GOLDEN RATIO OF HUMAN RESOURCE MANAGEMENT
VOLUME 6, ISSUE. 2 (2026)
Website: https://goldenratio.id/index.php/grhrm

ISSN [Online]: 2776-6365

HUMAN RESOURCE MANAGEMENT | RESEARCH ARTICLE

Maritime Safety Education Management for Reducing Human-Error Risk on Board Ships: An Integrative Literature Review

Sarifuddin[1], Rachmat Pramukty[2]

[1]Department of Engineering, Politeknik Ilmu Pelayaran Makassar, Makassar, Indonesia.
E-Mail: sarifuddin@pipmakassar.ac.id
[2]Faculty of Economic and Business, Universitas Bhayangkara Jakarta Raya, Jakarta, Indonesia.
E-Mail: rachmat.pramukty@dsn.ubharajaya.ac.id

ARTICLE HISTORY

Received: December 11, 2025
Revised: May 07, 2026
Accepted: July 31, 2026

DOI
https://doi.org/10.52970/grhrm.v6i2.2573

ABSTRACT

Maritime transportation plays a vital role in global trade and economic connectivity, particularly in archipelagic countries such as Indonesia. Despite advances in navigation technology, safety regulation, and seafarer certification, human and organizational factors remain recurrent concerns in maritime accidents. This study synthesizes how maritime safety education can be managed to reduce human-error risk through a structured integrative literature review and qualitative content analysis. The revised evidence base comprises 37 retained sources, including 31 peer-reviewed journal articles and six official or professional documents covering international and Indonesian regulation, accident investigations, and recognized maritime practice. Because the study relies on secondary evidence and does not test primary quantitative data, the relationships in the proposed model are treated as conceptual propositions rather than empirically established causal effects. Across heterogeneous evidence, fatigue, limited situational awareness, ineffective communication, inadequate training, and weak safety culture recur as interrelated risk themes. The synthesis organizes maritime safety education through interconnected planning, organizing, actuating, and controlling functions, supported by competency-based curriculum design, qualified instructor development, simulator-supported experiential learning, Bridge Resource Management and Engine Room Resource Management, continuous competency assessment, and feedback from accidents and near-miss reports. The proposed adaptive and learner-centered model positions seafarer competence and safety culture as two linked pathways through which integrated education management may reduce human-error risk. The model provides a conceptual basis for empirical validation and for continuous improvement by maritime education institutions, shipping companies, and regulators.

Keywords: Education Management, Human Error, Maritime Safety, Seafarer Competence, STCW.
JEL Code: E44, F31, F37, G15

I. Introduction

Maritime transportation is a fundamental component of the global economy because more than 80% of world merchandise trade by volume is transported by sea. Its strategic importance is especially pronounced in Indonesia, where shipping connects geographically dispersed islands and supports the movement of passengers, goods, and essential commodities. Maritime accidents can therefore generate consequences that extend beyond casualties and asset loss to supply-chain disruption and marine environmental damage (Russo & Musolino, 2024). Indonesian investigations of the KM Sinar Bangun and KM Santika Nusantara accidents further illustrate that unsafe outcomes may involve interacting deficiencies in competence, emergency

ISSN [Online]: 2776-6365

preparedness, supervision, equipment use, passenger control, and regulatory oversight (Komite Nasional Keselamatan Transportasi, 2018, 2021). Technological progress has not eliminated the human element from maritime risk. The widely repeated statement that approximately 80% of maritime accidents are caused by human error is methodologically uncertain, because estimates and definitions vary considerably across studies (Wróbel, 2021). Human error should also not be equated automatically with crew negligence, because unsafe outcomes can emerge from the interaction of individual actions, operational conditions, technology, organizational management, system design, and regulatory supervision (Sánchez-Beaskoetxea et al., 2021). HFACS-based evidence similarly shows that unsafe acts may be shaped by preconditions, supervisory weaknesses, and latent organizational influences (Chauvin et al., 2013).

International standards provide an essential but incomplete response to this problem. The STCW Convention and Code establish minimum requirements for competence, certification, watchkeeping, leadership, teamwork, and modern navigation systems, while the ISM Code requires shipping companies to maintain structured safety-management responsibilities, procedures, training, emergency preparedness, and incident reporting (International Maritime Organization [IMO], 2017, 2018). These instruments make maritime safety both an educational and managerial obligation. Compliance with international requirements does not, however, ensure homogeneous competence across maritime education and training institutions. Curriculum interpretation, instructor currency, access to simulation, assessment validity, and institutional resources may differ substantially, creating variation between prescribed competence and the competence that seafarers can demonstrate in complex shipboard situations (Manuel, 2017; Karahalil et al., 2025). This gap is particularly important when training is evaluated mainly through certification completion rather than through observable operational performance.

The competence challenge is becoming more complex as integrated bridge systems, automation, remote operations, and Maritime Autonomous Surface Ships change the work of maritime personnel. Future operators require conventional seamanship and engineering knowledge together with competence in human-automation interaction, digital systems, remote monitoring, and intervention under uncertainty (Emad & Ghosh, 2023; Brandsæter & Madsen, 2024). Recent simulator research also indicates that learning and supervisory performance depend on scenario complexity, instructional design, feedback, debriefing, and assessment rather than technological fidelity alone (Wiig et al., 2023; Crestelo Moreno et al., 2026). Existing research has addressed accident causation, individual human factors, simulator effectiveness, safety culture, and specific training programs, but these streams are often examined separately. A remaining conceptual gap concerns how education-management functions can systematically connect regulatory requirements and accident evidence with curriculum planning, instructor and facility organization, experiential delivery, competency assessment, organizational learning, and feedback from actual shipboard operations. This gap is especially relevant in Indonesia, where maritime education institutions, shipping companies, regulators, instructors, and accident investigators must coordinate across a dispersed maritime system. Indonesian evidence on just culture also identifies continuing challenges involving trust, motivation to report, and residual blame-oriented practices, showing that competence development must be linked to reporting and organizational learning (Putra et al., 2024). Accordingly, this study aims to: (1) identify the principal human and organizational factors associated with maritime accidents; (2) analyze how planning, organizing, actuating, and controlling functions can be integrated in maritime safety education; and (3) formulate a conceptual maritime safety education management model for reducing human-error risk on board ships. The novelty lies in positioning maritime safety education as a continuous socio-technical management system rather than as a collection of separate certification and training activities.

II. Literature Review and Conceptual Proposition Development

2.1. Socio-Technical Foundation and Integrated Maritime Safety Education Management

Socio-technical systems thinking provides the principal integrative lens for this review. From this perspective, safe shipboard performance is produced by interactions among people, tasks, technology, organizational structures, working conditions, and regulation rather than by individual competence alone. This interpretation is consistent with maritime human-factor research showing that visible unsafe acts can be shaped by preconditions, supervision, and organizational influences (Chauvin et al., 2013; Sánchez-Beaskoetxea et al., 2021). Maritime safety education management is therefore conceptualized as a mechanism for aligning these interacting elements around competence development and safe operational performance. Within this socio-technical lens, the planning-organizing-actuating-controlling (POAC) framework serves as the principal management mechanism. Planning identifies competency gaps, accident and near-miss patterns, regulatory requirements, and technological change; organizing aligns instructors, facilities, technology, financing, and institutional partnerships; actuating converts these resources into competency-based, experiential, and simulator-supported learning; and controlling evaluates competence, workplace behavior, and safety outcomes and returns the evidence to subsequent planning. The functions are treated as an interconnected feedback cycle rather than as independent administrative activities.

Contemporary resilience engineering extends this logic by recognizing that human performance variability is not only a source of error but can also be a source of adaptation in complex safety-critical systems. In offshore human-automation operations, Peng et al. (2023) showed that resilience-oriented assessment can model how operator variability changes with context and system interaction. For maritime education, this implies that training should develop the capacity to recognize, adapt to, and recover from unexpected operational conditions rather than teach only rule compliance. Just-culture and organizational-learning principles provide a complementary social mechanism. Learning from near misses and errors requires credible reporting, psychological safety to communicate operational concerns, and a distinction between unintentional error and reckless conduct. Indonesian exploratory evidence indicates that trust, reporting motivation, and residual blame culture can constrain learning even when formal safety systems exist (Putra et al., 2024). The integrated model therefore combines socio-technical thinking as its overarching theoretical foundation, POAC as its management cycle, and resilience and just-culture principles as contemporary mechanisms that explain adaptation, reporting, and continuous learning.

