JOURNAL OF MARITIME RESEARCH

Vol XXIII. No. II (2026) pp 149–158

ISSN: 1697-4840, www.jmr.unican.es

Satisfaction Survey for the Evaluation of Training in a Modern Bridge Simulator: A User Satisfaction Study in Relation to STCW Convention and Code Requirements

Vasileios Tsoukalas[1], Panagiota Lalou[1,*], Despoina Cheilari[1], Vasileios Bantidakis[1]

ARTICLE INFO

Article history:
Received 28 May 2025;
in revised from 16 Jun 2025;
accepted 25 Jul 2025.

Keywords:
Simulator Training, Human Error, Maritime Safety, STCW, User Satisfaction.

ABSTRACT

This study examined the satisfaction of seafarers and instructors with simulator-based training as a means of reducing human error and reinforcing compliance with STCW Convention and Code requirements. A questionnaire covering four evaluation indices, namely the prevention of primary errors, the avoidance of unsafe behaviors and actions, the correction of errors, and the overall contribution of simulator training to accident reduction, was administered to 120 respondents, including captains, engineers, cadets and instructors trained on the Navi-Sailor NTPRO 5000 bridge handling simulator and a Norcontrol Kongsberg full-mission engine room simulator at the Merchant Marine Academy of Aspropyrgos. Non-parametric statistical tests (Mann-Whitney U and Kruskal-Wallis) were used to compare the four indices across groups defined by onboard experience, rank, and status. Respondents with more than six months of onboard experience and senior officers reported significantly higher satisfaction than cadets and less experienced trainees, whereas no significant difference was found between instructors and students. Overall satisfaction with simulator training was found to be high, although non-technical competencies such as stress management and leadership development received comparatively lower ratings. The findings support the adoption of a blended training approach that combines simulator exercises with onboard experience in order to strengthen maritime safety and reduce human-error-related accidents.

1. Introduction.

A sufficient number of statistics indicate that the main contributor to marine accidents are human errors. Some studies suggested that 80 to 95 percent of all maritime accidents, including groundings, collisions, fires, explosions and various other workplace accidents, are attributable to human error (Yisi Liu Z. L., 2020). The human factor behind these accidents is also especially relevant to a study in Malaysia where just a few of these incidents can greatly impact society, as revealed in the article exploring this topic. To improve maritime safety and prevent future similar incidents and tragedies, research should focus on understanding the complex interactions among organizational factors, unsafe supervision, preconditions for unsafe acts and the unsafe acts of the operators themselves (Suzanna Razali Chan, 2016).

It is worth noticing that, on a more positive note, a detailed study of maritime accidents within the waters of the European Union (EU) for the year 2007 to the year 2010 indicated that traditional incidents such as sinkings, collisions and groundings have significantly decreased. However, accidents caused by fires and explosions have increased, showing a change in the character of maritime risks. This changing trend of accidents indicates that safety behavior on board, the training of crew and

[1]Dept. of Marine Engineering, Merchant Marine Academy of Athens. Greece.
[2]Dept. of Marine Engineering, Merchant Marine Academy of Athens.
[3]Dept. of Marine Engineering, Merchant Marine Academy of Athens.
[4]Dept. of Marine Engineering, Merchant Marine Academy of Athens.
[*]Corresponding author: Panagiota Lalou. E-mail Address: [email not specified].

multicultural communication can be made more effective. It is a shocking example of how a lack of focus on the human element in maritime operations has detrimental real-world influence, and it is evident that no matter how sophisticated technology gets, the maritime industry needs to find solutions in order to mitigate the effects of human factors, preventing undesired catastrophes (B. Ćorović, 2013). Maritime safety and human error have become an issue that every seafarer has to deal with.

Human factors still represent a significant challenge to the International Maritime Organization (IMO) with regards to the improvements required in maritime safety, as evidenced by the adoption of Resolutions such as A.850(20) and A.947(23), in which human error was identified as a contributory factor to the issue of accidents. Human error was the cause of 81% of marine accidents from 2014 to 2020, and crew members also caused 81% of deaths. Over this period, there were 6,921 injuries linked to 6,211 incidents that were complicated by external circumstances, such as the COVID-19 pandemic and a shortage of workers. Latest studies show that situational and social systems interactions are key enablers of shipboard safety. Detailed analysis has shown that poor procedure adherence and lack of awareness of regulations often contribute to incidents. Additionally, training programs commonly overlook distraction challenges and situations under high pressure. The enhancement of onboard safety will require a detailed written policy that includes a written marine accident resolution and investigation of human factors. The three-dimensional approach to maritime safety consists of developing safety culture, training programs, and formal competence assessment. Even though shipping has become safer with technology, there is a need to focus on human errors. Understanding the human element holistically is critical to prevent incidents and to promote safer onboard behaviour (Lech Kasyk, 2023).

