Influence of cognitive dissonance on Maritime Industry Safety Culture, Marine Accidents & Casualty, Human Factor and Safety Engineering

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Abstract
Even when all sorts of improvements and innovations are made regarding maritime technology and regulation, marine accidents and marine victims remain a thorn in the flesh, and human related factors are often pointed out as the major causes. It is therefore necessary to have an insight on the interplay between cognitive behaviour and organizational conditions and system design, as well as determine the impact of these factors on safety outcomes. The purpose of this study is to investigate the effects of cognitive and human-related variables on the maritime safety culture, marine accidents and victims, and safety engineering practice by conducting a qualitative review on the secondary data. The study takes the form of a narrative review because the study will utilize peer-reviewed journal articles, analytical reviews, and research books that focus on maritime safety and safety science. The major academic databases were searched and identified using relevant literature and analysed through a thematic and interpretative approach. The review concentrated on evidence synthesis of the evidence that touches on cognitive strain, human error, psychosocial pressures, safety culture, and human-system interaction in maritime operations. The results have shown that the maritime accidents are not often related to isolated human errors, but rather manifested as cumulative cognitive load, behavioural adjustment, and organizational circumstances of normalization of unsafe practices. Cognitive vulnerabilities and risk of accidents were found to be encouraged by weak safety cultures, inadequate reporting systems, and production-oriented priorities. In addition, new developments in automation and safety engineering have changed the exposure of human risks through the increased cognitive workload and new challenges of human-system interaction. The research also outlines the drawbacks of mainly proactive safety management strategies that are based on post-incidence examination. This study is relevant to the study of maritime safety because it presents a holistic view where cognitive behaviour, safety culture of the organization, and the engineering of safety are interlinked. The results assume the necessity of proactive, systems-based, and human-centered safety measures to improve the performance of maritime safety.

Keywords: Maritime safety; Human factors; Cognitive behaviour; Safety culture; Marine accidents; Safety engineering; Human–system interaction

1. INTRODUCTION

The maritime sector is an important part of international trade and transportation, and it still has to deal with the constantly ongoing safety issues despite the constant improvement of ship designs, navigation systems, and regulations. The issue of marine accidents and victims is still of great concern because of its critical impacts on human life, environment, and economic sustainability. Although the technological innovation has made vessels performance far better than before, the accident investigations always prove that technical failures cannot sufficiently explain maritime incidence occurrence. Rather, anthropogenic factors have been considered as the most significant ones, which suggests the necessity to learn more about the analytical impact of human behaviour, cognition, and organizational environment on the maritime safety outcomes (Galieriková, 2019).

New studies of maritime safety are placing more and more stress on the role of the human factor in a accident. As it is shown by Ma, Shi, and Liu (2023), notions of human element, human factor, and human error are often interchanged in the maritime literature as the concepts do not have clear limits. This ambiguity makes it difficult to analyse accidents and intervene by safety measures because the inherent cognitive and organizational processes that influence unsafe behaviour are blurred. Instead of being sporadic, human error in maritime operations frequently is the outcome of overall interactions among people, processes and operational pressures.

Even with the well-developed safety management systems and official procedures, unsafe practices are still allowed to appear and, in the majority of cases, are accepted as a part of the routine shipboard activities. Dominguez-Péry et al. (2021) note that the human error aspect has been at the heart of the solution to the problem of maritime accidents, but the majority of current strategies are aimed at differentiating and labeling errors or ensuring compliance instead of the psychology behind the decision-making process. It introduces a disconnect between formal requirements in safety and practice on the sea where seafarers can act with knowledge of going against the procedures in order to manage the time and workload or organizational pressures.

Empirical research also indicates that the severity of accidents and risk of fatality are strictly related to human error. Maternova et al. (2023) demonstrate that particular patterns of human errors are also possible contributors to the increased risk of death during maritime accidents, which is why the issue of decision-making and situational judgment is particularly crucial. Nevertheless, although these predictive models can be used to gain a deeper insight into the risk, they still create a limited insight as to why people continue to engage in unsafe behaviour despite knowing the outcomes. This weakness implies that a psychological approach should be considered in which the internal cognitive conflicts determining safety behaviour should be evaluated.

