducing vigilance, and contributing to skill degradation (Salmon et al., 2022). In particular, the concept of "automation complacency" suggests that operators may become less engaged and less able to respond effectively in critical situations when automated systems are in use (Kim et al., 2021). Furthermore, fatigue, a longstanding issue in the industry, continues to undermine safe performance, particularly for seafarers subjected to long shifts, irregular sleep patterns, and extended periods at sea (Bailey et al., 2023)

Organizational factors, including safety culture and management practices, are equally important in understanding the role of human factors in marine accidents. The implementation of the International Safety Management (ISM) Code and other regulatory measures has provided a framework for mitigating human error, but compliance and enforcement remain inconsistent across the industry (IMO, 2023). Additionally, poor safety cultures, where communication of safety concerns is discouraged or ignored, further exacerbate the risks of human error (Yildirim et al., 2023). Such cultures can prevent early identification of issues, reducing the ability of crews and management to take corrective actions before an accident occurs. Given the critical role of human factors in marine accidents, there is an urgent need to deepen our understanding of how these factors

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interact with emerging technologies and organizational systems. This research aims to analyze the impact of human factors on marine accidents, with the objectives below to address the research problems of the study.

Identify the most common human factors contributing to marine accidents

LITERATURE REVIEW

Human factors have been identified as critical contributors to the high incidence of marine accidents, with studies estimating that between 75% and 96% of maritime incidents are caused by human error (Bhattacharya, 2021; Mellahi & Wilkinson, 2020). This broad category encompasses cognitive, physical, and organizational aspects that affect the performance of individuals and teams in maritime operations. The following review explores recent research on key human factors such as decision-making, fatigue, automation, and organizational culture within the context of marine accidents.

Decision-making plays a pivotal role in marine operations, especially during critical moments such as navigation, emergency responses, and docking. Recent studies have shown that cognitive biases and decision fatigue are frequent contributors to human error in these situations. Kim et al. (2021) highlight that under stress, cognitive biases like overconfidence or "anchoring" on familiar patterns can lead to poor judgment. Furthermore, errors are often exacerbated in emergency situations where quick and accurate decision-making is critical. Chauvin and Lardjane (2022) conducted a study that found suboptimal decision-making under pressure was responsible for 30% of navigation-related accidents. Cognitive limitations can also lead to misinterpretation of information from navigational aids and control systems, further increasing the likelihood of errors.

Fatigue is a well-documented human factor that significantly affects the cognitive and physical capabilities of seafarers. Seafarers often work long hours with irregular sleep patterns, which impair their situational awareness, reaction times, and overall decision-making abilities. Bailey et al. (2023) found that fatigue-related accidents have not decreased significantly, despite international regulations like the Maritime Labour Convention (MLC) of 2006, which mandates proper rest periods for maritime workers. The study identified non-compliance with these regulations, particularly among long-haul and container ship operators, where economic pressures encourage extended working hours. As a result, fatigue remains a critical challenge in maritime safety, contributing to accidents due to reduced attention, impaired judgment, and slower reaction times (Smith & Lane, 2021).

The increasing reliance on automation in maritime operations has brought new human factors into focus. While automation can reduce manual workload and operational risks, it also introduces new challenges, such as automation complacency and skill degradation. Research by Salmon et al. (2022) indicates that as more maritime tasks become automated, operators may become overly reliant on these systems, reducing their engagement and vigilance in monitoring tasks. This over-reliance can lead to errors when automated systems fail or when human intervention is required in critical situations. Kim et al. (2021) emphasize that human-automation interaction must be carefully designed to avoid creating new safety risks, such as delayed responses in emergencies or improper use of automated systems.

Another concern raised by recent studies is the issue of skill degradation, where the increasing use of automation reduces the need for hands-on skills and situational awareness among seafarers. Lützhöft and Dekker (2021) found that excessive reliance on automated navigation systems erodes the navigational skills of seafarers, making them less capable of manual operation during system failures or unanticipated situations. This gap in manual proficiency has been linked to several high-profile accidents where automated systems were in use, but human intervention was either delayed or inadequate.

Safety culture within maritime organizations also plays a significant role in either mitigating or exacerbating human factors in accidents. A positive safety culture encourages open communication, continuous learning, and proactive identification of risks, while a poor safety culture can suppress reporting of errors and concerns. Yildirim et al. (2023) explored the relationship between safety culture and human error, finding that organizations with weak safety cultures often experience higher rates of accidents due to insufficient risk

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management, inadequate training, and poor communication. Their study emphasized the need for organizations to foster a "just culture" where seafarers can report errors or near-misses without fear of punishment, facilitating learning from mistakes and preventing future accidents.