The literature records that the root causes of human error on board are complicated. Human error on board may come from things such as cognitive overload, fatigue, stress, poor communication and failure to respond directly in adverse situations. Even with all the technical advancements in modern vessels, human performance remains error-prone, particularly under high-pressure situations. Moreover, psychological factors like loneliness, strain and long working hours can adversely impact judgement, leading to poor decisions during critical moments (Yisi Liu X. H., 2016). Maritime accidents can also result from cognitive errors, problems in the organization and management of human resources, and issues regarding human-technology interaction (Carine Dominguez-Péry, 2021).

As human factors play a primary role in the occurrence of multiple serious accidents, such as the Thai Phoenix ferry disaster, the Korean Sewol, and the Chinese Eastern Star, a new human factors analysis and classification system for marine accidents (HFACS-MA) was developed. The HFACS-MA model reveals four main groupings that lead to these collisions: inadequate supervision, organizational deficiencies, legislative gaps, and ineffective ship-Vessel Traffic Services (VTS) communication. The literature discloses unsafe acts and supervision, as well as organizational influences, as key contributors to the sinking of the MV Sewol. Given its maritime significance and possible threats in the Strait of Malacca, the authors advocate for more in-depth studies, especially in Malaysia. While the accidents in Malaysia have a low rate, the authors support that human error must be addressed there, preventing deaths of people, loss of third-party property, as well as environmental degradation (Suzanna Razali Chan, 2016).

Another recent study identified human error in the operation and maintenance of ships as a key area to research to ensure the integration of technology and maritime safety on merchant vessels, in order to reduce mishaps. The research aims to delve into practical mitigation techniques, leading to improvements in ship management and safety through making sense of accident causation and the causes of human error. The findings indicate that human factors such as seafarers' ignorance and complacency are crucial elements in marine accidents. By improving seafarers' capabilities and skills, a significant decrease in marine accidents could be achieved. The study also provides a methodology considering a range of factors, such as nationality, the engineering field in which they operate, and the organizational structure. Furthermore, the study highlights the need to establish a culture of good safety, communication and environmental awareness, ensuring safer navigation with fewer accidents and injuries (Muidun Nabi Chowdhury, 2024).

Another reason why human error can lead to accidents is the utilization of technology in marine operations. Even though technology was meant to enhance safety, 31% of marine accidents can be traced to the improper application or comprehension of technology. Common problems include poorly designed systems, inadequate training, and a lack of adaptation to new technologies. The study suggests a design approach centered on the user, high standards of crew training, and practices that promote teamwork, as well as cultivating a safety culture (Toni Bielić, 2017).

Established Maritime Education and Training (MET) still tends to be biased toward aligning MET students with technical capability through classroom-formed education and conventional simulation-based training, with the emphasis placed on technical capability. Specifically, while seafarers know how to perform their tasks, this does not help them cope with the mental, emotional and psychological aspects of life onboard. A study by Inger Johanne Kristensen (2023) records that conventional approaches fail to address stress, cognitive overload, and emotional behaviour under pressure, such as in high-risk training scenarios. As a result, there is a lack of such training, which increases the chances of human error during onboard operations (Inger Johanne Kristensen, 2023).

The International Maritime Organization (IMO) mandates and strongly supports the use of simulators in maritime training to address the complex reasons for human error as defined by the STCW codes. The benefits of the IMO Model Course 2.07 regarding improving the technical proficiency and operational skills of seafarers, through engine-room simulation, help mitigate human error by focusing on hands-on training and assessing competencies, knowledge, and understanding, meeting the requirements described in the STCW Code. In addition, human skills such as leadership, teamwork, effective communication, situational awareness, and decision-making under pressure in both routine and emergency situations were practiced through exercises. The findings indicated that seafarers' capacity to reduce human error and fulfil STCW competency standards was improved by the course, which also fosters these non-technical skills in a safe simulated environment (International Maritime Organization(IMO), 2017; International Maritime Organization, 2002).

Simulation-based training is among the most highly regarded methods to reduce human error in the maritime working environment and operations. Simulators introduce trainees to realistic, controlled, but risk-free training situations to acquire technical skills, decision-making and teamwork in a safe environment. Similar research by Francis A. Alterado (2018) has shown that simulators play an important role in maritime training, as such training can enhance not only the technical knowledge and skills of the trainee but also other non-technical attributes such as leadership and teamwork, which are essential for the efficient management of emergencies.