The multidimensional character of human-related safety issues is also represented by the operational conditions within ships, in the engine rooms, in particular. According to Chowdhury et al. (2024), the common risk factors of what compromises the safe performance include fatigue, poor communication, inadequate training, and procedural overload. These situations frequently force seafarers to make operational continuity rather than strict compliance paramount, which strengthens work routines of unsafe practices over time. These results suggest that the concept of safety cannot be conceptualized based on the adherence to the procedures only but also in view of the human ability to adjust to challenging workplace conditions in a cognitive manner.

Safety culture has thus been found to be an important dimension of maritime safety. According to Kasyk (2024), navigational accidents are becoming more demanding when it comes to placing increased emphasis on safety culture since frequently the experienced operators can justify their rule violations due to a certain measure of success in the past or operational need. This rationalization process is consistent with the processes of cognitive dissonance, in which people mitigate psychological discomfort that results when safety knowledge and real behaviour are in conflict with each other by justifying or redefining unsafe behaviours.

The role of psychosocial factors also contributes to further the argument of a cognitive approach to a maritime safety. Studies of high-risk sectors indicate that stress, workload, and organizational expectations play a major role in influencing safety-related behaviour and risk perception (Derdowski and Mathisen, 2023). These psychosocial forces have interplay with hierarchical organizations and authority curves in a maritime environment, which tend to discourage open communication and support the norms of unsafe behaviors.

Concurrently, developments in the maritime technology and engineering have added complexity of the system to the extent that it elevates cognitive load on the operator. According to Soares and Santos (2024), today, there are a need to align human cognition and engineering design closer to the development of modern maritime systems as technological sophistication is not sufficient to ensure the safety. Systems that do not fit human capabilities properly can also become the contributors of cognitive overload and unsafe decision-making.

The literature indicates a gaping flora in the research of maritime safety: whereas the human error, safety culture and technological variables have been extensively dissected, little was done concerning the psychological processes that perpetuate the unsafe behaviour. Cognitive dissonance provides a useful theoretical perspective on comprehending how seafarers balance the differences between the safety expectations and operational realities, and, as a result, affects the safety culture, the number of accidents, and the contact with the safety engineering systems.

Objectives

1. To examine the role of cognitive dissonance in maritime safety culture,
2. To analyse how cognitive dissonance contributes to marine accidents and casualties
3. To explore the implications of cognitive dissonance for human factors and maritime safety engineering.

2. METHODOLOGY

The research design that was adopted in this study is the qualitative, secondary-data-based research design to investigate the role played by cognitive and human-related factors in assessment of the maritime safety culture, marine accidents and casualty, and safety engineering. The secondary data method is suitable considering the presence of a large body of published research, accident investigation studies, and industry reports that report the contribution of human factor to the outcome of maritime safety. One of the areas where accident causation, behavioural effects, and organizational practices are well recorded in the academic and professional literature is in the field of maritime safety, which makes the secondary data a suitable place to base the analysis. The methodology will thus be aimed at synthesizing and interpreting the available evidence and not creating new empirical evidence, which will provide an opportunity to consider in detail the conceptually based capitalization of safety-related human behaviour in maritime operations.

Research Design

The study is conducted in the form of a qualitative narrative review that should help to come up with a combined concept of the effect of cognitive and human related elements on maritime safety culture, the occurrence of accidents and safety engineering practices. Such a design is the one that focuses on analytical interpretation and synthesis of concepts over statistical aggregation, which is especially applicable to the study of complex behavioural and organisational phenomena. The results of maritime safety are usually a result of the interaction between human cognition, pressures of operations, and technological systems, which cannot be effectively measured by use of purely quantitative methods.

The narrative review design facilitates the ability to be flexible on the assimilation of results of various methodological traditions such as empirical analysis of accidents, conceptual studies and applied safety studies. The study can study interrelationships among human cognition, safety practices, and engineering systems in practical maritime operations by emphasizing on interpretation and thematic integration. This method helps to comprehend safety in a holistic way, as a socio-technical phenomenon that is influenced by human and system-level factors.

