

Analysis of the Impact of Low Seafarer Competency on Maritime Accident Trends: Empirical Evidence from 2023–2025

Huske Dwi Gustian

Sekolah Tinggi Ilmu Maritim “AMI” Jakarta
Email: huskedg@gmail.com

Maritime accidents remain a critical concern for global shipping safety despite the widespread implementation of international regulatory frameworks, particularly the Standards of Training, Certification and Watchkeeping for Seafarers (STCW) Convention. Accident data from 2023–2025 indicate that human factors especially inadequate seafarer competence—continue to be the dominant contributors to maritime incidents. This study examines the impact of low seafarer competence on maritime accident trends during the 2023–2025 period and identifies systemic factors influencing competency development from the perspectives of regulators, shipping companies, and maritime education and training institutions. A mixed qualitative–quantitative research design was applied. Data were collected through document analysis of international maritime accident reports, STCW audit records, and semi-structured interviews with key stakeholders, including maritime regulators, shipping companies, training institutions, and seafarer associations. The analysis employed descriptive statistical assessment, accident cause-factor mapping, and systemic interaction analysis among institutional actors. The findings reveal that maritime accidents during 2023–2025 were dominated by collisions, groundings, and vessel sinkings, with approximately 60–70% of incidents associated with human error linked to low seafarer competence. The study identifies three major contributing factors: weak regulatory oversight, limited corporate accountability in verifying crew competence, and inadequate quality assurance in maritime training institutions. These findings indicate a persistent gap between STCW competency standards and their practical implementation, which often remains compliance-oriented rather than competency-based. The study concludes that low seafarer competence represents a structural challenge within the maritime safety system. Strengthening competency-based regulatory enforcement, improving institutional governance of maritime training systems, and involving seafarer associations as independent professional oversight actors are recommended to enhance maritime safety. Future research should employ broader longitudinal datasets and advanced inferential analytical methods to further examine the relationship between seafarer competence and accident risk.

Keywords: seafarer competence; maritime accidents; human factor; STCW; maritime safety governance

This is an open-access article under the [CC BY-NC](#) license



Corresponding Author:

Huske Dwi Gustian
Sekolah Tinggi Ilmu Maritim “AMI” Jakarta
huskedg@gmail.com

1. Introduction

Maritime safety is a fundamental pillar of the global trading system and international maritime security. More than 80% of the world's trade volume is transported by sea, making the shipping sector highly dependent on the reliability of safety systems and the quality of human resources on board. In this context, seafarers not only serve as technical operators but also as key actors in safety decision-making in high-risk operational environments. Despite advances in navigation technology and automation, global maritime accident data consistently indicate that human factors remain the dominant determinant of incidents at sea [1], [2].

Recent maritime safety reports demonstrate that accident trends during the 2023–2025 period show a persistent pattern in which most incidents are associated with human error rooted in insufficient seafarer competence [3], [4], [5]. Empirical studies across multiple maritime regions suggest that between 55% and

80% of maritime accidents are directly linked to human-related factors, including decision-making failures, lack of procedural understanding, and inadequate application of safety management practices [3], [4]. Moreover, technological advancements and digitalization in shipping operations have not significantly reduced accident rates when they are not accompanied by improvements in crew competence and professional capability [6], [7].

To address these challenges, the international maritime community has developed a comprehensive regulatory framework, primarily through the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW). The STCW Convention establishes minimum global standards for seafarer training, certification, and watchkeeping responsibilities, placing seafarer competence at the center of maritime safety governance [7]. Nevertheless, several post-implementation evaluations indicate that formal regulatory compliance does not necessarily guarantee the actual operational competence of seafarers, particularly in developing maritime sectors and emerging shipping markets [8], [9].

The issue of low seafarer competency should therefore be understood as a systemic phenomenon involving multiple institutional actors. First, weak regulatory supervision as stipulated in STCW Regulation I/4 (Control Procedures) may allow certification practices without rigorous competency verification. Second, shipping companies may fail to ensure that recruited personnel possess competencies consistent with STCW Regulation I/14 (Company Responsibilities). Third, variations in the quality of maritime education and training institutions may lead to training outcomes that do not fully meet the standards defined in STCW Regulation I/6 (Training and Assessment) and Regulation I/8 (Quality Standards) [8], [10].

In the Indonesian context, this issue becomes increasingly critical due to the high intensity of national and international shipping activities. Indonesia has adopted the International Safety Management (ISM) Code through national regulations, including Minister of Transportation Regulation No. PM 45 of 2012 concerning Ship Safety Management, which emphasizes that ship safety is highly dependent on the competence and readiness of both shore-based personnel and seafarers on board vessels [11].

Despite these regulatory frameworks, numerous maritime safety audits and empirical studies reveal a persistent gap between regulatory standards and practical implementation. In many cases, supervisory systems prioritize document compliance rather than evaluating actual competency performance [12], [13], [14]. As a result, the overall quality of seafarers produced by the regulatory–corporate–training ecosystem has not significantly reduced maritime accident risks [12], [13].

In this context, seafarers' professional associations may play a strategic role as an additional layer of quality assurance within the maritime safety governance system [15], [16], [17]. Such organizations can facilitate collaboration between regulators, companies, and maritime professionals while promoting professional ethics, continuous learning, and competency-based recruitment practices [15], [16].

However, empirical studies that integrate regulatory oversight, corporate responsibility, and training institution quality in explaining recent maritime accident trends remain limited. Based on this background, the present study aims to empirically analyze the impact of low seafarer competency on maritime accident trends during the 2023–2025 period. The analysis integrates the regulatory framework of STCW, the ISM Code, and relevant national regulations to examine systemic interactions among regulators, shipping companies, and maritime training institutions. Theoretically, this study contributes to maritime safety literature by integrating recent accident trend analysis with a systemic governance perspective that connects regulatory oversight, corporate responsibility, and training quality as interdependent determinants of seafarer competence.