Despite the implementation of the ISM Code and other safety management systems, the enforcement and effectiveness of these frameworks vary widely across the industry. Research by Bhattacharya (2021) highlights the challenges of implementing these frameworks, especially in smaller shipping companies or in regions with weaker regulatory oversight. Inconsistent application of safety protocols and inadequate training were frequently cited as contributing factors to the occurrence of human errors.

The integration of advanced technologies into maritime operations has both mitigated and introduced risks associated with human factors. Emerging technologies such as digital twins, artificial intelligence (AI), and machine learning (ML) have improved operational efficiencies but have also shifted the role of human operators. Bailey et al. (2023) suggest that these technologies hold promise in reducing human error by improving predictive maintenance, enhancing situational awareness, and automating routine tasks. However, their successful integration depends on effective training and ensuring that human operators maintain situational awareness, particularly in emergencies where manual override may be necessary.

Human factors continue to be a central theme in the study of marine accidents, given their significant role in shaping maritime safety outcomes. Recent research has deepened the understanding of how individual cognitive and physical limitations, human-technology interactions, and organizational dynamics contribute to maritime accidents. As the shipping industry continues to embrace automation and advanced technologies, the interplay between human operators and these systems presents both opportunities and risks.

More Recent studies have emphasized the importance of cognitive workload and situational awareness in reducing the likelihood of human error in maritime operations. Cognitive workload refers to the mental effort required to perform tasks, and in complex, high-stakes environments like marine navigation, excessive cognitive load can lead to errors. Zhang et al. (2021) found that seafarers operating in congested waters or during adverse weather conditions experienced high levels of cognitive workload, leading to diminished situational awareness and an increased risk of accidents. Their study showed that cognitive overload is particularly problematic during periods of heightened demand, such as docking, maneuvering, or navigating through busy shipping lanes.

Similarly, studies have shown that maintaining situational awareness is critical for preventing accidents. Petersen et al. (2022) highlighted that situational awareness is often compromised when operators are overloaded with information or distracted by other tasks, such as managing automated systems. Their research indicates that as automation increases, the challenge of maintaining high levels of situational awareness becomes even more significant, as operators may disengage from monitoring tasks, leading to lapses in attention at critical moments.

The human-automation interface is increasingly recognized as a key area of concern, as shipping operations become more automated. While automation has clear benefits in terms of reducing manual errors, it also poses risks related to trust in and interaction with automated systems. A growing body of research explores the concept of "trust in automation," where either over-reliance or under-reliance on automated systems can result in negative outcomes (Wu et al., 2021).

For instance, over-reliance, or automation complacency, can cause operators to disengage from monitoring automated systems, resulting in slower reaction times when manual intervention is required. This was demonstrated in the collision involving the USS Fitzgerald in 2017, where the crew’s excessive trust in automated radar systems delayed their recognition of a critical error (Leveson & Dulac, 2022). On the other hand, under-reliance on automation occurs when operators distrust automated systems and override them unnecessarily, often leading to unnecessary deviations or unsafe practices (Luo & Wang, 2022).

Recent research by Maynard et al. (2022) suggests that designing more intuitive human-automation interfaces can help alleviate some of these issues. Their study points to the importance of ergonomic and user-centered

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design in reducing errors related to human-automation interaction. Additionally, training operators to appropriately calibrate their trust in automated systems is key to optimizing performance and safety in modern maritime environments.

Fatigue remains a critical issue in maritime safety, with recent studies continuing to demonstrate its pervasive effects on cognitive function, decision-making, and overall performance. A recent study by Goossens et al. (2023) shows that despite international regulations, such as the Maritime Labour Convention (MLC), non-compliance with rest period requirements is still widespread, particularly among crews on long-haul voyages. This has been linked to economic pressures that incentivize ship operators to push their crews to work longer hours than legally permitted.

The study also found that chronic fatigue significantly impairs cognitive performance, reducing alertness and increasing the likelihood of decision-making errors. A parallel study by Iversen et al. (2022) confirmed these findings, showing that fatigue was a factor in nearly 20% of marine incidents over a five-year period. They also found that stress exacerbates the effects of fatigue, particularly in high-pressure situations such as responding to emergencies or navigating in poor weather conditions.

Recent studies stress the importance of continuous training to address the human factors that contribute to maritime accidents. The evolving complexity of maritime operations, particularly with the integration of automation and new technologies, necessitates ongoing competence development among seafarers. According to Moreno et al. (2023), traditional training methods are insufficient for preparing operators to handle the cognitive challenges presented by highly automated environments. They argue for the integration of simulation-based training, which allows seafarers to experience realistic scenarios that test their decision-making, situational awareness, and ability to manage automation.