Data Sources

The data to be used in the study was acquired using the already existing scholarly and professional data pertinent to the field of maritime safety and human factors. These sources will be peer reviewed journal articles, scholarly review articles, and edited academic books published by reputable publishers. The literature was determined in search in the largest academic databases such as Scopus, Web of Science, ScienceDirect, SpringerLink, IEEE Xplore, and Taylor and Franklin Online databases, and the search in Google Scholar was also performed to supplement database-based searches. The selection of these platforms was based on the fact that they offer a comprehensive and reliable access to the interdisciplinary research in the field of maritime studies, safety science, human factors, and engineering disciplines.

The search was conducted to find the publications related to maritime accidents, human factors, safety culture, cognitive and behavioral factors, and human-safety system interaction. The keywords and combinations of the following terms were applied to search: maritime safety, human factors, human error, safety culture, marine accidents, casualties, and safety engineering. Sources that specifically dealt with maritime operational settings were only considered so as to ensure relevancy as well as consistency with the research objectives. Publications whose focus was not clear on safety or human issues in maritime settings were not added.

Sample Characteristics

The research sample in this case comprises published documents as opposed to human subjects. The chosen literature contains the empirical research, analytical and scholarly reviews, or chapters discussing the human error, cognitive behaviour, organizational safety culture, or the causes of accidents in the maritime sector. The analysis of documents as the sampling of analysis enables the study to resort to an abundance of the real-world evidence created in the course of accident investigations, academic research, and the applied safety analysis.

These sources have been chosen depending on their relevance to the subject of the research, level of analysis and their contribution in understanding of safety related human behaviour. Priority was given to the studies which specifically discussed the behavioural mechanisms or decision-making processes or organizational factors that influence the safety outcome. No publications that were strictly technical in nature or those that had no clear-cut linkage to human or safety-related matters were allowed. This selection procedure has been purposive to the extent that the material reviewed was relevant to the conceptual scope of the study, and offered informative details to the behavioural and cognitive aspects of maritime safety.

Data Analysis Procedures

A thematic and interpretative approach of analytical analysis was used in analysing the selected literature. All the sources were analyzed in a thorough way to find core arguments, findings, and conceptual frameworks on maritime safety and human factors. The recurring themes that were identified through the iterative reading and comparison across studies related to cognitive behaviour, safety culture, psychosocial influences, pattern of accident causation and interaction between human and system used in safety engineering.

After identifying the theme, the analysis was devoted to synthesising the insights within the sources to investigate how cognitive and human-related factor lead to safety outcome and risk of accidents in the maritime operations. Instead of describing the individual studies, the analysis has focused on determining relationships, patterns, and explanatory mechanisms that cross-cut the literature. This synthesis has facilitated the elaboration of a comprehensive story corroborating behavioural theory with engineering design and practical considerations in the maritime safety management.

Inclusion and Exclusion Criteria

The studies had to be considered in case they discussed maritime safety or accident situation and specifically focused on human factors, cognitive or psychosocial factor, safety culture, or human-system interaction. Peer-reviewed journal articles, scholarly reviews and academic book chapters were only taken into account including only the articles written in the English language and being in the full text version. The sources that contain conceptual, empirical or analytical information pertinent to safety management and safety engineering in maritime were considered.

The studies that were discarded included those that concentrated on technical or mechanical considerations but not on human or safety considerations, those that were not peer reviewed or had purely opinion based articles, those studies that did not concentrate on maritime industries and those that were not analytical enough. Duplicates and sources that were not in full-text were also eliminated.

Ethical Considerations

The study used several sources that were independent of one another to increase the level of analytical rigor, which were published in various journals and academic sources. Similarity in results obtained in various studies contributed to the interpretative credibility, whereas, different opinions were critically reviewed to prevent the risk of oversimplification and bias. The fact that only peer-reviewed and academic published sources have been used is also in favor of the reliability of the analysis.

Since the research will use solely the secondary sources that are publicly available and since no human subjects or personal information, or confidential data were used, no formal ethical approval was needed. The research process was transparent and academically sound, as the ethical practices were ensured by correct citation, proper recognition of the original authors, and objective interpretation of the published material.