Full-mission simulators replicate engine room and bridge functions, enabling trainees to rehearse common but high - standard tasks, such as preventing a collision, mooring under difficult conditions and responding to emergencies like engine failure, providing trainees with the ability to understand the impact of their actions (Yisi Liu Z. L., 2020).

With the emergence of Virtual Reality (VR) and Immersive Virtual Reality (IVR), simulators started to act as a one-stop destination for an immersive and holistic learning experience. These advanced immersive training environments enable trainees to face onboard and time-demanding scenarios, such as piloting ships in bad weather and responding to onboard system failures and malfunctions (Mohammud Hanif Dewan, 2023). According to another study, immersive VR training improves critical decision-making, crisis management, and teamworking skills (Elsayed, 2023). However, cloud-based simulators may have their effectiveness diminished due to connectivity issues (W. Gyldensten, 2023).

The literature also points to a similar conclusion regarding how to lessen human error through dynamic training. MET will implement emerging technologies such as virtual reality, EEG monitoring and gamified simulators to provide dynamic training. These advancements could, through improved decision-making, resilience and teamwork in high-stress environments, help mitigate human error. While solutions will be unique to each ship and even each voyage, there is no doubt that simulation technologies will be integral to preparing seafarers in a way that reflects the challenges onboard, ultimately enhancing safety and creating a culture of lifelong learning in the industry (Mohammud Hanif Dewan, 2023). Interestingly, Tarkkanen et al. found that maritime students preferred the hedonic richness and engagement of a gamified VR system over environmental realism, even if they rated it slightly lower in terms of pragmatic quality than traditional simulators. This reinforces the need to balance realistic system simulation with an engaging virtual world (Kimmo Tarkkanen, 2023).

The literature also records the use of EEG (electroencephalography) devices to track the mental state of cadets in real time, such as stress, focus and attention. EEG technology is a simple, accessible and low-cost technology that is devoted to human factor studies in the maritime environment. By tracking students' brain activity in real time, trainers can record cognitive overload or high stress, which could ultimately lead to poor decisions. For example, by assessing these physiological responses alongside more traditional performance measures, such as the error rate and the time required for task completion, trainers would be better positioned to provide feedback that informs decision-making under pressure and in high-stress environments (Yisi Liu X. H., 2016).

The advantage of simulator use is that it operates as a safe and cost-effective means of fulfilling certification requirements, reducing reliance on costly and potentially dangerous on-the-job training. According to a Dutch study, time on a simulator can be accepted as the equivalent of sea time: five days (40 hours) of simulation correspond to 10 days onboard, 10 days (80 hours) correspond to 30 days, and 15 days (120 hours) correspond to 60 days (Netherlands Maritime Study, 1994). The use of simulators is an alternative that can be more cost-effective and time-efficient than traditional onboard training, allowing cadets to acquire experience (CHO THET MAUNG, 2019).

The current study investigates how efficient simulator training can be as a tool for enhancing skills and minimizing human errors with respect to the STCW Convention and Code. During the debriefing phase, a questionnaire survey was carried out among trainees in order to record their opinions regarding simulator training. The primary distinction was between cadets and officers, with cadets consistently rating the training's influence lower, and statistically significant differences in satisfaction were found across ranks. According to the survey, the evaluations of instructors and students were similar, which may be due to the fact that, as both instructors and students use the simulator regularly, their views may be aligned. A key finding of the present survey is the need for improvement in non-technical competencies, including human factors such as stress management, fatigue and leadership, which received lower satisfaction ratings. In addition, the present work suggests that the best scenario for training maritime professionals is a hybrid approach combining simulator and onboard exposure.

2. Materials and Research Methodology.

A questionnaire was used for the present study, and students, captains, engineers, and instructors, as well as those who had trained on the Maritime Academy's simulators, were asked to complete it. This study was conducted using the Navi-Sailor NTPRO 5000 ship bridge handling simulation system from the Deck Officers department and a Norcontrol Kongsberg full - mission engine room simulator from the Engineers department of the Merchant Marine Academy of Aspropyrgos. All students and instructors were invited to join the current project after completing the simulator training. Questionnaires were collected anonymously and separated from information and consent sheets in order to preserve confidentiality. There were four sections in the questionnaire, described in the Appendix, that dealt with: Part I, evaluation index of simulator training's contribution to preventing the primary mistakes that cause marine accidents; Part II, evaluation index of simulator training's contribution to preventing human behaviors or actions that cause marine accidents; Part III, evaluation index of the contribution of simulator training to the process of correcting errors that cause marine accidents; and Part IV, evaluation index of the overall contribution of simulator training to reducing marine accidents. In June 2024, a total of 120 people responded to the questionnaire. Groups of respondents were formed according to their rank, onboard experience, and status (instructor or student).