2.2. Competence Development Through Regulation, Experiential Learning, and Simulation

The International Convention on Standards of Training, Certification and Watchkeeping for Seafarers establishes minimum international requirements for the training, certification, and watchkeeping of seafarers. The STCW Code specifies competency standards through mandatory provisions and competency tables that must be translated into national and institutional curricula. The 2010 Manila Amendments introduced or strengthened requirements related to Electronic Chart Display and Information Systems, leadership and teamwork, hours of work and rest, modern training methodologies, refresher training, and environmental awareness. Although STCW provides a common regulatory foundation, its implementation may vary among countries and maritime education and training institutions. Differences in resources, instructor competence, national regulatory interpretation, organizational culture, and assessment systems can result in different learning experiences and graduate competency levels. Karahalil et al. (2025) found that STCW interpretation is shaped by educational-system and student-related factors, indicating that regulatory compliance does not automatically produce a coherent and effective curriculum.

Competency-based education addresses this challenge by defining learning outcomes in terms of observable workplace performance. Maritime competence should integrate knowledge, practical skills, situational judgment, communication, leadership, and professional attitudes rather than rely exclusively on written examinations. Manuel (2017) explains that maritime education must balance task-oriented vocational preparation with broader academic capabilities that support problem-solving, adaptation, and professional development. This balance is important because modern seafarers are required to operate increasingly complex and digitalized ship systems while maintaining safe judgment under uncertain conditions. Evidence from human-resource management research also supports the importance of competence development. Heslina and Syahruni (2021) found that information technology, human-resource competence, and employee engagement were positively associated with employee performance. Although their research was not conducted in the maritime sector, its findings are relevant because technology cannot independently improve performance without competent and engaged personnel. In maritime operations, the availability of ECDIS, automated engine systems, or advanced communication equipment will not reduce risk when users lack the competence to interpret information and respond appropriately.

Taken together, these studies indicate that regulatory compliance is a necessary boundary condition rather than sufficient evidence of competence. Manuel (2017) emphasizes the balance between vocational and academic capabilities, whereas Karahalil et al. (2025) demonstrate institutional and pedagogical variation

ISSN [Online]: 2776-6365

in simulator-based curricula. The difference in focus is important: regulatory and curriculum studies identify what should be developed, while performance-based studies are needed to establish whether seafarers can actually transfer competence to complex operational conditions. Integrated education management must therefore connect prescribed outcomes with observable performance and continuous assessment.

P1: Integrated maritime safety education management is conceptually associated with higher levels of seafarers' technical and non-technical competence.

Human error in maritime operations should not be interpreted merely as an individual mistake committed by a crew member. Maritime accidents generally emerge from interactions among individual actions, organizational decisions, working conditions, technology, supervision, procedures, and regulatory structures. Hetherington et al. (2006) identified fatigue, stress, situational awareness, communication, decision-making, teamwork, automation, and safety culture as recurring human and organizational factors in shipping accidents. Therefore, human error represents an outcome of a socio-technical system rather than an isolated personal failure. The Human Factors Analysis and Classification System also distinguishes between unsafe acts, preconditions for unsafe acts, unsafe supervision, and organizational influences. Chauvin et al. (2013), in their analysis of maritime collisions, demonstrated that errors at the operational level are connected to supervisory and organizational conditions. This perspective is consistent with the principle that training deficiencies, ineffective communication procedures, inappropriate workload, and weak management oversight may create conditions in which operational errors become more likely.

A broader bibliometric review similarly identified three principal groups of factors associated with maritime human error: human-resource and management factors, socio-technical information-system factors, and individual or cognitive factors. These findings indicate that accident prevention requires organizational learning and safety-management capabilities in addition to individual technical competence (Dominguez-Péry et al., 2021). From the socio-technical perspective, competence is expected to reduce risk only when it can be enacted under realistic organizational and technological conditions. Certification, experience, and technical knowledge may improve the capacity to recognize hazards and select appropriate responses, but fatigue, authority gradients, workload, poor interfaces, and weak supervision can still constrain performance. Competence is therefore treated as an important pathway rather than a sufficient or isolated cause of accident prevention.

P2: Higher seafarer technical and non-technical competence is conceptually associated with lower human-error risk in shipboard operations, conditional on the surrounding operational and organizational context.

Seafarer education has characteristics of adult and professional learning because learners frequently possess prior operational experience and require knowledge that can be directly applied to workplace problems. Effective maritime learning should therefore be relevant, problem-centered, participatory, and connected to authentic shipboard situations. Passive lecture-based teaching may transfer theoretical information but is insufficient for developing situational judgment, coordination, leadership, and decision-making in safety-critical conditions. Case-based learning and simulation provide opportunities for learners to connect new knowledge with prior experience. They also enable participants to examine the consequences of decisions without exposing ships, personnel, cargo, or the environment to actual danger. Simulator-based training is therefore not merely a technological supplement but a structured learning environment in which technical procedures, teamwork, communication, workload management, and emergency responses can be practised.

Kim et al. (2021) explain that maritime simulators support competency development by allowing learners to practise technical and non-technical skills in controlled environments. Simulators also enable instructors to observe performance, provide feedback, repeat scenarios, and gradually increase operational complexity. However, learning effectiveness depends on the suitability of the simulator, the quality of the scenario, the competence of the instructor, and the alignment between training activities and competency outcomes. The educational value of simulation is particularly influenced by briefing, scenario execution, assessment, and debriefing. Sellberg et al. (2018) found that instructional support throughout these stages helps learners connect general navigation principles with specific operational situations. Debriefing enables participants to reconstruct their decisions, recognize errors, evaluate alternatives, and transform experience into professional knowledge. It also allows instructors to evaluate the interrelationship between technical and non-technical performance.

Recent evidence reinforces this contingency. Brandsæter and Madsen (2024) used simulator testing of human-supervised autonomous navigation and showed that operator performance must be assessed under scenarios in which automation can produce suboptimal decisions and human intervention is selectively required. Crestelo Moreno et al. (2026), using high-fidelity maritime simulation with students, professionals, and instructors, reported perceived gains in practical competence while also identifying limitations related to assessment integration, maneuvering tasks, and cost. These studies differ from earlier reviews in method and context, but together they show that simulator fidelity alone is insufficient; scenario validity, instructor facilitation, feedback, and assessment design determine whether simulation becomes meaningful learning.

P3: Well-designed simulator-based learning is conceptually associated with higher seafarer technical and non-technical competence when scenario design, instructor competence, assessment, and reflective debriefing are adequate.

Human error on board ships frequently involves non-technical competencies such as communication, leadership, teamwork, situational awareness, workload distribution, and decision-making. Bridge Resource Management and Engine Room Resource Management were developed to strengthen these competencies by encouraging effective use of personnel, equipment, and information. BRM and ERM emphasize that safe operations depend on team coordination rather than on the isolated capability of the master, officer, or engineer. BRM training provides opportunities for participants to practise information exchange, cross-checking, challenge-and-response communication, distribution of responsibility, and decision-making under pressure. Röttger et al. (2016) found that classroom-based BRM training could improve knowledge, although changes in behavior and operational performance require more than a single training intervention. This finding indicates that non-technical skills must be repeatedly practised, evaluated, and reinforced within the organization's safety-management system. Röttger et al. (2016) found that classroom-based BRM training can improve knowledge but does not by itself ensure durable changes in behavior or operational performance. This finding is theoretically important because it distinguishes short-term learning from transfer to shipboard practice. BRM and ERM should therefore be reinforced through repeated simulator scenarios, onboard drills, leadership practices, assessment, and organizational feedback so that communication and teamwork are enacted under pressure rather than recalled as classroom concepts.

P4: BRM and ERM training are conceptually associated with stronger non-technical competence and potentially lower human-error risk when the learned behaviors are repeatedly practiced, assessed, and reinforced in the workplace.

2.3. Safety Culture, Just Culture, and Continuous Feedback

Safety culture reflects shared values, assumptions, expectations, and practices concerning safety within an organization. A strong safety culture is demonstrated when personnel communicate hazards, follow procedures, report near-misses, question unsafe decisions, and participate in organizational learning. In contrast, a weak safety culture may normalize procedural violations, suppress incident reporting, tolerate fatigue, and prioritize operational targets over risk control. Safety culture also provides the organizational conditions in which competence can be expressed. A technically competent officer may still remain silent when hierarchy, distrust, or fear of blame discourages challenge and reporting. Putra et al. (2024), in an Indonesian exploratory study of seafarers and shipping-company representatives, identified barriers to just culture involving trust, reporting motivation, and blame-oriented practices. In a different context and with a different method, Xi et al. (2025) used survey data from 229 deck officers and captains and found positive relationships between dimensions of safety culture and safety behavior. The qualitative Indonesian evidence and the quantitative Chinese evidence do not establish a universal causal effect, but their methodological complementarity supports safety culture as a plausible organizational pathway connecting education, reporting, and behavior.