3. RESULTS

Analytical Profile of the Reviewed Evidence Base

Peer-reviewed journal articles, analytical review studies, and scholarly edited volumes were reviewed to provide evidence on maritime safety through the prism of human factors, accident causation, safety culture and safety engineering. In the literature, analytic focus on the study of human error and accident investigation is given a high priority, and relatively less focus is observed on cognitive, psychosocial, and anticipatory safety mechanisms. This distribution shows a strong bias towards reactive analysis of safety and an emergent trend of proactive and system-level safety analysis like leading safety indicators and human systems integration.

Table 1-Analytical Distribution of Reviewed Literature by Dominant Safety Perspective

Dominant Perspective	Relative Representation	Primary Analytical Focus	Source(s)
Human factors and human error	High	Behavioral failures and decision errors	Hetherington et al. (2014); Ma et al. (2023)
Accident and casualty analysis	High	Causal pathways and severity outcomes	Dominguez-Péry et al. (2021); Maternová et al. (2023)
Safety culture and organizational influences	Moderate	Norms, leadership, reporting behavior	Psarros et al. (2010); Kasyk (2024)
Safety engineering and system design	Moderate	Human–system interaction, indicators	Soares & Santos (2024); Wróbel et al. (2023)
Psychosocial and cognitive dimensions	Emerging	Stress, cognition, risk perception	Derdowski & Mathisen (2023)

Table 1 below provides an analytical distribution of the literature that has been reviewed about maritime safety by research perspective of dominance. It demonstrates a high level of interest in the causes of human errors and accidents, increasing interest in the safety culture, and system-level safety engineering. Cognitive and psychosocial aspects are also relatively underexplored, which implies the continued focus on the reactive and not anticipatory safety measures. The distribution brings out the necessity of integrative frameworks linking cognitive behavior to organizational and system-level safety mechanisms.

Cognitive and Human Factors Associated with Accident Occurrence

In all the analysed studies, maritime accidents are always linked to cognitive strain and adaptive behaviour and not singular operational errors. The components associated with humans show themselves in the form of fatigue, lack of situational awareness, procedural variance, and uncertainty misjudgement. Notably, involvement in accidents is often an experienced group, and it is possible that operational familiarity is one factor that promotes the normalization of risk instead of a protective control against unsafe behaviour.

Table 2-Cognitive and Human Factors Linked to Maritime Accident Development

Factor Category	Operational Manifestation	Safety Implication	Source(s)
Cognitive overload	Multitasking and information saturation	Loss of situational awareness	Hetherington et al. (2014)
Fatigue	Extended duty periods and circadian disruption	Impaired judgment	Hetherington et al. (2014)
Risk normalization	Repeated exposure to unsafe routines	Elevated accident probability	Galieriková (2019)
Situational misjudgment	Inaccurate threat assessment	Event escalation	Maternová et al. (2023)
Procedural adaptation	Rule deviation for operational efficiency	Latent system failure	Chowdhury et al. (2024)

The following table 2 is a synthesis of both cognitive and human factors that led to the development of maritime accidents. The results show that fatigue and cognitive load are two key factors in the worsening of judgment and situational awareness and risk normalization strengthens unsafe behavioural adaptation in the long term. Accidents are thus viewed in a more positive light as the results of the impact of progressive cognitive decay than an individual error. These trends are consistent with the human-factor studies on maritime safety.

Safety Culture as a Mediating Mechanism

Safety culture emerges as a critical mediating mechanism linking individual cognition with organizational safety outcomes. The reviewed literature demonstrates that weak safety cultures normalize procedural deviations, suppress incident and near-miss reporting, and discourage challenges to authority. Such cultural conditions legitimize unsafe decision-making and amplify cognitive strain, thereby increasing accident likelihood.