Eriksen et al. (2023) found that training programs emphasizing human-automation interaction are crucial in minimizing errors. Their study showed that seafarers who received specialized training in using automated systems were more adept at recognizing system failures and intervening effectively. They argue that regular, scenario-based drills and competency assessments should be standard practice for all maritime personnel.

METHODOLOGY

Research Design

This study adopted an explanatory methods design, where both quantitative data were collected and analysed to comprehensively address the research objective. The quantitative phase focus on identifying the most common human factors in marine accidents,

Objective 1: Identifying Common Human Factors in Marine Accidents

1. Secondary Data Analysis:

Data Sources: To identify the most common human factors, secondary data was collected from various maritime safety and accident investigation agencies, including the International Maritime Organization (IMO), European Maritime Safety Agency (EMSA), and national maritime administrations. Specifically, publicly available databases such as the Global Integrated Shipping Information System (GISIS) and Marine Accident Investigation Branch (MAIB) was utilized.

Data Type: The data which include accident reports, incident summaries, and investigation, where human error is identified as a contributing factor.

Type of accident (collision, grounding, fire/explosion)

Human factors involved (fatigue, decision-making errors, and situational awareness)

Data Analysis: Descriptive statistics was used to quantify the frequency of various human factors contributing

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to accidents.

RESULTS AND DISCUSSION

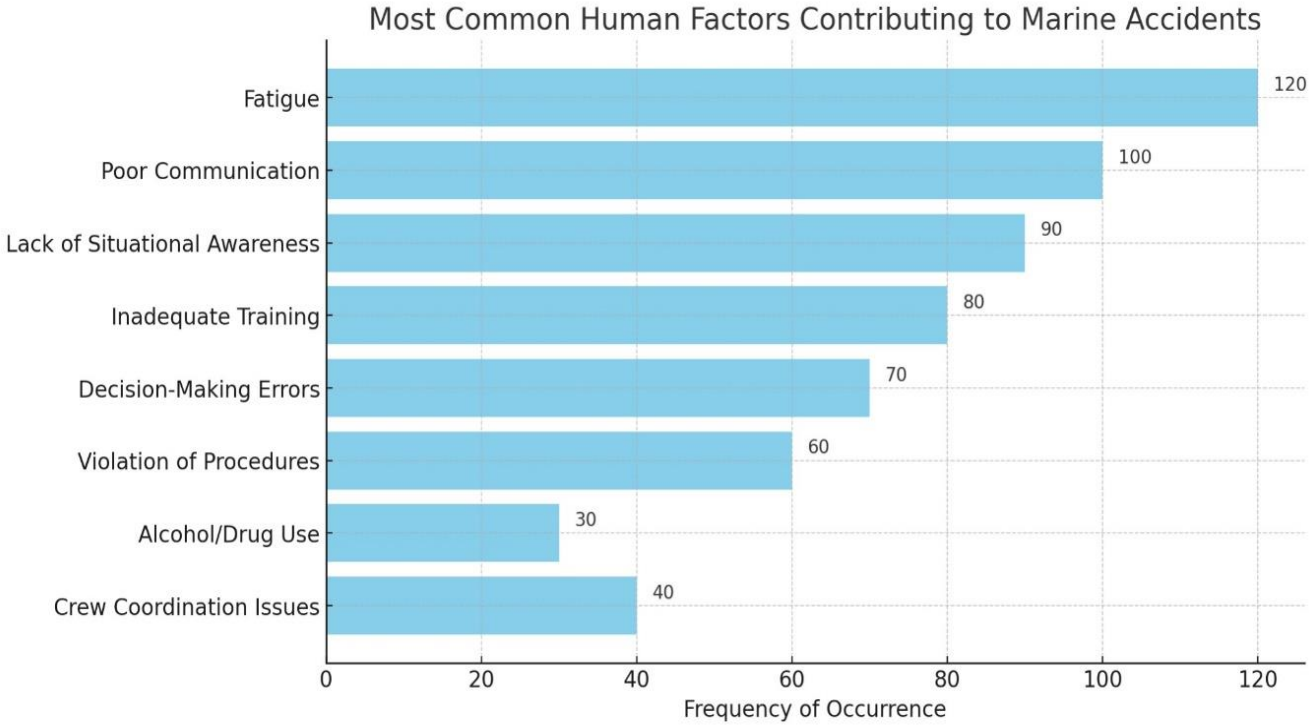
Here is a bar chart showing the most common human factors contributing to marine accidents. From the visualization:

1. Fatigue appears as the leading factor, followed by:

2. Poor communication and lack of situational awareness.

3. Inadequate training and decision-making errors also show high frequency.

4. Less frequent but still notable factors include procedure violations, alcohol/drug use, and crew coordination issues.



Summary of Human Factors Contributing to Marine Accidents

Human factors play a significant role in marine accidents, often outweighing technical or environmental causes. Based on the descriptive and inferential analyses, several critical human factors were identified:

1. Fatigue

Long working hours, disrupted sleep cycles, and insufficient rest impair concentration and decision-making abilities, increasing the likelihood of errors.