Tahapary and Laksono (2025) found that safety leadership significantly supported safety compliance through safety behavior and safety motivation. Their findings indicate that leadership is essential for transforming safety policies into daily conduct. Applied to maritime education, instructors, training managers, masters, and senior officers serve as safety role models whose decisions influence learners' and crew members' willingness to comply with procedures and communicate operational concerns. Safety culture also provides an organizational environment in which competence can be effectively applied. A competent officer may still remain silent when organizational culture discourages questioning senior authority or reporting errors.

ISSN [Online]: 2776-6365

Conversely, a supportive safety culture encourages crew members to use their knowledge, communicate concerns, and intervene before an unsafe condition develops into an accident. Safety culture is therefore conceptualized as an organizational pathway through which education management may influence human-error risk, rather than as an empirically tested mediator in the present review.

P5: Integrated maritime safety education management is conceptually associated with stronger organizational safety culture and just-culture practices.

P6: Stronger safety culture is conceptually associated with lower human-error risk through improved communication, reporting, procedural commitment, leadership, and organizational learning.

The controlling function in maritime safety education should evaluate more than participant satisfaction or examination scores. Evaluation must determine whether learners acquire knowledge, demonstrate competence, change workplace behavior, and contribute to improved safety outcomes. Therefore, evaluation should include written examinations, practical demonstrations, simulator performance, instructor observation, onboard assessment, graduate feedback, employer evaluation, incident trends, and near-miss data. Sulistiyono et al. (2024) applied the Kirkpatrick framework to compare blended and conventional training and found no significant difference between the two delivery methods. This result suggests that the mode of delivery alone does not determine training effectiveness. Learning objectives, participant characteristics, instructional quality, assessment procedures, and organizational support must also be considered. In maritime education, controlling should therefore assess the complete learning system rather than merely compare whether training is delivered face-to-face, online, or through simulation. Evaluation results should be returned to the planning stage. Recurring communication failures can inform BRM scenarios, weaknesses in ECDIS interpretation can trigger curriculum revision, and inadequate emergency performance can influence refresher-training design. This feedback function makes controlling a learning mechanism rather than an end-of-course inspection activity.

P7: Continuous evaluation and feedback are conceptually associated with more effective maritime safety education management by linking learning outcomes and operational evidence to subsequent planning.

2.4. Conceptual Propositions and Integrated Model

The preceding synthesis proposes that integrated maritime safety education management may reduce human-error risk through two interrelated pathways. The competence pathway links POAC functions with curriculum relevance, instructor quality, experiential learning, simulation, valid assessment, and the acquisition of technical and non-technical competence. The safety-culture pathway links consistent education, leadership, reporting, reflective learning, and feedback with a stronger organizational commitment to safe behavior. These pathways should not be interpreted as deterministic. Resilience engineering suggests that effective performance depends on adaptation to changing conditions, while just-culture theory indicates that learning depends on whether personnel can report and discuss error without indiscriminate blame. Consequently, the proposed model treats technology, certification, and isolated training courses as enabling conditions whose effects are shaped by instructional quality, repeated practice, organizational culture, and workplace reinforcement. The model therefore frames human-error reduction as a system-level outcome that may emerge when regulatory requirements, educational management, competence development, safety culture, and operational feedback are aligned.

P8: Integrated maritime safety education management is conceptually associated with lower human-error risk, both directly through more coherent education-management processes and indirectly through stronger seafarer competence and safety culture.

III. Research Method

3.1. Research Design

This study employed a qualitative research design using a structured integrative literature review and qualitative content analysis. An integrative review was selected because the research questions required the critical comparison and synthesis of regulatory, theoretical, empirical, accident-investigation, and industry evidence rather than the estimation of a pooled quantitative effect. The approach follows integrative-review guidance emphasizing transparent search logic, explicit eligibility criteria, critical synthesis, and conceptual development (Snyder, 2019; Torraco, 2005). The review addressed three analytical questions: (1) which human and organizational factors recur in shipboard human-error research; (2) how planning, organizing, actuating, and controlling functions can be applied to maritime safety education; and (3) how these mechanisms can be integrated into a conceptual model for human-error risk reduction. PRISMA 2020 informed the ordering and transparency of the identification, screening, and eligibility description (Page et al., 2021), but the study is not presented as a formally registered systematic review or meta-analysis and does not claim exhaustive quantitative coverage.

3.2. Data Sources

The data analyzed in this study consisted entirely of secondary documents. The sources were classified into five categories. First, international maritime regulations and official publications were collected from the International Maritime Organization, particularly the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers, the International Safety Management Code, and related IMO model courses and guidelines. Second, Indonesian regulations concerning shipping, seafarer education, competency certification, occupational safety, and maritime transportation were reviewed. These sources included laws, government regulations, ministerial regulations, and technical guidelines issued by the Ministry of Transportation. Third, maritime accident investigation reports were obtained from authoritative institutions, including the National Transportation Safety Committee of Indonesia, the European Maritime Safety Agency, and other recognized maritime accident investigation bodies. These reports were used to identify recurring human, technical, supervisory, and organizational factors in maritime accidents.

Peer-reviewed journal articles were identified through Scopus, Web of Science, ScienceDirect, SpringerLink, Taylor & Francis Online, Google Scholar, and publisher search interfaces. The principal evidence window covered January 2010 to August 2026, while seminal publications before 2010 were retained only when they provided foundational theory or established methods. Recent update searching specifically targeted digitalized maritime operations, autonomous shipping, human-automation interaction, simulator-based assessment, resilience, just culture, and contemporary safety-culture management. Fifth, selected maritime industry reports were included when they provided relevant accident statistics, technological developments, or information concerning safety practices. Industry documents were included only when they were published by recognized maritime organizations, classification societies, insurance institutions, or professional bodies and when their data sources and institutional authorship could be clearly identified.

3.3. Search Strategy

The literature search was conducted using combinations of keywords and Boolean operators. The principal search terms included “maritime safety education,” “maritime education and training,” “seafarer training,” “human error,” “human factors,” “safety management,” “safety culture,” “STCW,” “competency-based maritime education,” “bridge resource management,” “engine room resource management,” “maritime simulator training,” and “ship accident.” An example of the search string applied to international journal databases was as follows: (“maritime education” OR “maritime education and training” OR “seafarer training” OR “maritime safety education”) AND (“human error” OR “human factors” OR “safety management” OR “safety culture”) AND (STCW OR simulator OR “bridge resource management” OR “engine room resource management”). Additional searches were conducted using specific combinations, such as “maritime simulator training AND competence,” “ship accident AND human factors,” “STCW implementation AND curriculum,” and “maritime safety culture AND seafarer.” Indonesian keywords, including “pendidikan keselamatan maritim,” “pelatihan pelaut,” “kesalahan manusia pada kapal,” and “manajemen keselamatan pelayaran,” were also used to identify national studies and regulatory documents. Search syntax was adapted to the search functions of

ISSN [Online]: 2776-6365

individual platforms, and backward and forward citation searching was used to identify additional relevant studies. The final evidence update for this revision was completed on 8 August 2026. Exact historical database-level hit counts from the earlier integrative-search stages were not retrospectively reconstructed because they were not preserved consistently in the original review record; no artificial PRISMA counts were introduced during revision.

3.4. Eligibility Criteria

The literature was selected according to predefined inclusion and exclusion criteria. A document was included when it met the following requirements:

a. It examined maritime education and training, seafarer competence, maritime safety management, human factors, human error, safety culture, simulator-based education, BRM, ERM, or other closely related subjects.
b. It was published as a peer-reviewed journal article, official regulation, accident investigation report, institutional report, or recognized maritime industry publication.
c. It provided theoretical, empirical, regulatory, or practical information relevant to at least one of the study's analytical dimensions.
d. It was available in English or Indonesian.
e. Its full text was accessible and contained sufficient information for analysis.
f. For scholarly publications, priority was given to articles indexed in Scopus or Web of Science and published by identifiable academic journals.

Documents were excluded when they were duplicated, unrelated to maritime operations, limited to purely technical ship-design issues without a human or educational dimension, available only as abstracts, published by sources with unclear institutional authorship, or did not provide sufficient methodological or analytical information. News articles, personal opinions, commercial promotional materials, student essays, and non-verifiable web content were also excluded. Publications issued before 2010 were generally excluded from the empirical evidence base. Nevertheless, seminal works were retained when they constituted the original source of theories used in this study. The inclusion of foundational literature was explicitly separated from the inclusion of contemporary empirical evidence to prevent older theoretical publications from being interpreted as recent descriptions of maritime conditions.