Table 3-Safety Culture Characteristics and Their Effects on Safety Performance

Cultural Attribute	Operational Expression	Effect on Safety Performance	Source(s)
Production-driven priorities	Safety subordinated to schedule pressure	Increased latent risk	Dominguez-Péry et al. (2021)
Informal rule adaptation	Tacit acceptance of deviations	Erosion of safety margins	Kasyk (2024)
Limited reporting culture	Under-reporting of incidents and near misses	Delayed corrective action	Psarros et al. (2010)
Authority gradient	Restricted upward communication	Error propagation	Dominguez-Péry et al. (2021)

This table 3 illustrates how safety culture characteristics influence safety performance in maritime organizations. Under-reporting of incidents and strong authority gradients emerge as critical barriers to organizational learning and proactive risk management. Weak safety cultures do not merely reflect organizational values but actively shape risk perception and decision-making behaviour. These findings reinforce safety culture as a key mediator between cognition, behaviour, and accident outcomes.

Human–System Interaction and Safety Engineering Outcomes

The assessment shows that human risk exposure in maritime operations has been changed but not removed due to technological improvement in maritime operations. More automation, interface complexity, saturation of alarms and dependence on reactive indicators increase cognitive load of operators. In situations where safety engineering fails to consider human cognitive abilities, system reliability is not enough to avoid accident

Table 4-Human–System Interaction Issues Identified in Safety Engineering Literature

Engineering Dimension	Identified Limitation	Impact on Human Performance	Source(s)
Automation integration	Over-reliance and reduced vigilance	Skill degradation	Soares & Santos (2024)
Alarm architecture	Alarm saturation and prioritization loss	Delayed response	Ma et al. (2023)
Interface complexity	High information density	Cognitive overload	Soares & Santos (2024)
Safety indicators	Predominant use of lagging indicators	Reactive safety management	Wróbel et al. (2023)

This table 4 indicates key human system interaction issues in maritime safety engineering. Besides interface and automation challenges, the proactive identification and prevention of risks is limited by the lack of major safety indicators adoption. With the advancement of maritime activities to a more automated and autonomous state, the need to integrate cognitive compatibility with predictive safety metrics becomes more critical. These results highlight the importance of human and proactive safety engineering solutions.

Psychosocial Pressures and Behavioural Adaptation

Psychosocial factors like stress, workload, fatigue and organizational demands have a profound impact on safety related behaviour during maritime operations. The evidence reviewed shows that these pressures interact with the cognitive processes to impair attention and risk-taking and encourage behavioural compromise of safety and performance, especially in situations involving time-critical operations

Table 5 -Psychosocial Influences on Maritime Safety Behaviours

Psychosocial Factor	Behavioural Effect	Risk Consequence	Source(s)
Occupational stress	Reduced attentional control	Increased error likelihood	Derdowski & Mathisen (2023)
Time pressure	Procedural shortcuts	Reduced safety margins	Chowdhury et al. (2024)
Performance expectations	Risk-taking normalization	Accident susceptibility	Hetherington et al. (2014)
Fatigue-related stress	Cognitive impairment	Decision failure	Derdowski & Mathisen (2023)

This table 5 summarizes psychosocial factors influencing safety-related behaviour in maritime operations. Stress, fatigue, and performance expectations impair cognitive control and reinforce unsafe behavioural adaptation. These pressures act as accelerators of cognitive strain, increasing the likelihood of unsafe decisions and accident occurrence. Addressing psychosocial risks is therefore essential for sustainable improvement in maritime safety performance.

Synthesized Accident Causation Pathway

In totality, the outcome findings present a repetition of an accident causation pathway where cognitive strain, which is reinforced by organizational safety culture and human-system interaction constraints, worsens over time as a result of safety performance. This process is enhanced by psycho social pressures as well as reactive practices of safety management, which make marine accidents and casualties more probable. This constructed pathway indicates the stability of patterns that have been reported in studies of human-factors, research on the safety culture, and literature on safety engineering.

4. DISCUSSION

This research has shown that the maritime safety issues can be best viewed in a systemic and adaptive lens and not in some detached concepts of human error or technical breakdown. The prevalence of cognitive strain, behavioural adjustment, and organizational safety deficiencies imply that unsafe consequences are the result of interactions in the form of socio-technical systems and not the result of the personal non-compliance (Reason, 2016). This explanation supports the perception that organizational structures, decision environments and system design influence safety performance.

In organizational accident view, the findings are helpful in supporting the argument that accidents are formed on the basis of latent conditions that are inherent in operational systems. Normalization of risky behaviors and deviations of the procedures that have been found in the maritime suggest how individuals respond to the competing demands and performance pressure. These adaptations can also be seen as logical reactions to the system restrictions instead of intentional violations, which means that human error can be considered the result of the system design, not a major cause (Dekker, 2017).