2. Literature Review

Seafarer Competency and International Standards

Seafarer competency is a multidimensional concept that encompasses technical, managerial, interpersonal, and non-technical skills necessary to ensure the safety of ships, crews, cargo, and the maritime environment. In modern maritime operations, seafarer competence includes not only the ability to operate navigation systems or perform routine operational tasks but also the capacity to make effective decisions, communicate efficiently in multicultural crew environments, and respond appropriately to emergency situations. Recent literature highlights that competency should not be measured solely through the possession of certificates or formal qualifications but also through the ability of seafarers to apply knowledge, skills, and professional attitudes in real operational contexts [2], [16].

As a global regulatory framework, the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW) establishes minimum standards for seafarer training, certification, and watchkeeping responsibilities that must be implemented by member states of the International Maritime Organization (IMO). The convention places seafarer competence at the center of maritime safety governance by defining internationally recognized requirements for maritime education and training systems. STCW emphasizes that maritime safety can only be achieved when all stakeholders regulators, shipping companies, and training institutions—perform their roles consistently and collaboratively within an integrated governance framework [18].

STCW Regulation I/4 (Control Procedures) specifically emphasizes the obligation of flag states to conduct effective supervision of the implementation of seafarer training and certification standards. This supervision includes auditing maritime education and training institutions, verifying the validity and authenticity of competency certificates, and taking corrective action against institutions that fail to comply with international standards. However, empirical studies on maritime governance reveal that regulatory oversight capacity varies significantly across countries. Limitations in institutional capacity, insufficient training of maritime auditors, and inconsistent implementation of control procedures often create gaps between the normative requirements of STCW and actual practices in the field [10].

Furthermore, STCW Regulation I/6 (Training and Assessment) and Regulation I/8 (Quality Standards) position the quality of maritime education and training institutions as the fundamental foundation for producing competent seafarers. These regulations require training institutions to provide qualified instructors, updated curricula aligned with technological developments in shipping, objective competency-based assessment systems, and documented quality assurance mechanisms that are periodically audited. Despite these regulatory requirements, recent studies reveal that many maritime training institutions still prioritize administrative compliance or the completion of training hours (seat time) rather than achieving measurable competency outcomes through competency-based training approaches [5], [8].

From the perspective of the shipping industry, STCW Regulation I/14 (Company Responsibility) emphasizes that shipping companies are responsible for ensuring that recruited and employed seafarers possess valid certificates and competencies appropriate to their assigned duties. This responsibility includes verifying certification authenticity, ensuring crew familiarity with shipboard procedures, and providing additional training when necessary. The literature highlights that companies' failure to fulfil this responsibility—particularly through cost-driven recruitment practices that prioritize operational efficiency over competency verification has contributed significantly to increased maritime accident risks, especially in commercial and passenger shipping operations [1].

Human Factors in Maritime Accidents

Human factors are consistently identified as the dominant cause of maritime accidents across various vessel types and operational environments. Numerous empirical studies in maritime safety research indicate that human error remains the primary contributing factor to maritime incidents even in the era of advanced navigation technologies and digitalized ship operations. Global analyses of maritime accidents during the period 2023–2025 suggest that more than 60% of maritime incidents are directly associated with human-related factors, including navigational errors, communication failures on the bridge, inadequate situational awareness, and non-compliance with safety procedures [3], [4].

However, human error in the maritime context should not be interpreted merely as an individual failure. Contemporary safety research emphasizes that accidents often arise from complex interactions between human operators, organizational structures, technological systems, and the working environment. Within this perspective, low seafarer competence is often a manifestation of systemic weaknesses rather than purely personal limitations. Weak regulatory oversight, inadequate training quality, and unprofessional recruitment practices within shipping companies are frequently identified as structural factors contributing to competency gaps among seafarers [13], [15].

Empirical research further demonstrates that improvements in seafarer competence can significantly reduce maritime accident risks. For example, McMahon's analysis of global maritime accident data shows that ships operated by crews who received competency-based training and continuous performance evaluation experienced approximately a 30% reduction in operational incidents compared with vessels relying on traditional training approaches [3]. Similar findings were reported by Čok et al., who concluded that the quality of maritime education, training systems, and competency monitoring mechanisms plays a more significant role in accident prevention than technological modernization alone [5].

These findings underline the importance of strengthening competency-based maritime education systems, improving regulatory oversight mechanisms, and reinforcing the responsibility of shipping companies in ensuring the competence of their crews. Without improvements in these institutional mechanisms, technological advancements in navigation systems and ship automation will have limited impact on reducing maritime accident rates.

Factors Contributing to Low Seafarer Competency

Regulatory Oversight

Regulatory oversight plays a crucial role in ensuring the competence and professionalism of seafarers within the global maritime safety framework. STCW Regulation I/4 explicitly requires maritime auditors and marine inspectors to possess adequate competence, professional independence, and a comprehensive understanding of STCW standards and competency-based evaluation systems. Effective oversight mechanisms are essential to ensure that maritime education and training institutions comply with internationally recognized competency standards.

However, several empirical studies indicate that regulatory oversight in many maritime administrations remains limited in effectiveness. In some cases, auditors responsible for evaluating maritime training institutions lack specialized certification or sufficient experience in competency-based assessment methodologies. As a result, audit processes tend to emphasize administrative compliance rather than evaluating the substantive quality of training outcomes or the operational competence of graduates. Such administrative-oriented supervision often fails to identify structural weaknesses within maritime education systems, thereby allowing training deficiencies to persist [19].