The following research hypotheses were formulated in relation to the independent variables:

H0.1a: Onboard experience does not affect the satisfaction index about how much simulation training helps prevent the primary mistakes that cause a marine accident.

H1.1a: Onboard experience affects the satisfaction index about how much simulation training helps prevent the primary mistakes that cause a marine accident.

H0.1b: Onboard experience does not affect the satisfaction index of simulator training's contribution to preventing human behaviors or actions that cause marine accidents.

H1.1b: Onboard experience affects the satisfaction index of simulator training's contribution to preventing human behaviors or actions that cause marine accidents.

H0.1c: Onboard experience does not affect the satisfaction index regarding the role that simulation training plays in correcting errors that lead to a maritime accident.

H1.1c: Onboard experience affects the satisfaction index regarding the role that simulation training plays in correcting errors that lead to a maritime accident.

H0.1d: Onboard experience does not affect the satisfaction index of the overall contribution of simulation training to the reduction of marine accidents.

H1.1d: Onboard experience affects the satisfaction index of the overall contribution of simulation training to the reduction of marine accidents.

H0.2a: Respondent's rank does not affect the satisfaction index about how much simulation training helps prevent the primary mistakes that cause a marine accident.

H1.2a: Respondent's rank affects the satisfaction index about how much simulation training helps prevent the primary mistakes that cause a marine accident.

H0.2b: Respondent's rank does not affect the satisfaction index of simulator training's contribution to preventing human behaviors or actions that cause marine accidents.

H1.2b: Respondent's rank affects the satisfaction index of simulator training's contribution to preventing human behaviors or actions that cause marine accidents.

H0.2c: Respondent's rank does not affect the satisfaction index regarding the role that simulation training plays in correcting errors that lead to a maritime accident.

H1.2c: Respondent's rank affects the satisfaction index regarding the role that simulation training plays in correcting errors that lead to a maritime accident.

H0.2d: Respondent's rank does not affect the satisfaction index of the overall contribution of simulation training to the reduction of marine accidents.

H1.2d: Respondent's rank affects the satisfaction index of the overall contribution of simulation training to the reduction of marine accidents.

H0.3a: Respondent's status does not affect the satisfaction index about how much simulation training helps prevent the primary mistakes that cause a marine accident.

H1.3a: Respondent's status affects the satisfaction index about how much simulation training helps prevent the primary mistakes that cause a marine accident.

H0.3b: Respondent's status does not affect the satisfaction index of simulator training's contribution to preventing human behaviors or actions that cause marine accidents.

H1.3b: Respondent's status affects the satisfaction index of simulator training's contribution to preventing human behaviors or actions that cause marine accidents.

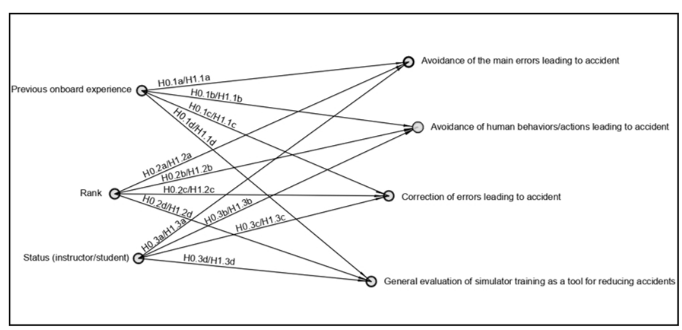
H0.3c: Respondent's status does not affect the satisfaction index regarding the role that simulation training plays in correcting errors that lead to a maritime accident.

H1.3c: Respondent's status affects the satisfaction index regarding the role that simulation training plays in correcting errors that lead to a maritime accident.

H0.3d: Respondent's status does not affect the satisfaction index of the overall contribution of simulation training to the reduction of marine accidents.

H1.3d: Respondent's status affects the satisfaction index of the overall contribution of simulation training to the reduction of marine accidents.

Figure 1: Research hypotheses diagram.



Source: Authors.

Depending on the independent variable, the Kruskal-Wallis or Mann-Whitney U tests were used to investigate the aforementioned hypotheses. IBM SPSS Statistics was used for all calculations.