The prevalence of reactive safety methods that were witnessed in the findings is indicative of the shortcomings of the traditional Safety-I thinking model in which safety is considered to be the absence of accidents. Dependence on post-incident investigation and trailing indicators give minimal understanding of the variability of operations day to day. The Safety-II viewpoint on the other hand focuses on how work is performed in practice and how systems work in variable conditions (Hollnagel, 2017). The results indicate that the maritime safety management is still not practicing this proactive orientation in its entirety.

The idea of resilience provides a valuable framework of interpreting the adaptive behaviours that were defined in this paper. The first trait of resilient systems involves their capability to foresee, observe, act to and learn with the changing conditions. The findings show that the maritime organisations are usually unable to build up these capabilities, especially when it comes to learning about weak signals and near misses. The inadequate feedback mechanism and ineffective reporting culture decreases the ability of the system to be adaptable prior to its failure (Bergström et al., 2015).

These implications are far-reaching to the safety management practice. The safety management needs combined interventions that can address behavioural, organizational, and managerial aspects of safety management. Safety programs where the main emphasis is on rules or technical training are not always effective in impacting the decision-making in the face of pressure. A literature review on safety management intervention indicates that the leadership, communication, and organizational reinforcement mechanism is essential in the creation of safe behaviour (Newnam and Oxley, 2016).

In terms of systems engineering, the outcomes give a solid argument to the fact that safety is a control issue and cannot be discussed as a component reliability issue. The human-system interaction issues like automation dependency and interface complexity show that safety risks lie in the system design and administrative systems. Systems thinking focuses on creating constraints to follow safe behaviour in real conditions of operation instead of considering the ideal human performance (Leveson, 2016).

In general, the discussion reveals the necessity of the change of the current approach to the management of maritime safety to the more proactive, system-oriented models that are error-focused. By combining the organizational accident theory, modern conceptualizations of human error, resiliency engineering, and Systems thinking, one can get a holistic approach to the concept of the improvement of the safety performance in the maritime system.

This research supports the opinion that to make maritime safety sustainable, it is necessary to go beyond the personal responsibility of blame and procedural adherence. The ideas of cognitive demands, organizational learning, alignment of system design and human capabilities are crucial in minimizing marine accidents and casualties in more and more complicated maritime operations.

5.CONCLUSION

The research contributes to the existing body of knowledge on maritime safety by challenging the conceptualizations of accidents and safety performance as the results of the complex socio-technical interactions instead of the outcomes of the individual human or technical failures. The results support the position that cognitive behavior, organizational norms, and system design have a joint influence on the way safety is practiced. Through this, the study questions the further use of the traditionally reactive and compliance-based safety management paradigms, which are still widely used in the maritime sphere.

One of the main implications of the conducted research is the understanding that human adaptability, though being the key to ensuring the continuity of operational processes, may also be a source of latent risk when the mechanism of its identification and control is in place. Local rational choices as a result of cognitive adaptation to conditions of workload, uncertainty and operational pressure that gradually diminish safety margins are common. To overcome this phenomenon, it is necessary to focus on the change of the individual-oriented approach of intervention toward the strategies that would redesign the structural and cultural conditions of the decision-making.

Regarding engineering safety, this paper also points out the shortcomings of solutions that are technology focused to insufficiently consider human cognitive and constriction abilities. Since more and more of the maritime operations are automated and equipped with advanced decision-support systems, cognitive compatibility and transparency become of critical concern. Design engineering needs to focus then on human-centered design, system-level safety constraints to facilitate safe operation in variable environment.

On a wider level, the results highlight the significance of including organizational learning, proactive safety indicators, and resilience-oriented thinking in the process of representing maritime safety. The possibility to foresee the new risks, experience the daily functioning, and the correspondence of the technological advancements with reality of human beings and organization will also be the key to the sustainable enhancement of the safety. Through system-oriented and cognitively informed thinking, the sector of the marine industry can proceed to stronger and more sustainable safety results.

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