Consequently, the effectiveness of regulatory supervision becomes limited in ensuring that training institutions genuinely produce competent seafarers capable of operating safely in complex maritime environments.

Responsibilities of Shipping Companies

From the perspective of shipping companies, low seafarer competency is also influenced by recruitment practices that are not fully aligned with competency-based standards. Several studies indicate that some shipping companies continue to recruit seafarers primarily based on certificate availability rather than through rigorous competency verification procedures. In many cases, recruitment processes do not involve qualified maritime experts or systematic validation of the authenticity and relevance of competency certificates.

Moreover, shipping companies frequently fail to implement continuous competency monitoring mechanisms for seafarers throughout their employment. Without periodic evaluation, retraining programs, or competency development initiatives, seafarers may experience gradual degradation of professional skills due to technological changes, evolving operational procedures, and increasingly complex maritime environments.

Previous research highlights that companies' failure to verify crew competence and provide continuous professional development significantly increases the likelihood of operational errors and unsafe decision-making on board ships. Such practices ultimately contribute to higher maritime accident risks, particularly in commercial and passenger shipping operations [1], [9].

Quality of Training Institutions

The quality of maritime education and training institutions represents a fundamental factor in shaping the competence of seafarers. Effective training systems require strong institutional commitment to quality management, adequate training infrastructure, qualified instructors, and competency-based curriculum implementation aligned with international maritime standards.

Empirical studies show that several structural issues continue to affect the effectiveness of maritime training institutions. These include limited simulation facilities, outdated training materials, insufficient instructor qualifications, and weak institutional quality assurance systems. Such deficiencies directly affect the learning outcomes of maritime cadets and reduce their preparedness to handle real operational challenges in modern shipping environments [2].

In addition, ineffective learning processes such as overly compressed training schedules, reliance on theoretical instruction without sufficient practical simulation, subjective evaluation systems, and low levels of instructor professionalism may result in training graduates who possess formal certification but lack the practical competence required for safe maritime operations. Recent research emphasizes that deficiencies in training quality significantly increase the risk of operational errors and contribute to accident occurrence in maritime environments [5], [14].

These findings indicate that maritime safety challenges cannot be explained solely by individual human error but must be understood through the interaction of regulatory oversight, training quality, and organizational safety practices within the maritime industry.

Table 1. Summary of Previous Research Related to Seafarer Competence and Maritime Accidents

No	Author & Year	Research Focus	Methods & Data	Key Findings	Relevance to This Article
1	Meštrović et al.	Maritime education and	Systematic literature	Training quality directly influences	Supports the argument that
Analysis of the Impact of Low Seafarer Competency on Maritime Accident Trends: Empirical Evidence from 2023–2025. Huske Dwi Gustian					

No	Author & Year	Research Focus	Methods & Data	Key Findings	Relevance to This Article
	[2]	training in modern shipping	review (Scopus, WoS)	maritime safety; seat-time training is ineffective	seafarer quality is determined by training quality rather than certification alone
2	McMahon [3]	Human error in global maritime accidents	Statistical analysis of accidents (2018–2024)	More than 60% of maritime accidents are linked to human error rooted in low competency	Provides empirical evidence connecting seafarer competency with accident trends
3	Çok et al. [5]	Training quality and accident risk	Mixed-method (training audit and European accident data)	Seafarers from low-quality training institutions show higher accident risk	Strengthens the role of STCW Regulation I/6 and I/8
4	Belabyad et al. [1]	Seafarer competence in modern shipping systems	Bibliometric and policy analysis	Failure of companies to verify crew competence increases accident risks	Relevant to STCW Regulation I/14 (Company Responsibility)
5	Chauvin et al. [4]	Human and organizational factors in maritime accidents	Accident investigation analysis	Human and organizational factors dominate accident causation	Reinforces the narrative of human factors as the dominant cause
6	Hetherington et al. [15]	Human element in maritime safety	Safety research review	Situational awareness and communication are critical non-technical competencies	Supports the interpersonal competency dimension
7	Barnett et al. [10]	Human factors governance in shipping	Policy and institutional analysis	Regulatory oversight gaps weaken maritime safety management	Reinforces STCW Regulation I/4 (Control Procedure) issues
8	Rajapakse & Emad [16]	Work culture and procedural compliance	Qualitative study (seafarer interviews)	Procedural uncertainty and competency gaps increase accident risk	Explains mechanisms of human error in maritime operations
9	Sampson et al. [13]	Seafarer competence and organizational pressure	International survey (2023–2024)	Competency gaps are linked to inadequate training and organizational pressure	Highlights organizational influences on seafarer competency

No	Author & Year	Research Focus	Methods & Data	Key Findings	Relevance to This Article
10	Grech et al. [12]	Human factors in maritime operations	Human factors framework analysis	Human-system interaction significantly affects safety outcomes	Provides theoretical foundation for human factor analysis
11	Mevik [8]	Global maritime qualification landscape	Policy analysis	STCW compliance does not necessarily guarantee training quality	Shows the gap between regulation and implementation
12	Kitada & Bhattacharya [14]	Maritime human resource development	Training policy analysis	Improved maritime education systems are required to enhance crew competency	Emphasizes human-resource-based safety governance

3. Method

Types and Approaches to Research

This study employs a mixed-method research design with primary emphasis on a descriptive quantitative approach, complemented by qualitative analysis. This research design was selected because the relationship between seafarer competence and maritime accidents requires both statistical trend analysis and contextual interpretation of systemic safety factors. Mixed-method approaches are widely recognized as suitable for examining complex and multidimensional phenomena related to human factors and safety management in maritime operations [9], [20].