3. Results.

3.1. Analyzing the Data.

The survey was completed by 130 participants, including instructors, who were also captains or engineers in the merchant navy, and students (captains or engineers) who had received training in the Academy's simulators, using the NaviSailor NTPRO 5000 ship bridge handling simulation system and a Norcontrol Kongsberg full-mission engine room simulator. Upon completion of the questionnaires and analysis of the survey data, Table 1 displays the distribution of participants across the chosen independent variables. The Likert scale, a psychometric response scale commonly used in these surveys, was employed, with five possible answers for each question: "strongly disagree" (score 1), "disagree" (score 2), "neither disagree nor agree" (score 3), "agree" (score 4), and "strongly agree" (score 5).

Table 1: Research hypotheses diagram.

Variable	Category	*n* (%)
Gender	Male	116 (89.2%)
	Female	14 (10.8%)
Age	Up to 30 years	71 (54.6%)
	31–45 years	35 (26.9%)
	46–55 years	20 (15.4%)
	Over 55 years	4 (3.1%)
Status	Student	119 (91.5%)
	Teacher	11 (8.5%)
Rank	Captain/Engineer Class A	38 (29.2%)
	Captain/Engineer Class B	28 (21.5%)
	Captain/Engineer Class C	13 (10.0%)
	Cadet Captain/Engineer	51 (39.2%)
Onboard experience	Up to 6 months	35 (26.9%)
	More than 6 months	95 (73.1%)
Total		**130 (100.0%)**

Source: Authors.

For the statistical analysis, the following continuous variables were created, expressing the average score of the responses for each part of the questionnaire:

a) Evaluation index of Part I:

$$EI\text{-}I = \frac{\sum(\text{scores of questions I1–I2–I3})}{3}$$

b) Evaluation index of Part II:

$$EI\text{-}II = \frac{\sum(\text{scores of questions II1–II2–II3–II4–II5–II6})}{6}$$

c) Evaluation index of Part III:

$$EI\text{-}III = \frac{\sum(\text{scores of questions III1–III2–III3})}{3}$$

d) Evaluation index of Part IV:

$$EI\text{-}IV = \frac{\sum(\text{scores of questions IV1–IV2–IV3})}{3}$$

The mean value and standard deviation of each indicator are displayed in Table 2. The respondents' satisfaction level with the contribution of simulation training to preventing the primary errors that lead to marine accidents (EI-I), to preventing human behaviors or actions that lead to marine accidents (EI-II), and to correctly correcting errors that lead to marine accidents (EI-III), is relatively high (3.94, 3.91, and 3.84, respectively). Additionally, the satisfaction level increases when respondents are asked about the overall satisfaction level with simulation training as a tool for reducing marine accidents (EI-IV), with a mean value of 4.13. The average score and standard deviation for every question are shown in Table 3.

Table 2: Mean of scores and standard deviation.

Index	Score	
	Mean	**Std. Deviation**
EI-I	3,94	1,15
EI-II	3,91	1,04
EI-III	3,84	0,94
EI-IV	4,13	1

Source: Authors.

Table 3: Average score and standard deviation of each question.

I. Evaluation index of the contribution of simulator training to the avoidance of the main errors that lead to marine accidents		Mean (StdDeviation)
I-1	Did the simulator training help you gain a better understanding of the ship's bridge/engine work environment?	3,99 (1,13)
I-2	Did the simulator training help you acquire the necessary skills to perform routine actions and tasks and avoid related mistakes on the ship's bridge/engine room?	3,9 (1,22)
I-3	Did the simulator training help you make decisions and avoid mistakes on the ship's bridge/engine room?	3,87 (1,27)
II. Evaluation index of the contribution of simulator training to the avoidance of human behaviours/actions leading to marine accidents		
II-1	Has simulator training help you deal with fatigue and stress during onboard service?	3,69 (1,25)
II-2	Did the simulator training contribute positively to the acquisition of the required technical knowledge in the bridge/engine room on ship?	3,89 (1,08)
II-3	Did the training in the bridge/engine room simulator contribute positively to the understanding of the real ship automations?	4,12 (1,1)
II-4	Did the simulator training contribute positively to the use of communication systems on the?	3,91 (1,15)
II-5	Did the simulator training contribute positively to dealing with dangerous situations (through indications, alarms, etc.) on the real ship?	4,05 (1,09)
II-6	Did the simulator training help you develop leadership skills to deal with difficult situations on board?	3,77 (1,12)
III. Evaluation index of the contribution of simulator training to the process of correction of errors leading to a marine accident		
III-1	Did the simulator training help you improve your ability to find out errors/malfunctions on the real ship?	3,81(0,96)
III-2	Did the simulator training help you, after identifying the error/wrong action, to describe it and communicate it immediately to your superiors on board?	3,76 (1,02)
III-3	Did the simulator training helped you take the required actions and work together to fix the error?	3,91 (1,08)
IV. General evaluation index of the contribution of simulator training to the process of correction of errors that lead to a marine accident		
IV-1	Do you think that overall simulator training helps to avoid and correct human errors that can lead to marine accidents?	4,03(1,11)
IV-2	Do you think that training in modern VR marine simulators would help reduce human errors/actions that could lead to a marine accident?	4,15 (1,02)
IV-3	Do you think increasing training hours in marine simulators would help reduce human errors/actions that could lead to a marine accident?	4,19 (1,04)

Source: Authors.