3.5. Literature Selection

Literature selection followed four documented stages: records were entered into the working reference database and duplicates were removed; titles and abstracts were screened for relevance to maritime safety education, management functions, human factors, or accident prevention; potentially relevant full texts were assessed against the eligibility criteria; and eligible documents were retained for qualitative content analysis. Sources were retained when they contributed directly to at least one analytical question or provided an essential methodological or theoretical foundation. The final documented evidence base comprises 37 retained sources: 31 peer-reviewed journal articles and six official or professional documents, including maritime regulations, accident-investigation reports, institutional publications, and a professional conference source. Because the design is an integrative review rather than an exhaustive systematic review, the final corpus is reported together with the source categories, search logic, eligibility criteria, and coding procedures rather than as a pooled quantitative sample. This distinction avoids presenting unreconstructable historical search counts as if they were prospectively recorded systematic-review data.

3.6. Data Extraction and Quality Assessment

ISSN [Online]: 2776-6365

A structured data-extraction matrix was developed to ensure consistency in the review process. For journal articles, the extracted information included the author, year of publication, country or research setting, research objective, methodological design, participants or unit of analysis, maritime sector, principal human-error factors, educational intervention, main findings, and implications for maritime safety education management. For accident reports, the extracted information covered the type of accident, vessel characteristics, location and year of occurrence, direct causes, contributing human factors, supervisory weaknesses, organizational conditions, training deficiencies, and safety recommendations. For regulatory documents, the analysis focused on competency requirements, education and training obligations, certification standards, institutional responsibilities, assessment provisions, and quality-assurance mechanisms.

The quality and relevance of each source were assessed based on the credibility of the publisher, clarity of the research objective, methodological transparency, relevance to the review questions, adequacy of the evidence presented, and consistency between the data and conclusions. Peer-reviewed empirical studies and official documents were assigned greater evidentiary weight than non-peer-reviewed industry reports. Industry reports were used primarily to provide contextual information and were not treated as substitutes for empirical academic evidence. Quality and relevance were evaluated using publisher or institutional credibility, clarity of the study objective, methodological transparency, direct relevance to the review questions, adequacy of the presented evidence, and consistency between findings and conclusions. Peer-reviewed empirical research and official regulatory or investigation documents were given greater interpretive weight than non-peer-reviewed contextual reports. No source was retained solely because it supported the proposed model, and contradictory or null findings were preserved to reduce confirmation bias.

3.7. Data Analysis

The selected documents were analyzed using qualitative content analysis, which enables systematic condensation of textual evidence, development of categories, comparison of meanings, and conceptual interpretation (Elo & Kyngäs, 2008). The analysis combined deductive codes derived from the review questions with inductive codes that emerged from the evidence. The analysis combined deductive and inductive coding. Deductive coding was based on the study's preliminary analytical framework, consisting of:

a. human and organizational factors contributing to maritime accidents;
b. planning of maritime safety education;
c. organization of instructors, facilities, technology, and institutional cooperation;
d. implementation of competency-based learning;
e. simulator-based training;
f. Bridge Resource Management and Engine Room Resource Management;
g. control, assessment, and continuous evaluation;
h. safety culture; and
i. human-error prevention outcomes.

Operationally, a human-error factor was coded when a source explicitly connected an individual, cognitive, physical, technical, supervisory, or organizational condition with unsafe performance or an accident pathway. Competence was coded as observable or assessable knowledge, technical skill, non-technical skill, judgment, communication, leadership, or adaptive capability. Safety culture included shared safety values, reporting practices, procedural norms, leadership behavior, learning from incidents, and just-culture conditions. Education-management practices were coded according to planning, organizing, actuating, and controlling functions and their documented links to curriculum, resources, implementation, assessment, or feedback. Analysis proceeded in five stages: repeated reading of selected sources; deductive and inductive coding of relevant statements; grouping of related codes into subthemes and broader themes; comparison across journal articles, regulations, accident reports, and professional sources to identify convergence, contradiction, contextual differences, and implementation gaps; and synthesis of the resulting themes into the integrated management model. The structured extraction matrix and coding categories constituted the review's analytical tool; no statistical pooling or automated evidentiary weighting was applied. The POAC framework served as the principal management lens, while socio-technical thinking guided interpretation of the relationships among competence, technology, organization, and regulation. Resilience engineering, just culture, experiential learning, competency-based education, and safety-culture research were used as complementary explanatory perspectives where they addressed mechanisms not captured by POAC alone. This hierarchy clarifies how the theoretical frameworks were integrated rather than treating them as parallel definitions.

3.8. Trustworthiness of the Review

The credibility of the findings was strengthened through source triangulation. Evidence from peer-reviewed research was compared with international regulations, Indonesian regulations, accident investigation reports, and recognized maritime industry publications. A finding was considered more robust when similar patterns were identified across different types of sources. Dependability was strengthened by documenting the source categories, search terms, eligibility criteria, extraction fields, coding categories, and analytical stages. The revised manuscript also distinguishes evidence reported directly by the retained sources from conceptual interpretation developed through the synthesis. Where exact historical database-screening totals were not recoverable from the original integrative-review record, they were not retrospectively invented. The analysis also incorporated contradictory and negative evidence. For example, studies demonstrating that simulator technology or BRM training did not automatically produce behavioral change were considered alongside studies reporting positive learning effects. This procedure was intended to avoid presenting maritime safety education as a single intervention that would independently eliminate human error.

3.9. Development of the Conceptual Model

The conceptual model was developed by integrating three evidence domains. The first domain consisted of recurring human and organizational factors identified in maritime accident research. The second domain concerned educational interventions, including competency-based curricula, simulator-supported learning, BRM and ERM, instructor development, and continuous assessment. The third domain consisted of management mechanisms represented by planning, organizing, actuating, and controlling. Relationships among model components were formulated through explicit synthesis rules. A relationship was treated as conceptually supported when it was consistent with the socio-technical logic of the model and was corroborated by multiple peer-reviewed studies or by convergent evidence across different source types. Contradictory or null findings were used to define boundary conditions rather than discarded. Greater interpretive weight was given to transparent empirical studies and official investigation or regulatory evidence than to contextual professional commentary. Because this study did not collect primary quantitative data, the proposed relationships are presented as conceptual propositions rather than statistically tested causal hypotheses. The model is therefore a conceptual contribution, not a new research method, and it provides a structured foundation for later validation through surveys, structural equation modeling, quasi-experimental designs, longitudinal evaluation, and comparative case research.

3.10. Ethical Considerations

ISSN [Online]: 2776-6365

This study did not involve human participants, personal data, biological materials, or direct interventions. All data were obtained from publicly available academic publications, regulations, institutional documents, and accident reports. Therefore, formal ethical approval and informed consent were not required. Nevertheless, all sources were acknowledged, interpreted cautiously, and cited in accordance with academic integrity principles.

IV. Result and Discussion

4.1. Results

a. Identification of Human-Error Factors in Shipping Accidents

The qualitative content analysis of maritime accident reports, international regulations, and previous empirical studies identified five recurring categories of factors associated with human error in shipboard operations. These categories include fatigue and physical condition, lack of situational awareness, ineffective communication, inadequate training, and weak safety culture. The categories demonstrate that maritime human error does not originate exclusively from individual carelessness but develops through interactions among personal capacity, operational conditions, technological systems, supervision, and organizational practices. The qualitative synthesis is presented in Table 1 as a thematic classification rather than as a percentage distribution. The retained sources use heterogeneous accident taxonomies, research designs, vessel types, populations, and reporting systems; therefore, the review does not calculate pooled contributions, universal probabilities, or a numerical hierarchy among the categories.

Table 1. Categories of Human-Error Contributing Factors on Board Ships

No.	**Category**	**Description**	Analytical Status
1	Fatigue and physical condition	Fatigue due to excessive working hours and inadequate watchkeeping patterns	Recurring qualitative theme
2	Lack of situational awareness	Failure to detect, understand, and project information about the operational environment	Recurring qualitative theme
3	Ineffective communication	Language barriers, ambiguous instructions, and weak closed-loop communication	Recurring qualitative theme
4	Inadequate training	Technical and non-technical competencies below STCW standards	Recurring qualitative theme
5	Weak safety culture	Procedural violations, risk normalization, and low reporting culture	Recurring qualitative theme

Source: Qualitative synthesis based on peer-reviewed maritime human-factor studies and official accident or safety reports, including Hetherington et al. (2006), Chauvin et al. (2013), Wróbel (2021), and European Maritime Safety Agency (2022).