The descriptive quantitative approach was applied to identify and analyze maritime accident trends during the 2023–2025 period, including accident types, frequency of occurrence, and their relationship with indicators of seafarer competence. Meanwhile, the qualitative component was used to explore the perceptions, institutional practices, and operational challenges faced by regulators, shipping companies, maritime education and training institutions, and seafarer associations in ensuring seafarer competency standards. The integration of these two approaches enables the study to generate findings that are not only descriptive but also explanatory regarding systemic safety challenges in the maritime sector.

Data Sources and Types

This research utilizes both secondary and primary data sources. Secondary data consist of global and regional maritime accident statistics for the 2023–2025 period obtained from official reports of the International Maritime Organization (IMO), national maritime safety authorities, and internationally recognized maritime accident databases. These data include information regarding accident types (such as collisions, groundings, fires, and loss of stability), accident causes, and the contribution of human factors to incident occurrence.

Previous maritime safety research indicates that more than 60% of maritime accidents are associated with human-related factors [3], [4]. Additional secondary data include audit reports of maritime training institutions, STCW compliance assessments, and relevant international and national regulatory documents, particularly:

- STCW Convention and Code (2017)

- b. International Safety Management (ISM) Code (2018)
- c. Minister of Transportation Regulation No. PM 45 of 2012 on Ship Safety Management

These documents are used to evaluate the alignment between regulatory requirements and the actual implementation of seafarer competency systems in practice.

Primary data were obtained through semi-structured interviews and limited field observations involving key stakeholders in the maritime safety system. Interview participants included representatives from maritime regulators, shipping company management, maritime training institutions, and seafarer associations. Interviews focused on issues related to competency supervision, recruitment practices, training quality, and institutional challenges in implementing the STCW Convention and the ISM Code.

Data Collection Techniques

Quantitative data were collected through documentation analysis of maritime accident reports and international shipping safety databases covering the period from 2023 to 2025. The collected data were classified based on year of occurrence, geographic area of operation, vessel type, and primary accident causes in order to identify patterns and trends within maritime accident statistics.

Qualitative data were obtained through in-depth interviews with purposively selected key informants, namely individuals directly involved in the supervision, management, or implementation of seafarer competency systems. The purposive sampling technique was selected to ensure that interview participants possess relevant experience and institutional knowledge related to maritime safety governance.

Data Analysis Techniques

Data analysis was conducted through several integrated stages.

First, descriptive statistical analysis was used to examine the frequency, distribution, and trends of maritime accidents during the study period. This analysis aimed to identify accident patterns, including the prevalence of specific accident types related to human factors.

Second, a correlation analysis was conducted between seafarer competency indicators—such as certification levels, training audit results, and STCW non-compliance findings—and the frequency and type of maritime accidents. This analysis was intended to evaluate the relationship between seafarer competency quality and maritime accident risks [5].

Third, the study developed an accident-cause matrix, mapping seafarer competency components (technical, managerial, and non-technical competencies) against specific accident types. This matrix functions as an analytical tool for identifying dominant competency-related risk factors associated with particular maritime accidents, such as collisions or navigational errors.

Fourth, a systemic analysis was conducted by integrating quantitative accident data with qualitative findings from stakeholder interviews. This analysis aimed to evaluate how failures within one subsystem—such as regulatory oversight, training institutions, or corporate recruitment practices—may influence other subsystems and collectively increase maritime accident risks. The analysis framework follows the systems thinking approach to safety management, which emphasizes that accidents often result from systemic interactions rather than isolated individual failures [21], [22].

Research Validity and Reliability

To ensure the validity and reliability of the research findings, the study applied data triangulation techniques by comparing multiple sources of information, including accident databases, regulatory audit documents,

and interview findings. Triangulation strengthens the credibility of the results by ensuring consistency across different types of evidence.

Furthermore, the analytical framework of this research was developed based on internationally recognized maritime safety standards, particularly the STCW Convention and the ISM Code, to ensure alignment between theoretical frameworks, regulatory standards, and empirical observations. Through this approach, the study aims to produce findings that are both academically robust and relevant for maritime safety policy development.

4. Results and Discussion

Maritime Accident Trends 2023–2025

Analysis of global and regional maritime accident data for the period 2023–2025 indicates that maritime accidents remain dominated by three primary types: collisions, groundings, and sinkings/capsizing incidents. These categories consistently appear as the most frequent accident types reported in international maritime safety reports across commercial shipping, passenger vessels, and specialized maritime operations. This pattern indicates that the primary risks in modern maritime operations remain strongly associated with navigational activities and operational decision-making and onboard safety management rather than purely technical failures of ship systems[23].

Although the total number of maritime accidents between 2023 and 2025 fluctuates across regions and operational contexts, the proportion of accidents associated with human error shows a persistent trend. This phenomenon is particularly evident in maritime areas with high traffic density, such as major international shipping routes and coastal waters with intensive maritime activities. Safety assessments conducted by international maritime organizations highlight that increasing operational complexity, time pressure, and variations in crew competency significantly contribute to the occurrence of operational errors at sea [24].

Table 2 Distribution of Maritime Accident Types and Dominant Contributing Factors (2023–2025)

Types of Accidents	Average Percentage	Dominant Factors
Collision	38–42%	Navigation errors, communication failures, decision-making errors
Grounding	27–31%	Limited navigational competence and situational awareness
Sinking / Capsizing	18–22%	Errors in stability management and emergency response
Other	7–10%	Technical failures and environmental factors

Source: Synthesized by the author based on data from IMO GISIS, EMSA reports, and empirical maritime safety studies [3], [5], [19]

Caption:

This table presents the average distribution of maritime accident types and their dominant contributing factors during the 2023–2025 period.