4. Hypothesis Testing.

It was investigated whether there is a significant difference in the mean score of each of the four indices between groups of the independent variables: a) onboard experience, b) rank, and c) status. The significance level was set at 0.05. Data were tested for normality using the Kolmogorov-Smirnov and Shapiro-Wilk tests. The results, depicted in Table 4, show that none of the four variables were normally distributed (p-value < 0.05), and therefore non-parametric tests were used.

Table 4: Results of normality tests.

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
EvaluationIndexPart I	,207	119	<,001	,830	119	<,001
EvaluationIndexPart II	,165	119	<,001	,872	119	<,001
EvaluationIndexPart III	,230	119	<,001	,895	119	<,001
EvaluationIndexPart IV	,192	119	<,001	,815	119	<,001

a. Lilliefors Significance Correction

Source: Authors.

The Mann-Whitney test was used to determine whether the mean score of the indices differed statistically significantly between those who had a longer onboard experience (more than 6 months) and those who had a shorter onboard experience (less than 6 months). The p-values in Table 5 (Asymp. Sig.) are all less than 0.05, showing that there is a statistically significant difference between the two groups in all four indices.

Table 5: Results of the Mann-Whitney test.

TestStatistics[a]

	EvaluationIndex Part I	EvaluationIndex Part II	EvaluationIndex Part III	EvaluationIndex Part IV
Mann-Whitney U	783,000	634,500	750,500	1115,500
Wilcoxon W	1378,000	1195,500	1380,500	1710,500
Z	-4,474	-4,988	-4,715	-2,686
Asymp. Sig. (2-tailed)	<,001	<,001	<,001	,007

a. Grouping Variable: Onboard experience

Source: Authors.

Table 6 shows that respondents with more than six months of onboard experience had significantly higher mean scores for all four indices than respondents with less than six months. Boxplots (Figure 2) further confirm that respondents who had more than six months of onboard experience scored higher than those with less.

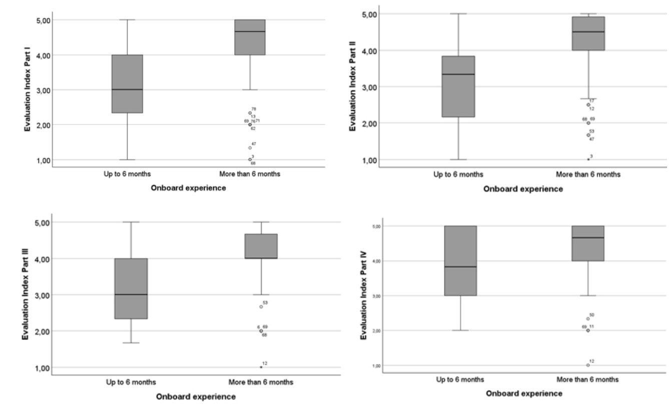
Table 6: Mean score and standard deviation of the indices depending on the duration of onboard experience.

Index	Mean (Std Deviation) depending on board experience	
	Up to 6 months	More than 6 months
EI-I	3,24 (1,13)	4,33 (0,92)
EI-II	3,1 (1,09)	4,28 (0,75)
EI-III	3,2 (0,94)	4,17 (0,72)
EI-IV	3,68 (0,73)	4,4 (0,73)

Source: Authors.

The Kruskal–Wallis test was used to determine whether the mean score of the indices varies statistically significantly based on rank. Given that every p-value was less than 0.05, the results indicate that there is a significant difference across all indices (Table 7). The average values of the cadet Captain/Engineer group are lower than those of all other ranks, but there is no significant difference in the means of the indices between Captain/Engineer Class A, Class B and Class C (Table 8). The boxplots in Figure 3 lead to the same conclusion regarding the engineers and cadet masters.

Figure 2: Boxplots of indices depending on onboard experience.



Source: Authors.

Table 7: Results of the Kruskal–Wallis test.