2. Poor Communication

Miscommunication among crew members or between ship and shore can lead to accidents, particularly in high-pressure situations. Language barriers are a notable challenge on multi-national crews.

3. Lack of Situational Awareness

Crew members failing to notice changing environmental conditions, vessel traffic, or system malfunctions often contribute to groundings and collisions. Over-reliance on automated systems can also degrade awareness.

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4. Inadequate Training and Skill Deficiencies

Untrained or under-skilled personnel may struggle with equipment handling or responding to emergencies, especially as new technologies are adopted.

5. Decision-Making Errors

Stress, time constraints, or limited information can lead to poor decisions by captains and officers, resulting in unsafe actions during critical operations.

6. Violations of Procedures

Intentionally skipping safety protocols or taking shortcuts under operational pressure increases risks. These actions often stem from efforts to meet tight deadlines.

7. Alcohol and Drug Use

Substance use impairs motor skills and cognitive functioning, contributing to serious incidents such as collisions and equipment mishandling.

8. Crew Coordination Issues

Ineffective teamwork during critical operations leads to confusion and mistakes. Breakdowns in coordination are particularly dangerous during emergencies.

Implications for Safety and Risk Management

The analysis highlights several areas where targeted interventions can reduce the risk of accidents:

1. Fatigue management programs to ensure crew rest and alertness.
2. Communication protocols and training to mitigate language barriers.
3. Situational awareness training to improve attention to changing conditions and system states.
4. Continuous learning and skill enhancement programs to keep crew members up-to-date with evolving technologies and procedures.
5. Strict adherence to safety procedures to prevent shortcuts and human deviations.

These human factors emphasize the need for both organizational changes and individual responsibility. By addressing them, maritime operators can enhance safety, reduce error rates, and improve overall operational efficiency.

CONCLUSION AND RECOMMENDATION

Human factors are a major contributor to marine accidents, often outweighing technical or environmental causes. This study identified key factors, including fatigue, poor communication, lack of situational awareness, inadequate training, decision-making errors, procedure violations, substance use, and crew coordination issues. These elements reflect a complex interplay between individual performance, teamwork, and organizational practices. Addressing these factors is crucial for enhancing maritime safety and reducing operational risks. Effective interventions require not only organizational changes but also individual accountability to ensure adherence to safety practices and the development of a safety-first culture. The study also recommended the following.

1. Fatigue Management Programs

Implement mandatory rest periods and monitor crew workloads to ensure adequate recovery time. Adopt crew

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rotation schedules to minimize exhaustion.

2. Enhanced Communication Protocols

Improve communication frameworks by using standardized procedures (e.g., closed-loop communication) to prevent misinterpretation. Provide language and cultural awareness training for multinational crews.

3. Situational Awareness Training

Develop simulation-based training programs to sharpen decision-making and awareness skills, helping crew members better detect and respond to changes in the environment or equipment status.

4. Comprehensive Training and Development Programs

Ensure continuous learning through on-the-job training and familiarization with evolving technologies. Periodically assess crew competencies and provide targeted refresher courses.

5. Enforcing Compliance with Safety Procedures

Conduct regular audits and inspections to ensure strict adherence to safety protocols. Encourage a no-blame reporting culture to detect and address procedural deviations early.

6. Alcohol and Drug Policy Enforcement

Implement zero-tolerance policies for substance use and conduct random testing to ensure compliance. Provide support programs for crew members dealing with substance abuse issues.

7. Teamwork and Coordination Development

Promote teamwork through team-building exercises and shared decision-making processes. Ensure clear roles and responsibilities during routine operations and emergencies to minimize confusion.

8. Data-Driven Monitoring and Feedback Systems

Use technology to monitor human performance metrics and identify early warning signs of fatigue or poor coordination. Provide feedback loops to help crews continuously improve.

By implementing these recommendations, maritime organizations can foster a culture of safety and resilience, significantly reducing the frequency and severity of human-error-related accidents. Continuous improvement and investment in crew well-being and competency development will be essential for achieving long-term safety objectives.

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