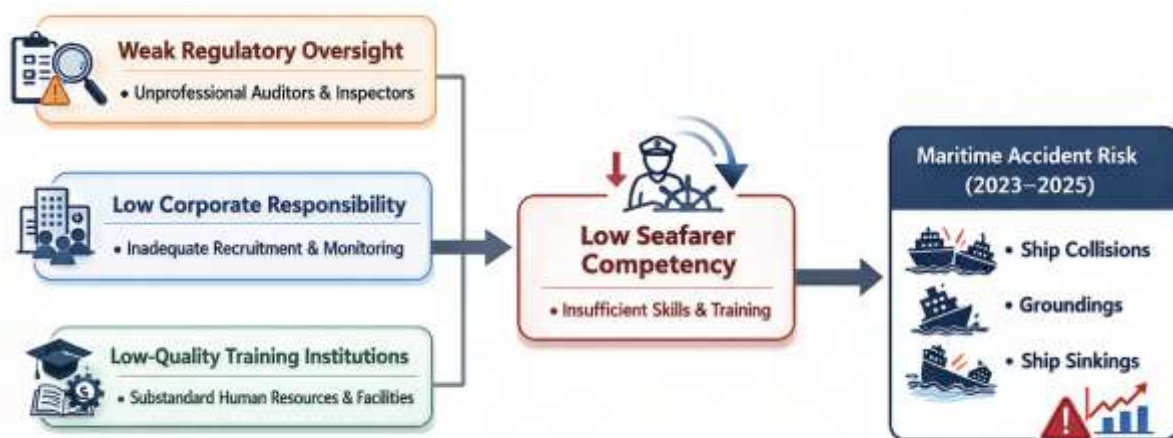
Furthermore, the synthesis of accident data indicates that approximately 60–70% of maritime accidents during the study period are directly associated with human factors, particularly those rooted in low seafarer competence. These competencies include technical skills such as navigation and equipment operation, managerial competencies related to decision-making and leadership, and non-technical skills including communication, teamwork, and situational awareness. These findings confirm that even as navigation

technologies and automation systems continue to evolve, human competence remains the central determinant of maritime safety performance [3], [12].

In many collision and grounding incidents, accident investigation reports demonstrate that navigational errors are rarely caused by equipment malfunction. Instead, they are frequently associated with the crew's inability to correctly interpret navigational data, maintain effective bridge communication, or follow established operational procedures. Similar patterns are observed in sinking accidents, where failures in stability management and emergency response procedures often stem from insufficient practical training and limited understanding of safety protocols. These findings illustrate a persistent gap between the competencies prescribed by regulatory frameworks and the competencies actually demonstrated in operational practice [5].

These findings are consistent with contemporary maritime safety research indicating that technological modernization alone cannot significantly reduce accident rates. McMahon argues that excessive reliance on automation may even increase the likelihood of operational errors when not supported by adequate crew competence and training [3]. Similarly, other studies demonstrate that the quality of maritime training systems and competency assurance mechanisms has a stronger influence on accident prevention than the sophistication of onboard technological systems [12].

Figure 1 Systemic Factors Contributing to Low Seafarer Competency and Maritime Accident Risk (2023–2025)



Caption:

Figure 1 illustrates the systemic relationship between weak regulatory oversight, limited corporate responsibility, and inadequate training institution quality, which collectively contribute to reduced seafarer competency. This competency gap increases the risk of maritime accidents, particularly collisions, groundings, and vessel sinkings during the 2023–2025 period.

From a regulatory perspective, these findings indicate that the implementation of the Standards of Training, Certification and Watchkeeping for Seafarers (STCW) has not yet fully achieved its principal objective of reducing accidents caused by human error. Although the STCW Convention provides comprehensive regulations regarding training standards, certification procedures, and competency monitoring systems, accident trends during the 2023–2025 period reveal a significant gap between regulatory standards and operational practices. This situation highlights the urgent need to strengthen regulatory oversight mechanisms, enhance corporate responsibility within shipping companies, and improve the governance of maritime education and training institutions as an integrated maritime safety system [22], [23].

Analysis of Low Competency Factors

The results of this study indicate that low seafarer competency should not be interpreted merely as an individual deficiency, but rather as a systemic problem arising from interactions among multiple actors within the maritime safety ecosystem. The analysis highlights three primary determinants regulatory: oversight, shipping company responsibility, and the quality of maritime education and training institutions which collectively shape the competency level of seafarers as outputs of the maritime governance system.

Regulatory Oversight

Analysis of audit documents and stakeholder interviews reveals that limited professionalism among maritime auditors and inspectors constitutes a major factor contributing to the persistence of low seafarer competence. In several cases, auditors responsible for evaluating maritime training institutions lack specialized certification or adequate understanding of competency-based auditing systems. As a result, audit practices frequently emphasize administrative compliance such as document completeness and procedural conformity rather than assessing the actual competency outcomes of training programs.

This situation contradicts the fundamental principle of STCW Regulation I/4 (Control Procedures), which requires flag states to ensure effective and objective supervision of seafarer training and certification systems [18]. The regulation explicitly requires competent and independent auditors capable of evaluating the consistency between established standards and operational practices.

When supervision becomes primarily administrative, competency certificates risk losing their substantive meaning as indicators of professional capability. Consequently, individuals with limited operational competence may still obtain certification. Empirical studies demonstrate that failures in regulatory supervision significantly increase the likelihood of human error in maritime operations and weaken overall maritime safety governance [3], [9]. Therefore, weak regulatory oversight can be considered the starting point of a systemic chain of maritime safety risks.

Responsibility of Shipping Companies

From the perspective of shipping companies, the study finds that the selection and monitoring of crew competency remain insufficient in many operational contexts, particularly in companies that prioritize cost efficiency and rapid crew deployment. Recruitment decisions are often based solely on the administrative validity of certificates rather than comprehensive competency verification.