TestStatistics[a,b]

	Evaluation IndexPart I	Evaluation IndexPart II	Evaluation IndexPart III	Evaluation IndexPart IV
Kruskal-Wallis H	30,539	31,287	16,675	8,853
df	3	3	3	3
Asymp. Sig.	<,001	<,001	<,001	,031

a. KruskalWallisTest

b. GroupingVariable: Rank

Source: Authors.

Table 8: Mean score and standard deviation of the indices depending on rank.

Index	Mean (Std Deviation) depending on Rank			
	Captain/Engineer Class A	Captain/Engineer Class B	Captain/Engineer Class C	Cadet Captain/Engineer
EI-I	4,53 (0,85)	4,32 (1,05)	4,3 (0,75)	3,4 (1,07)
EI-II	4,46 (0,79)	4,19 (0,68)	4,42 (0,37)	3,32 (1,08)
EI-III	4,17 (0,71)	4,09 (0,75)	4,42 (0,47)	3,46 (1)
EI-IV	4,33 (0,77)	4,5 (0,73)	4,64 (0,38)	3,82 (1,05)

Source: Authors.

In order to examine whether there is a statistically significant difference in the mean score of the indices between trainees and teachers, the Mann-Whitney test was used. According to the results, there is no significant difference in any of the indices, since all the p-values are over 0.05 (Table 9).

Table 9: Results of Mann Whitney Test.

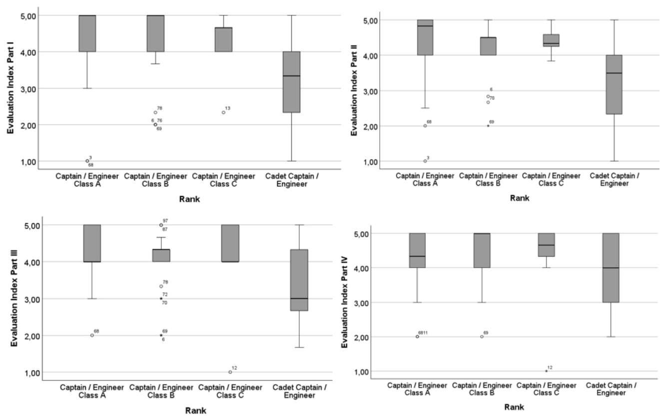
TestStatistics[a]

	Evaluation IndexPart I	Evaluation IndexPart II	Evaluation IndexPart III	Evaluation IndexPart IV
Mann-Whitney U	563,500	515,500	583,000	589,500
Wilcoxon W	629,500	581,500	7486,000	655,500
Z	-,658	-,980	-,018	-,474
Asymp. Sig. (2-tailed)	,511	,327	,985	,636

a. GroupingVariable: Status

Source: Authors.

Figure 3: Boxplots of indices depending on rank.



Source: Authors.

5. Discussion.

Maritime training based on simulation provides trainees with the ability to refine their technical skills while simultaneously gaining essential decision-making and teamwork skills in a safe environment. These systems present students with realistic but safe scenarios of real-world operations that can be outstanding regarding extreme situations (severe weather, failed equipment, heavy traffic in navigation) that are hard or risky to encounter in the real world. This method enhances not only the preparedness of trainees but also their ability and confidence to address complicated and dangerous circumstances (Yisi Liu Z. L., 2020; Mohammud Hanif Dewan, 2023). It is worth noting that modern simulators provide real-life environments designed to mirror the configuration of a ship's bridge, engine room and navigation systems. Such realistic environments allow trainees to receive training similar to real-life operations. Crew members are trained on how to respond to simulated emergencies such as fire, flooding or engine failure. By rehearsing such responses without being in real danger, anxiety and poor decision-making in real-life crisis circumstances can also be reduced. This also prepares the crew for making high-risk decisions by simulating scenarios such as disembarkation, collision avoidance and several extreme situations, reducing the likelihood of human errors occurring when facing such scenarios for the first time (Elsayed, 2023).

Automation and innovative technology, such as automated engine control, dynamic positioning systems, and electronic chart displays, are used on board and have increased in complexity (Toni Bielić, 2017). Nevertheless, inadequate training or defective equipment may lead to human errors that have been attributed to 80–90% of maritime accidents. Real-life environments used to train crew members are created by simulators, allowing them to integrate these systems and reducing human errors (Elsayed, 2023). These environments cultivate technical skills, decision-making, teamwork, and self-esteem (Toni Bielić, 2017; Elsayed, 2023), overcoming over-reliance on automation. To minimize the time needed for familiarization with basic behaviors and to facilitate the transition process, simulators should closely emulate what will be found onboard. Moreover, safety is also strengthened by encouraging open communication and feedback. Thus, simulators play a significant role in crew training to safely operate advanced technologies and prevent technology-related errors.