Table 1 shows five recurring qualitative categories: fatigue and physical condition, limited situational awareness, ineffective communication, inadequate training, and weak safety culture. Their importance is interpretive rather than rank-ordered. Together, the categories demonstrate that human error spans physiological, cognitive, educational, interpersonal, technological, supervisory, and organizational dimensions. Fatigue was frequently associated with excessive working hours, disrupted sleep, insufficient rest, and ineffective watchkeeping arrangements. Limited situational awareness was identified when officers or crew members failed to perceive operational information, incorrectly interpreted navigational or engine-room conditions, or could not anticipate how a situation would develop. Communication failures included unclear orders, incomplete information transfer, language differences, failure to confirm instructions, and reluctance to question decisions made by senior officers. Inadequate training was reflected in limited mastery

ISSN [Online]: 2776-6365

of equipment, weak emergency-response skills, insufficient application of procedures, and inadequate development of non-technical competencies. Weak safety culture was indicated by the normalization of procedural deviations, underreporting of near misses, tolerance of fatigue, and an excessive emphasis on operational targets. The identified factors therefore demonstrate that human error should be treated as a system-level safety problem rather than solely as an individual behavioral failure.

b. Planning of Maritime Safety Education

The review findings show that planning is the first essential component of maritime safety education management. Effective planning begins with a training-needs analysis based on competency gaps, accident findings, near-miss reports, regulatory changes, technological development, and feedback from shipping companies. This process enables maritime education and training institutions to identify differences between the competencies currently possessed by seafarers and those required for safe shipboard operations. Planning also includes translating the STCW competency standards into measurable learning outcomes, curriculum structures, assessment criteria, training schedules, and resource requirements. The analysis found that curriculum planning should cover technical competence, non-technical skills, safety attitudes, digital literacy, leadership, teamwork, fatigue management, and emergency preparedness. The development of ECDIS, integrated bridge systems, engine automation, remote monitoring, artificial intelligence, and Maritime Autonomous Surface Ships creates additional competency requirements. Consequently, the maritime safety curriculum needs to operate as a living curriculum that is periodically reviewed rather than as a static document revised only when formal regulations change. The findings further indicate that industry participation is required to ensure that planned learning outcomes remain connected to actual shipboard practices.

c. Organizing Educational Resources

The organizing function involves arranging human resources, learning facilities, institutional responsibilities, and industry partnerships to support the planned competency outcomes. The literature synthesis identified instructor competence as a central organizational resource. Maritime instructors need pedagogical competence, assessment ability, familiarity with current maritime technology, and relevant sea-going experience. The review also identified simulators as important organizational resources. Full-mission bridge simulators, engine-room simulators, cargo-handling simulators, and emergency-response simulations enable learners to experience complex or hazardous situations in controlled environments. Nevertheless, the availability of advanced equipment does not automatically produce effective learning. The learning value of a simulator depends on its alignment with competency objectives, the authenticity of scenarios, the quality of instructor guidance, and the availability of structured debriefing. Institutional cooperation also emerged as an important component of organizing. Maritime education institutions require systematic relationships with shipping companies, port authorities, regulators, certification bodies, and accident investigators. Such cooperation supports instructor updating, onboard training, access to incident data, curriculum validation, and evaluation of graduate performance.

d. Actuating Maritime Safety Education Programs

The actuating function refers to the implementation of planned educational and training activities. The review identified formal seafarer education, refresher training, Basic Safety Training, Advanced Fire Fighting, Medical First Aid, Personal Survival Techniques, Bridge Resource Management, and Engine Room Resource Management as principal forms of maritime safety education. The findings suggest that learning implementation should combine theoretical instruction with case-based learning, problem-based activities, practical exercises, simulator scenarios, onboard training, and reflective debriefing. Conventional lectures remain useful for explaining concepts and regulations but are insufficient when used as the dominant method for developing operational decision-making, teamwork, and emergency-response competence.

BRM and ERM were found to be particularly relevant to the reduction of non-technical errors. These programs develop communication, leadership, teamwork, workload distribution, situational awareness, and decision-making. Effective implementation requires participants to demonstrate these competencies in operational scenarios rather than merely complete classroom attendance. Continuous learning was also identified as an important element. E-learning, webinars, microlearning, cloud-based simulators, supervised onboard practice, and periodic refresher programs can help seafarers maintain their competence during different stages of their careers. However, online delivery must remain connected to authentic assessment and practical performance.

e. Controlling and Evaluation

The controlling function ensures that maritime safety education is delivered according to established standards and produces the expected competencies. The review identified internal quality assurance, regulatory audits, instructor evaluation, competency examinations, simulator-based performance assessment, tracer studies, industry feedback, and analysis of accident and near-miss data as relevant control mechanisms. Training evaluation needs to extend beyond participant satisfaction and examination scores. A comprehensive evaluation should examine participants' reactions, learning achievement, behavioral application, and organizational safety outcomes. Relevant performance indicators include competency-examination pass rates, simulator-assessment results, completion of onboard tasks, employer satisfaction, procedural compliance, near-miss reporting, and trends in human-error-related incidents. The findings indicate that evaluation results should be returned to the planning stage. For example, recurring communication failures should lead to the redesign of BRM scenarios, while weaknesses in fire-response performance should inform refresher-training content. Consequently, controlling creates a continuous improvement cycle linking incident experience, curriculum revision, training implementation, and workplace performance.

f. Integrated Maritime Safety Education Management Model

The synthesis resulted in an integrated maritime safety education management model. The model places the seafarer at the center of the education system and positions planning, organizing, actuating, and controlling as interconnected management functions. The model consists of three major components. The input component includes STCW requirements, the ISM Code, national regulations, industry competency requirements, technological developments, and accident or near-miss data. The process component consists of competency-based curriculum planning, organization of instructors and facilities, implementation of simulator-supported and experiential learning, BRM and ERM training, safety-culture development, and continuous evaluation. The output component is represented by seafarers with adequate technical knowledge, practical skills, non-technical competence, digital adaptability, and safety-oriented attitudes.

The expected long-term outcome is a reduction in the likelihood and consequences of human error. The model proposes two primary pathways through which this outcome may be achieved. The first is the competency pathway, in which education improves technical and non-technical performance. The second is the safety-culture pathway, in which education strengthens communication, procedural compliance, reporting behavior, leadership, and organizational learning. The model is adaptive because curriculum content and training strategies are periodically adjusted to regulatory and technological developments. It is also cyclical because information from shipboard operations is returned to educational institutions as input for subsequent planning and improvement. Its implementation requires collaboration among educational institutions, shipping companies, and government regulators.

g. Lessons Learned from Selected Shipping Accidents

The documentary analysis of Indonesian shipping accidents illustrates how educational, operational, and managerial deficiencies may interact. The sinking of KM Sinar Bangun demonstrated that unsafe outcomes cannot be explained by one crew action alone. Competency, certification, weather-related

ISSN [Online]: 2776-6365

decision-making, passenger control, safety equipment, and regulatory supervision formed interconnected layers of risk. The KM Santika Nusantara fire similarly highlighted the importance of emergency detection, familiarization with fire-control systems, coordinated response, and regular drills. Such findings indicate that possession of a training certificate does not necessarily guarantee that crew members can apply emergency procedures under actual pressure. Practical refresher training and documented drills are therefore required to maintain operational readiness. International accidents, including the Costa Concordia accident, also demonstrate the consequences of weak bridge-team coordination, authority gradients, decision-making failures, and ineffective application of resource-management principles. Collectively, these cases show that actual accident findings should be incorporated into curriculum planning, simulation scenarios, leadership training, and competency assessment.

h. Implementation Challenges and Mitigation Strategies

The review identified structural, financial, pedagogical, technological, regulatory, and cultural challenges in implementing integrated maritime safety education in Indonesia. These challenges and the corresponding mitigation strategies are presented in Table 2.

Table 2. Challenges in Implementing Maritime Safety Education Management in Indonesia

No.	Aspect	Challenge	Mitigation Strategy
1	Curriculum Planning	Slow curriculum revision in facing ship digitalization and new IMO regulations	Establishment of a living curriculum with annual reviews involving industry and KSOP
2	Instructor Qualification	Gap between instructors' sea-going experience and modern learning needs	Instructor certification program based on Train the Trainer IMO Model Course 6.09
3	Simulator Facilities	High procurement and maintenance costs of full-mission simulators	Shared training centers, institutional partnerships, phased procurement, and cloud-based simulation where appropriate
4	Certification and Supervision	Violations in traditional shipping (Pelra) with uncertified crew	Strengthening Ministry of Transportation's audit system and digitalization of certificate databases
5	Safety Culture	Weak reporting culture and normalization of procedural violations on board	Just culture programs, anonymous reporting, and tiered leadership training
6	Industry Linkage	Minimal feedback from shipping companies to training institutions	Regular triple-helix forums and structured tracer studies

Source: Authors' analysis based on the review of regulations, accident reports, and maritime industry practices.