Such practices contradict the provisions of STCW Regulation I/14 (Company Responsibility), which requires shipping companies to ensure that all employed seafarers possess competencies appropriate to their assigned duties [18]. The STCW framework further obligates companies to conduct continuous competency monitoring through retraining programs and periodic performance evaluations.

The absence of continuous competency monitoring results in crews that are insufficiently prepared to operate in increasingly complex maritime environments characterized by dense shipping traffic, advanced navigation technologies, and high operational pressure. Previous studies demonstrate that the failure of shipping companies to systematically verify and maintain crew competence is associated with increased accident risks caused by operational errors and flawed decision-making [1], [9]. In this context, shipping companies may function as risk amplifiers when organizational responsibility for crew competency is neglected.

Quality of Education and Training Institutions

The analysis also indicates that the quality of maritime education and training institutions remains a fundamental issue affecting the development of seafarer competencies. Ineffective training processes such as outdated curricula, limited simulation facilities, and instructors who do not fully meet STCW qualification requirements produce graduates who are formally certified but insufficiently prepared for the operational realities of shipboard service.

This situation contradicts the requirements of STCW Regulation I/6 (Training and Assessment) and Regulation I/8 (Quality Standards), which emphasize competency-based training systems and continuous quality assurance mechanisms[18]. The STCW framework explicitly requires training institutions to ensure that competency outcomes are evaluated through practical performance assessment, not merely theoretical examinations or attendance records.

These findings are consistent with empirical studies demonstrating that weak institutional commitment to quality management, limited resources, and inadequate training infrastructure significantly contribute to reduced graduate competency levels. Research by Meštrović et al. and Čok et al. confirms that deficiencies in maritime training quality directly influence operational safety performance in shipping activities [2], [5].

These results reinforce the argument that low seafarer competency represents a structural problem originating from systemic weaknesses in maritime education and training systems, rather than solely the result of individual shortcomings among seafarers.

Systemic Relationships Between Actors in Maritime Safety

The results of this study indicate that regulators, shipping companies, and maritime education and training institutions cannot be understood as independent entities. Instead, they form an interdependent maritime safety ecosystem in which each actor influences the overall performance of the system. From a systems thinking perspective, the quality of seafarer competence represents a collective outcome of interactions among these actors, while maritime accidents represent failures of the system in managing safety risks in an integrated manner [21], [22].

The findings show that weaknesses within one component of the system can trigger cascading effects throughout the maritime safety structure. For example, weak regulatory oversight—such as administrative STCW audits—allows training institutions to maintain suboptimal training standards without meaningful corrective action. This condition is further aggravated when shipping companies recruit seafarers without rigorous competency verification and provide limited monitoring of professional development during employment. Consequently, the system produces seafarers who may possess formal certification but lack the operational competence required to manage risks effectively on board vessels [1], [9].

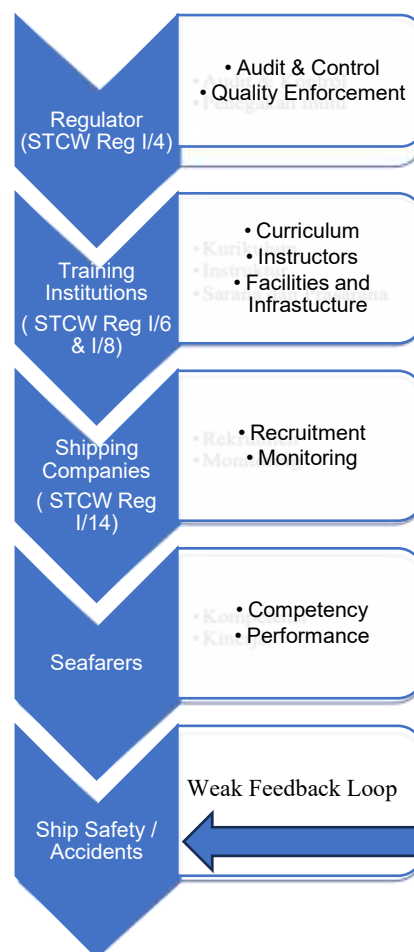
Within this systemic framework, seafarer competence becomes the convergence point of the entire maritime governance structure. When competency levels are inadequate, the probability of human error increases significantly, particularly in complex navigation situations, emergency decision-making, and bridge team coordination. Numerous maritime safety studies confirm that modern maritime accidents are rarely caused by isolated individual mistakes; instead, they typically result from systemic failures involving organizational, technological, and human components [3], [22].

Furthermore, this study identifies the existence of a vicious cycle in maritime safety governance. High accident rates caused by competency gaps are often followed only by administrative responses, such as tightening documentation procedures or introducing additional formal requirements. However, these measures rarely address the structural weaknesses in training systems and regulatory supervision. Without an effective feedback mechanism connecting accident investigations, competency evaluation, and

regulatory reform, the maritime safety system tends to reproduce the same weaknesses across successive generations of seafarers [5].

This situation contradicts the fundamental principles of STCW Regulation I/8 (Quality Standards) and the International Safety Management (ISM) Code, both of which emphasize continuous improvement through systematic feedback, safety audits, and learning from operational incidents. Failure to utilize maritime accidents as a source of systemic learning may lead to stagnation or even deterioration in the quality of maritime training systems and safety management practices [11], [18].

Figure 2 Systemic Relationship between Regulatory Oversight, Training Quality, Corporate Responsibility, and Accident Risk



Caption:

Figure 2 demonstrates that failures in regulatory oversight, training quality, and corporate responsibility collectively lead to low seafarer competence. In the absence of effective feedback mechanisms, maritime accidents fail to generate systemic improvements, causing safety risks to persist and recur within the maritime safety system.

From a policy perspective, these findings indicate that improvements in maritime safety cannot be achieved through isolated interventions. Instead, integrated institutional reforms are required. These reforms include strengthening the capacity of maritime regulators, professionalizing STCW auditing systems, improving the governance and quality of maritime training institutions, and reinforcing the responsibility of shipping companies in verifying and maintaining crew competence.

In this context, seafarers' professional associations may play an important role as independent oversight actors capable of supporting transparency and accountability within maritime safety governance. Previous

research suggests that non-state actors can contribute significantly to improving maritime safety by advocating professional standards, promoting continuous learning, and providing feedback on training and recruitment practices [3], [24].

Therefore, understanding the systemic relationships among actors in maritime safety not only explains the underlying causes of low seafarer competence but also provides a conceptual foundation for developing more effective and sustainable maritime safety policies.

Discussion

The findings of this study reinforce the consensus in international maritime safety literature that human factors remain the dominant cause of maritime accidents. Previous empirical studies indicate that more than 60% of global ship accidents are associated with human error, particularly errors related to decision-making, communication, and the implementation of safety procedures [3]. These findings are consistent with the results of the present study, which show that maritime accidents occurring during the 2023–2025 period particularly collisions, groundings, and sinkings are still predominantly linked to human-related factors rather than purely technical failures. Similar conclusions are reported in international accident investigation databases compiled by maritime safety authorities and global maritime organizations [19].

Likewise, recent research emphasizes that the quality of seafarer education and training has a strong correlation with accident rates in maritime operations. Studies demonstrate that accidents are significantly more frequent in situations where training programs are not competency-based and lack effective quality assurance mechanisms [15]. The findings of the present study expand this argument by showing that low seafarer competency is not solely a consequence of weaknesses within training institutions, but also the result of systemic failures involving regulators and shipping companies. Consequently, this study contributes to the literature by presenting recent empirical evidence that integrates these actors within a comprehensive maritime safety ecosystem framework.

Despite the existence of international regulatory instruments, the results of this study reveal a persistent gap between STCW standards and operational practices in the maritime industry. Normatively, the STCW Convention provides a comprehensive framework addressing regulatory supervision (Regulation I/4), training and assessment (Regulation I/6), quality assurance systems (Regulation I/8), and corporate responsibilities (Regulation I/14). However, empirical evidence indicates that the implementation of these regulations frequently remains compliance-based, emphasizing documentation and administrative conformity rather than evaluating the actual operational competence of seafarers. This implementation gap explains why maritime accidents caused by human error continue to occur at significant rates despite the long-standing presence of international safety regulations [18].

From a theoretical perspective, these findings align with the systems theory approach and the concept of organizational accidents, which argue that accidents result from the accumulation of latent failures within complex socio-technical systems rather than solely from individual mistakes [21], [22]. In the maritime context, weaknesses in regulatory auditing, inadequate corporate monitoring of crew competence, and deficiencies in training quality create latent systemic conditions that eventually manifest as operational failures on board vessels. Therefore, the present study strengthens the argument that maritime safety improvement should focus on systemic institutional reform, rather than relying exclusively on individual disciplinary enforcement.

The practical implication of these findings is the importance of strengthening independent oversight mechanisms within maritime governance. One potential mechanism is the involvement of seafarers' professional associations. Such organizations can function as independent quality-assurance actors by

advocating competency standards, providing feedback regarding training and recruitment practices, and facilitating collective learning from maritime accidents. Previous research indicates that the involvement of non-state actors in maritime governance can significantly enhance accountability and help reduce implementation gaps between regulatory frameworks and operational practice [9], [24].

Nevertheless, this study has several limitations. First, access to fully standardized cross-country maritime accident data remains limited, which means that the analysis relies on a synthesis of multiple secondary data sources. Second, the limited number of interview participants may restrict the generalizability of qualitative findings. Future research should therefore employ longitudinal datasets with broader geographical coverage, as well as apply inferential quantitative methods such as regression analysis or structural equation modelling to improve the robustness and generalizability of empirical findings.

Overall, the discussion confirms that low seafarer competency constitutes a structural and systemic challenge within the maritime safety system. By integrating recent empirical evidence, maritime safety theory, and international regulatory frameworks, this study provides a conceptual and empirical foundation for policymakers and maritime stakeholders to develop more effective and sustainable maritime safety improvement strategies.

5. Conclusion

This study concludes that low seafarer competency constitutes a significant and systemic factor contributing to maritime accidents during the period 2023–2025. Empirical findings demonstrate that maritime accidents particularly collisions, groundings, and sinkings are not solely caused by technical failures or environmental conditions but are predominantly associated with human error rooted in limitations of technical, managerial, and non-technical competencies among seafarers. These findings reinforce the widely accepted view in maritime safety research that human factors remain the principal determinant of maritime safety performance, even in the context of rapid technological advancement and increasing automation in shipping operations [3], [23].

Furthermore, this study provides a deeper understanding that low seafarer competency should not be interpreted merely as an individual deficiency but rather as the outcome of systemic weaknesses within the maritime safety ecosystem. Three dominant factors were identified: weak regulatory oversight, insufficient responsibility of shipping companies in ensuring crew competence, and suboptimal quality of maritime education and training institutions. These factors interact within the maritime governance system and create latent conditions that ultimately increase the probability of human error during ship operations. This systemic interpretation is consistent with organizational accident theory, which emphasizes that accidents emerge from accumulated structural failures within complex socio-technical systems rather than from isolated individual mistakes [21], [22].