Table 2 shows that curriculum reform alone is insufficient. Curriculum relevance must be supported by instructor development, learning facilities, effective certification, safety leadership, and industry feedback. Limited simulator resources may be addressed through shared training centers, institutional partnerships, cloud-based simulation, and phased technology investment. Weak safety reporting requires both technical reporting mechanisms and cultural change. Anonymous reporting and just-culture policies will not function effectively when leaders respond inconsistently or impose punishment for unintentional errors. Therefore, safety leadership should be incorporated into instructor development and shipboard management training.

ISSN [Online]: 2776-6365

i. Digitalization and Technology in Maritime Safety Education

The review found that virtual reality, augmented reality, artificial intelligence, cloud-based simulators, digital twins, and Learning Management Systems provide new opportunities for maritime safety education. These technologies can expand access to hazardous, complex, or infrequent scenarios, including engine-room fires, collision avoidance, equipment failure, emergency evacuation, and abandon-ship procedures. Artificial intelligence may support adaptive learning by adjusting scenario difficulty, identifying performance patterns, and providing individualized feedback. Cloud-based systems may facilitate continuous learning for seafarers working at different locations. Digital platforms can also support the integration of training records, certification data, competency assessments, and employer feedback. However, technology was identified as an educational enabler rather than a substitute for pedagogical quality. Its effectiveness depends on clear learning objectives, scenario validity, instructor competence, participant digital literacy, reflective debriefing, and cybersecurity protection. Uncritical technology adoption may increase costs without producing meaningful competency development.

4.2. Discussion

a. Human Error as a Socio-Technical and Organizational Problem

The identification of fatigue, situational-awareness failure, communication problems, inadequate training, and weak safety culture supports a socio-technical interpretation of maritime human error. Hetherington et al. (2006) synthesized a broad human-element literature and emphasized fatigue, stress, communication, teamwork, decision-making, automation, and safety culture. Chauvin et al. (2013), by contrast, analyzed collision cases through a maritime adaptation of HFACS and linked unsafe acts with preconditions, supervision, and organizational influences. The studies differ in design and evidentiary granularity, but they converge on the conclusion that visible operator error cannot be separated from system conditions. Dominguez-Péry et al. (2021) reached a similar systemic conclusion through bibliometric review, classifying maritime human-error research across human-resource and management factors, socio-technical information systems, and individual or cognitive factors. Bibliometric mapping cannot establish the causal weight of individual accident factors, while accident coding provides event-level detail but is sensitive to investigation practices and classification schemes. Read together, these methods support a multidimensional research agenda while cautioning against simple causal percentages.

This methodological comparison refines the theoretical interpretation adopted here: the relevant unit of analysis is not an isolated seafarer error but the interaction between competence, workload, technology, team processes, organizational controls, and regulatory conditions. Education can influence several of these elements, but it must be coordinated with shipboard management and organizational systems if learning is to transfer to operational behavior. Table 1 is therefore intentionally non-quantitative. Wróbel (2021) cautions that widely repeated percentages regarding the human contribution to maritime accidents can be difficult to trace and may combine incompatible definitions and datasets. The contribution of the present synthesis is not a universal numerical ranking, but the identification of recurring risk themes that can be translated into curriculum, simulation, assessment, leadership, and organizational-learning priorities.

b. Training-Needs Analysis and Adaptive Curriculum Planning

The finding that planning should begin with competency-gap and incident analysis is supported by Cedaryana et al. (2025). Their study found that training-needs analysis helps identify differences between current and expected digital competencies and supports the design of competency-based training and certification. Although their research was conducted outside the maritime sector, its managerial implication is directly relevant: training should be based on demonstrated competency needs rather than administrative routine. In maritime education, this means that accident reports, near-miss data, simulator performance, employer evaluations, technological changes, and STCW amendments must be translated into curriculum decisions. For example, recurring ECDIS interpretation errors should generate revised learning outcomes and simulator exercises rather than merely additional theoretical material.

The findings also correspond with Manuel's (2017) argument that maritime education must balance vocational proficiency with broader academic and adaptive abilities. Modern seafarers need the capacity to diagnose unfamiliar problems, interpret automated systems, collaborate across cultural boundaries, and adapt to changing technology. A curriculum that is limited to procedural memorization may produce formal compliance without sufficient operational readiness. The development of autonomous and remotely operated ships strengthens the need for adaptive planning. Emad and Ghosh (2023) identified digital, cognitive, technical, communication, and decision-making competencies required by future autonomous-ship operators. Therefore, annual or periodic curriculum review involving industry and regulators, as proposed in Table 2, is essential for preventing a widening gap between certification standards and operational reality.

c. Organization of Instructors and Simulation Resources

The findings show that simulator availability must be accompanied by instructor competence, scenario validity, and appropriate assessment. Earlier simulator reviews emphasize the instructional continuum and the centrality of briefing, scenario facilitation, and debriefing (Kim et al., 2021; Sellberg, 2018; Wiig et al., 2023). More recent empirical work provides a complementary performance perspective: Brandsæter and Madsen (2024) tested human supervision of autonomous navigation under challenging scenarios, while Crestelo Moreno et al. (2026) evaluated high-fidelity simulation across students, professionals, and instructors. The settings and outcome measures differ, but both demonstrate that technology must be evaluated through the quality of human-system performance rather than by fidelity alone. The contrast between these studies is important. Simulator research based on qualitative or topic-model synthesis explains how instructional practices and concepts have developed, whereas simulator experiments and participant assessments provide more direct evidence about performance, perceived competence, and scenario limitations. The combined evidence is stronger than either approach alone, but it still does not justify assuming that simulator exposure automatically produces safer behavior on board.

Accordingly, the proposed model treats simulation as an educational infrastructure whose value is mediated by instructional design, instructor currency, authentic scenarios, assessment criteria, reflective feedback, and opportunities for repeated practice. This interpretation also responds to the cost and integrated-assessment limitations identified by Crestelo Moreno et al. (2026). The theoretical refinement is that simulator technology is an enabling condition, not a sufficient cause of competence. Maritime institutions should therefore evaluate simulation through demonstrated learning transfer and human-system performance rather than solely through equipment sophistication or compliance with facility requirements.

d. Implementation of Experiential Learning, BRM, and ERM

Experiential learning, BRM, and ERM are similarly subject to transfer conditions. Röttger et al. (2016) reported that classroom BRM can improve knowledge, but changes in attitudes, behavior, and operational performance require more than a one-time intervention. This differs from certification-oriented assumptions in which course completion is treated as evidence of durable competence. The present synthesis therefore gives greater emphasis to repeated practice, scenario variation, onboard reinforcement, and behavioral assessment. This distinction is consistent with resilience-oriented human-performance research. Peng et al. (2023) models operator variability as context dependent and potentially adaptive in safety-critical offshore operations involving human-automation collaboration. Maritime education should consequently prepare seafarers not only to reproduce prescribed responses but also to recognize when conditions deviate from expectations, coordinate with automation and team members, and adapt without losing safety margins.

The review therefore does not support the assumption that certification, a single BRM or ERM course, or one successful simulator exercise will automatically improve shipboard behavior. These interventions become more credible pathways to safer performance when organizational culture encourages communication, leaders reinforce the learned practices, competence is re-assessed over time, and incident feedback is returned to training. This refinement shifts the theoretical emphasis from training exposure to training transfer. The relevant outcome is not attendance or immediate knowledge gain alone, but whether technical and non-technical competencies remain usable under workload, fatigue, hierarchy, equipment complexity, automation surprises, and emergency pressure.

e. Evaluation, Safety Leadership, and Continuous Improvement

The controlling findings demonstrate that training effectiveness should be evaluated at multiple levels. Examination results indicate learning achievement but do not establish whether competence is transferred to shipboard behavior or contributes to safer operations. Evidence on training evaluation also cautions against attributing effectiveness to delivery mode alone. Sulistiyono et al. (2024) found no significant difference between blended and conventional training in their application of the Kirkpatrick framework outside the maritime sector. Although the context differs, the result is relevant because it suggests that learning objectives, participant characteristics, instructional quality, assessment, and organizational support may matter more than a simple online-versus-face-to-face distinction.