In relation to previous studies, the results of this research confirm and expand earlier findings that demonstrate a strong correlation between seafarer competency and maritime accident rates. Previous empirical analyses have shown that inadequate competency levels significantly increase the likelihood of operational errors and unsafe decision-making in maritime environments [3], [5]. The main contribution of this study lies in integrating recent empirical evidence from the 2023–2025 period with the international regulatory framework of the STCW Convention. Through this integration, the study clearly identifies a persistent gap between normative regulatory standards and their practical implementation within maritime governance systems.

From a social and institutional perspective, the findings indicate that maritime safety cannot be achieved solely through stricter formal regulations or additional administrative requirements. Without improvements

in implementation quality, regulatory oversight effectiveness, and institutional learning from maritime accidents, the maritime safety system risks stagnation. Therefore, this study emphasizes the need to shift from a compliance-based regulatory approach toward a competency-based safety management paradigm in maritime governance.

This study has several limitations. First, access to standardized cross-country maritime accident datasets remains limited, which required the analysis to rely on synthesized information from multiple secondary sources. Second, the number of interview informants was relatively limited, which may constrain the generalizability of qualitative findings. Nevertheless, the qualitative approach adopted in this study enabled an in-depth exploration of systemic mechanisms and institutional dynamics that are difficult to capture solely through quantitative methods. These limitations also provide opportunities for future research to expand data coverage and apply more advanced analytical methods in order to deepen the understanding of the relationship between seafarer competence and maritime safety outcomes.

6. References

- [1] M. Belabyad, C. Kontovas, R. Pyne, and C. H. Chang, "Skills and competencies for operating maritime autonomous surface ships," *Maritime Policy & Management*, 2026, doi: 10.1080/03088839.2025.2475177.
- [2] T. Meštrović, I. Pavić, M. Maljković, and A. Androjna, "Challenges for the Education and Training of Seafarers in the Context of Autonomous Shipping: Bibliometric Analysis and Systematic Literature Review," Apr. 01, 2024, *Multidisciplinary Digital Publishing Institute (MDPI)*. doi: 10.3390/app14083173.
- [3] R. McMahon, "Human error and maritime accident causation," *Maritime Policy & Management*, 2025.
- [4] C. Chauvin, S. Lardjane, G. Morel, J. Clostermann, and B. Langard, "Human and organisational factors in maritime accidents," *Saf. Sci.*, vol. 59, pp. 26–37, 2013, doi: 10.1016/j.ssci.2013.06.006.
- [5] G. Cok, A. Androjna, I. Pavic, and M. Maljkovic, "Training quality and human error in maritime operations," *Maritime Policy & Management*, 2025.
- [6] B. M. Batalden and A. K. Sydnes, "Maritime safety and the ISM Code," *Maritime Policy & Management*, vol. 41, no. 3, pp. 293–309, 2014, doi: 10.1080/03088839.2014.932961.
- [7] M. Belabyad, C. Kontovas, R. Pyne, W. Shi, and N. Li, "The human element in autonomous shipping," *Journal of Maritime Economics & Logistics*, 2025, doi: 10.1007/s13437-025-00366-9.
- [8] C. Mevik, "Maritime skills and the changing qualification landscape," *Public Anthropologist*, 2024, doi: 10.1163/25891715-06020005.
- [9] P. Manuel, "Training and certification in the maritime sector," *Maritime Policy & Management*, 2017, doi: 10.1080/03088839.2017.1317688.
- [10] M. Barnett, D. Gatfield, and C. Pekcan, "Barriers to progress in human factors in shipping," *Maritime Policy & Management*, 2006, doi: 10.1080/03088830600688444.
- [11] IMO, "International Safety Management (ISM) Code," 2018.
- [12] M. Grech, T. Horberry, and A. Smith, *Human Factors in the Maritime Domain*. CRC Press, 2008. doi: 10.1201/9781315598895.
- [13] H. Sampson, "Seafarer competence, organizational pressure and safety outcomes," *Saf. Sci.*, 2025, doi: 10.1016/j.ssci.2025.105394.
- [14] A. O. Kitada and P. Bhattacharya, "Human resource development and training in the maritime industry," *WMU Journal of Maritime Affairs*, 2019, doi: 10.1007/s13437-019-00167-2.
- [15] C. Hetherington, R. Flin, and K. Mearns, "Safety in shipping: the human element," *J. Safety Res.*, 2006, doi: 10.1016/j.jsr.2006.04.007.

- [16] A. Rajapakse and G. Emad, "Work procedure uncertainty and maritime accidents," *Australian Journal of Maritime & Ocean Affairs*, 2025.
- [17] C. Kontovas and H. Psaraftis, "Maritime safety and human element in shipping," *Transportation Research Part A*, doi: 10.1016/j.tra.2019.02.012.
- [18] IMO, "STCW Convention and STCW Code 2017 Edition," 2017.
- [19] IMO, "Global Integrated Shipping Information System (GISIS)." [Online]. Available: <https://gisis.imo.org/Public/MCIR/InvestigationReportsDashboard.aspx>
- [20] J. W. Creswell and V. L. Plano Clark, *Designing and Conducting Mixed Methods Research*. Sage, 2018.
- [21] N. G. Leveson, *Engineering a Safer World: Systems Thinking Applied to Safety*. MIT Press, 2016. doi: 10.7551/mitpress/8179.001.0001.
- [22] J. Reason, *Managing the Risks of Organizational Accidents*. Routledge, 2016. doi: 10.4324/9781315543543.
- [23] KNKT, "KNKT Maritime Accident Statistics," 2025, Accessed: Mar. 06, 2026. [Online]. Available: <https://knkt.go.id>.
- [24] EMSA, "Annual Overview of Marine Casualties and Incidents 2025," 2025. [Online]. Available: <https://www.emsa.europa.eu/accident-investigation-publications/annual-overview.html>