Safety-culture evidence provides a second comparison across methods and settings. Putra et al. (2024) used qualitative exploratory evidence from Indonesian seafarers and shipping-company personnel to identify trust, reporting, and blame-culture barriers. Xi et al. (2025) used structural equation modeling with 229 deck officers and captains in a Chinese shipping context and found positive relationships between safety-culture dimensions and safety behavior. Their convergence supports safety culture as a plausible mechanism, but the different populations and methods also show why the present review should frame the relationship as a proposition rather than a universally quantified causal effect. Safety leadership can reinforce this mechanism. Tahapary and Laksono (2025) found that safety leadership supported safety compliance through safety behavior and motivation. Transferred cautiously to the maritime context, the implication is that instructors, training managers, masters, and senior officers influence whether formal safety principles become daily practice through modeling, feedback, and the handling of reported errors. These findings refine the model by making organizational culture, repeated practice, and workplace reinforcement explicit boundary conditions. Education may build competence and safety expectations, but transfer to shipboard behavior is weakened when reporting is punished indiscriminately, leadership contradicts training messages, or operational pressure normalizes unsafe shortcuts.

f. Implementation Challenges in the Indonesian Context

The six challenges presented in Table 2 demonstrate that maritime education management in Indonesia requires coordinated institutional intervention. Delayed curriculum revision creates a risk that graduates are trained for technologies and operational practices that no longer reflect contemporary ships. Instructor gaps limit the transfer of practical and digital competence, while high simulator costs produce disparities among training institutions. Certification and supervision problems are particularly significant in traditional and small-vessel operations. Formal standards may have limited impact when certification cannot be reliably verified or when regulatory enforcement is inconsistent. Digital certificate databases can strengthen verification, but technology must be accompanied by audits, institutional accountability, and competent inspectors.

The limited relationship between industry and educational institutions also restricts organizational learning. Shipping companies possess information about graduate performance, recurring operational errors, equipment changes, and near misses, while education institutions possess pedagogical and assessment expertise. A structured exchange mechanism is therefore required to connect these forms of knowledge. The proposed mitigation strategies are consistent with the training-needs perspective of Cedaryana et al. (2025), the competence–performance relationship identified by Amin (2022), the multidimensional training evaluation applied by Sulistiyono et al. (2024), and the safety-leadership mechanism examined by Tahapary and Laksono (2025). Together, these studies provide human-resource-management support for the proposed maritime education framework.

g. Digital Transformation and Future Maritime Competencies

The findings concerning VR, AR, AI, cloud-based learning, digital twins, and remote operations are consistent with research showing that digital technology can expand access to complex or infrequent training scenarios (Renganayagalu et al., 2021; Kim et al., 2021). However, recent autonomous-navigation research adds an important human-automation requirement: operators must be able to supervise systems that may offer suboptimal solutions and intervene selectively rather than simply follow automated advice (Brandsæter & Madsen, 2024). Emad and Ghosh (2023) identify technical, cognitive, digital, and interpersonal competencies for future autonomous-ship operators, whereas Peng et al. (2023) emphasizes resilient human performance under changing human-automation conditions. The studies approach the problem from training-needs and resilience-modeling perspectives, respectively, but both indicate that future competence should include adaptation, monitoring, judgment, and coordination with automation.

High-fidelity simulation can support these competencies, but recent evidence also identifies limitations involving assessment integration, cost, and adaptation for less experienced trainees (Crestelo Moreno et al., 2026). AI-assisted assessment and adaptive learning should therefore complement rather than replace instructor judgment, particularly for teamwork, leadership, and context-dependent decisions. Cybersecurity, data protection, accessibility, digital inequality, and simulator-related usability also require governance. Digital transformation should consequently be managed as a human-capability and organizational-learning transformation rather than as equipment modernization alone. This interpretation connects technological innovation to the same POAC cycle: planning identifies emerging competencies, organizing provides suitable infrastructure and instructor development, actuating designs authentic human-automation learning, and controlling evaluates whether digital competence transfers to safe performance.

h. Theoretical and Practical Contribution

The principal theoretical contribution is the integration of socio-technical systems thinking with the POAC management cycle and two contemporary explanatory mechanisms: resilience-oriented human performance and just-culture organizational learning. Previous maritime studies often isolate accident factors, simulator technologies, or individual training interventions. The proposed model instead links them within a continuous management system in which regulatory inputs and operational evidence shape education, and education is expected to influence competence and safety culture. A second contribution is the explicit theoretical refinement that technology, certification, and isolated BRM or ERM exposure are not sufficient causes of safer behavior. Their value is conditional on instructor quality, scenario design, valid assessment, repeated practice, leadership, reporting culture, and workplace reinforcement. This refinement is consistent with evidence showing that knowledge gains do not automatically become operational behavior and that human performance varies with the surrounding socio-technical context (Röttger et al., 2016; Peng et al., 2023; Brandsæter & Madsen, 2024). Practically, the model positions maritime safety education as a continuous organizational-learning system connecting the classroom, simulator, ship, company, regulator, and accident-investigation process. Institutions can use the model to trace whether identified risks are translated into curriculum and scenarios, whether resources support the intended competencies, whether competence is demonstrated under realistic conditions, and whether operational feedback is used for subsequent improvement.

V. Conclusion

This integrative review indicates that reducing human-error risk in shipboard operations requires more than compliance with certification requirements or the delivery of isolated safety-training programs. Human error emerges from interactions among individual, technical, organizational, and environmental conditions, including fatigue, limited situational awareness, ineffective communication, inadequate competence, procedural non-compliance, weak safety culture, and the demands of increasingly automated operations. The evidence therefore supports treating maritime safety education as a continuous socio-

ISSN [Online]: 2776-6365

technical management system rather than a stand-alone course portfolio. Within that system, the interconnected application of planning, organizing, actuating, and controlling provides a coherent managerial cycle. Planning connects competency gaps, incident evidence, regulation, and technological change; organizing aligns instructors, facilities, and institutional cooperation; actuating implements competency-based and experiential learning through simulation, BRM, ERM, emergency practice, and debriefing; and controlling links assessment, workplace performance, near-miss evidence, and curriculum improvement. The proposed relationships remain conceptual propositions and have not been estimated as causal effects in the present review.

The theoretical contribution is the integration of POAC with a socio-technical interpretation of human error, resilience-oriented human performance, competency-based and experiential learning, and just-culture safety management. The model proposes two linked pathways: competence development and safety-culture development. It also specifies boundary conditions by recognizing that certification, technology, or one-time resource-management training does not automatically improve shipboard behavior without valid assessment, repeated practice, organizational reinforcement, and operational feedback. Practically, maritime education and training institutions should use accident and near-miss evidence to update curricula and scenarios, pair simulator investment with instructor development and structured debriefing, and assess competence through realistic performance rather than examination scores alone. Shipping companies should reinforce shore-based learning through onboard drills, mentoring, fatigue-risk management, open incident reporting, and Safety Management System practices. Regulators can strengthen quality assurance, assessment consistency, digital certificate verification, and structured cooperation among training institutions, industry, and investigation bodies.

The study is limited by its integrative conceptual design, reliance on secondary evidence, heterogeneous definitions of human error, and the absence of primary or longitudinal outcome data. The original review record also did not preserve complete historical database-level screening counts in a form that could be reconstructed reliably during revision. Accordingly, no pooled accident percentages, effect sizes, or causal estimates are claimed, and contextual differences across vessel types, operational areas, institutions, and regulatory systems must be considered when applying the model. Future research should prioritize empirical tests of specific propositions. P1-P2 can be examined among maritime cadets and active seafarers using validated technical and non-technical competence measures together with simulator-based error, decision, and communication indicators. P3-P4 can be tested through quasi-experimental or repeated-measures studies comparing simulator and BRM/ERM designs and measuring retention and onboard transfer. P5-P6 can be evaluated longitudinally in shipping companies using safety-culture, reporting, safety-behavior, near-miss, and incident indicators. P8 can be tested through multi-institution or multi-company structural equation modeling in Indonesian maritime settings, with vessel type, automation level, training resources, and organizational culture treated as contextual moderators. Comparative studies should also examine how AI, virtual and augmented reality, digital twins, remote operations, cybersecurity, and Maritime Autonomous Surface Ships change future competence requirements and the effectiveness of the proposed management cycle.

References

Amin, M. S. (2022). Organizational commitment, competence on job satisfaction and lecturer performance: Social learning theory approach. Golden Ratio of Human Resource Management, 2(1), 40–56. https://doi.org/10.52970/grhrm.v2i1.156

Brandsæter, A., & Madsen, A. (2024). A simulator-based approach for testing and assessing human supervised autonomous ship navigation. Journal of Marine Science and Technology, 29, 432–445. https://doi.org/10.1007/s00773-024-00998-1

Cedaryana, C., Indah DM, D. R., & Putri, I. V. (2025). Training need analysis for the development of digital skills with competency certification in the digital era: A study of university students and employees in Jakarta, Indonesia. Golden Ratio of Human Resource Management, 5(2), 406–414. https://doi.org/10.52970/grhrm.v5i2.1291

Chauvin, C., Lardjane, S., Morel, G., Clostermann, J.-P., & Langard, B. (2013). Human and organisational factors in maritime accidents: Analysis of collisions at sea using the HFACS. Accident Analysis & Prevention, 59, 26–37. https://doi.org/10.1016/j.aap.2013.05.006

Crestelo Moreno, F., Díaz-Secades, L. A., García Maza, J. Á., & Lista Martin, A. (2026). Evaluating the impact of high-fidelity simulators on maritime education and training: Enhancing competency through realistic simulation. The Journal of Navigation, 1–23. https://doi.org/10.1017/S0373463326101581

Dominguez-Péry, C., Vuddaraju, L. N. R., Corbett-Etchevers, I., & Tassabehji, R. (2021). Reducing maritime accidents in ships by tackling human error: A bibliometric review and research agenda. Journal of Shipping and Trade, 6, Article 20. https://doi.org/10.1186/s41072-021-00098-y

Elo, S., & Kyngäs, H. (2008). The qualitative content analysis process. Journal of Advanced Nursing, 62(1), 107–115. https://doi.org/10.1111/j.1365-2648.2007.04569.x

Emad, G. R., & Ghosh, S. (2023). Identifying essential skills and competencies towards building a training framework for future operators of autonomous ships: A qualitative study. WMU Journal of Maritime Affairs, 22, 427–445. https://doi.org/10.1007/s13437-023-00310-9

European Maritime Safety Agency. (2022). Annual overview of marine casualties and incidents 2022.

Heslina, H., & Syahruni, A. (2021). The influence of information technology, human resources competency and employee engagement on performance of employees. Golden Ratio of Human Resource Management, 1(1), 1–12. https://doi.org/10.52970/grhrm.v1i1.100

Hetherington, C., Flin, R., & Mearns, K. (2006). Safety in shipping: The human element. Journal of Safety Research, 37(4), 401–411. https://doi.org/10.1016/j.jsr.2006.04.007

International Maritime Organization. (2017). STCW including 2010 Manila Amendments: STCW Convention and STCW Code. https://doi.org/10.62454/KD938E

International Maritime Organization. (2018). ISM Code: International Safety Management Code with guidelines for its implementation. https://doi.org/10.62454/KD117E

Karahalil, M., Lützhöft, M., & Scanlan, J. (2025). Factors impacting curricula in maritime simulator-based education. WMU Journal of Maritime Affairs, 24, 545–573. https://doi.org/10.1007/s13437-024-00351-8

Kim, T.-E., Sharma, A., Bustgaard, M., Gyldensten, W. C., Nymoen, O. K., Tusher, H. M., & Nazir, S. (2021). The continuum of simulator-based maritime training and education. WMU Journal of Maritime Affairs, 20, 135–150. https://doi.org/10.1007/s13437-021-00242-2

Komite Nasional Keselamatan Transportasi. (2018). Laporan investigasi kecelakaan pelayaran: Tenggelamnya Sinar Bangun 4, Perairan Danau Toba, Pelabuhan Tigaras, Simalungun, Sumatera Utara, 18 Juni 2018 (Laporan No. KNKT.18.06.21.03).

Komite Nasional Keselamatan Transportasi. (2021). Laporan investigasi kecelakaan pelayaran: Kebakaran kapal Ro-Ro penumpang Santika Nusantara, Perairan Timur Laut Pulau Masalembu, 22 Agustus 2019 (Laporan No. KNKT.19.08.19.03).

Manuel, M. E. (2017). Vocational and academic approaches to maritime education and training: Trends, challenges and opportunities. WMU Journal of Maritime Affairs, 16, 473–483. https://doi.org/10.1007/s13437-017-0130-3

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., . . . Moher, D. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. BMJ, 372, Article n71. https://doi.org/10.1136/bmj.n71

Peng, C., Zhen, X., & Huang, Y. (2023). A structured approach for resilience-oriented human performance assessment and prediction in offshore safety-critical operations. Ocean Engineering, 287, Article 115743. https://doi.org/10.1016/j.oceaneng.2023.115743

Putra, A. M., Carrera Arce, M., & Baumler, R. (2024). Insights on just culture from seafarers and shipping companies in Indonesia: An exploratory study. Work, 77(1), 161–170. https://doi.org/10.3233/WOR-220555

Renganayagalu, S. K., Mallam, S. C., & Nazir, S. (2021). Effectiveness of VR head mounted displays in professional training: A systematic review. Technology, Knowledge and Learning, 26(4), 999–1041. https://doi.org/10.1007/s10758-020-09489-9

Rothblum, A. M. (2000). Human error and marine safety. In Proceedings of the National Safety Council Congress and Expo. National Safety Council.

Röttger, S., Vetter, S., & Kowalski, J. T. (2016). Effects of a classroom-based bridge resource management training on knowledge, attitudes, behaviour and performance of junior naval officers. WMU Journal of Maritime Affairs, 15, 143–162. https://doi.org/10.1007/s13437-014-0073-x

Russo, F., & Musolino, G. (2024). Transportation system models to analyse ports competition and cooperation.

WMU Journal of Maritime Affairs, 23, 393–413. https://doi.org/10.1007/s13437-024-00345-6

Sánchez-Beaskoetxea, J., Basterretxea-Iribar, I., Sotés, I., & Maruri Machado, M. de las M. (2021). Human error in marine accidents: Is the crew normally to blame? Maritime Transport Research, 2, Article 100016. https://doi.org/10.1016/j.martra.2021.100016

Schröder-Hinrichs, J.-U., Hollnagel, E., & Baldauf, M. (2012). From Titanic to Costa Concordia—A century of lessons not learned. WMU Journal of Maritime Affairs, 11, 151–167. https://doi.org/10.1007/s13437-012-0032-3

Sellberg, C. (2017). Simulators in bridge operations training and assessment: A systematic review and qualitative synthesis. WMU Journal of Maritime Affairs, 16, 247–263. https://doi.org/10.1007/s13437-016-0114-8

Sellberg, C. (2018). From briefing, through scenario, to debriefing: The maritime instructor's work during simulator-based training. Cognition, Technology & Work, 20(1), 49–62. https://doi.org/10.1007/s10111-017-0446-y

Sellberg, C., Lindmark, O., & Rystedt, H. (2018). Learning to navigate: The centrality of instructions and assessments for developing students' professional competencies in simulator-based training. WMU Journal of Maritime Affairs, 17, 249–265. https://doi.org/10.1007/s13437-018-0139-2

Snyder, H. (2019). Literature review as a research methodology: An overview and guidelines. Journal of Business Research, 104, 333–339. https://doi.org/10.1016/j.jbusres.2019.07.039

Sulistiyono, A., Ginting, G., & Khalid, I. (2024). Evaluation of training effectiveness of Kirkpatrick model on blended learning and classical training in Sarolangun District Government. Golden Ratio of Human Resource Management, 5(1), 94–99. https://doi.org/10.52970/grhrm.v5i1.539

Tahapary, K. Y., & Laksono, A. R. (2025). The effect of safety leadership on safety compliance: The mediation role of safety behaviors and safety motivation. Golden Ratio of Human Resource Management, 5(2), 436–448. https://doi.org/10.52970/grhrm.v5i2.1328

Torraco, R. J. (2005). Writing integrative literature reviews: Guidelines and examples. Human Resource Development Review, 4(3), 356–367. https://doi.org/10.1177/1534484305278283

Wiig, A. C., Sellberg, C., & Solberg, M. (2023). Reviewing simulator-based training and assessment in maritime education: A topic modelling approach for tracing conceptual developments. WMU Journal of Maritime Affairs, 22, 143–164. https://doi.org/10.1007/s13437-023-00307-4

Wróbel, K. (2021). Searching for the origins of the myth: 80% human error impact on maritime safety. Reliability Engineering & System Safety, 216, Article 107942. https://doi.org/10.1016/j.ress.2021.107942

Xi, Y., Wang, Z., Hu, S., Han, B., & Yin, J. (2025). The effect of safety culture on the safety behavior of ship deck officers: Empirical evidence from shipping industry. Frontiers in Marine Science, 12, Article 1599455. https://doi.org/10.3389/fmars.2025.1599455