Simulators can also create stress situations, such as circumstances that occur in bad weather or at night, for crews to practice in. This lessens the possibility of making mistakes in real life due to stress or fatigue. Through simulator training, crews learn how to manage their cognitive load, sustaining their attention on their responsibilities without being overwhelmed during an emergency situation. Similar themes are apparent in andragogical development models designed for adult learner groups, placing a strong emphasis on real-life experience and practical implementation (Angelique Bosker, 2021). The findings of Angelique Bosker et al. record that managing the gap with real life is essential to enhance training effectiveness, for example, through incorporating more complicated and dynamic scenarios and better integrating human factor training parameters such as leadership and stress management, as well as involving technically advanced options such as virtual and augmented reality to provide more sophisticated, real-life training environments.

In the present study, the demographic data of the participants, as depicted in Table 1, showed that the majority of participants were male (89.23%), with more than half (54.3%) being under 30 years old. This suggests that the sample was primarily composed of young people, mostly students (91.5%). Specifically, 39.2% of respondents were cadets, and 73.1% had more than six months of onboard experience when giving their assessments of simulator training aspects. The technical aspects of handling emergencies (II-5: 4.05/5), understanding automation (II-3: 4.12/5), believing in VR simulators (IV-2: 4.15/5), and extended training hours (IV-3: 4.19/5) were deemed highly acceptable based on the mean satisfaction scores depicted in Tables 2 and 3. However, leadership development (II-6: 3.77/5) and stress management (II-1: 3.69/5) received lower scores, suggesting that human factors are not being adequately managed.

Statistical analyses showed that rank and experience had an important effect. As shown in the indices, respondents with over six months' sea time rated simulator training significantly higher. Specifically, cadets had a much lower EI rating than officers (4.33 vs. 3.24), with the difference in exposure being significant (Tables 5 and 6). The finding from the EI-I index for primary errors is noteworthy, recording that more experienced seafarers particularly favored the simulator's reinforcement of fundamentals (Table 6). The boxplots demonstrate good separation: the group with more experience had narrower interquartile ranges and higher medians, indicating higher levels of agreement and satisfaction overall. Cadets performed worse (Table 8) regarding rank-based differences. There was also a difference across rank (Table 7); cadet Captains or Engineers generally rated the training lower than more senior officers, as presented in Table 8 and Figure 3, particularly with respect to the prevention of human behaviors/actions that lead to accidents (EI-II: 3.32 vs. 4.46 for Class A officers). Senior officers are likely to have significantly more practical experience than junior officers, meaning they will have a better understanding of the difficulties of maritime operations and the potential consequences of human error. They might thus have higher expectations for training programs and be more capable of understanding the value of simulator training in reducing these errors. They are also more aware of the small actions and decisions that can cause mishaps. Each corresponding rank has different experience and responsibilities onboard, so training should be tailored accordingly: cadets would benefit from more primary training on guiding principles, while senior officers would gain more from facing advanced scenarios that challenge them to make decisions in difficult situations. Simulator training is probably not a "one-size-fits-all" approach. There are differences between ranks according to the statistical hypothesis testing, but on closer inspection the differences are mainly between cadets and officers rather than among the different ranks of officers. This implies that years of experience are more relevant than the difference in rank between a junior officer and a captain, and that having some officer experience is more important than rank itself (Table 8; Figure 3).

The mean scores of teachers and trainees did not show a statistically significant difference, since using the Mann-Whitney test, $p > 0.05$ was obtained. One explanation could be that both groups have similar outlooks due to regular interaction and engagement with the simulators. Conversely, it may indicate that varied perspectives on the effectiveness of simulator training are not necessarily proportional to instructor experience. These findings are in accordance with previous studies demonstrating the role of simulators in bridging the gap between theory and practice in maritime education (E. Demirel, 2022). The lower scores for both groups indicate the need for better stress management and leadership skills development, which in turn raises doubt about the effectiveness of existing simulator training in addressing non-technical skills, as highlighted by responses to questions II-1 and II-6 (Table 3). These abilities are crucial for effective decision-making and performance under pressure. Future studies should address how simulator training may be tailored to support these skills.

In summary, officers, instructors and students have a generally favorable view of simulator training, particularly with regard to dealing with emergencies and reinforcing technical skills. Those who had greater real-world experience (more than six months at sea) reported greater satisfaction and a greater ability to apply the training to real-world situations. However, enhancing simulation training remains an important area for improvement, in order to reduce primary errors. While statistically significant differences in satisfaction were observed across ranks, most of the variation came from the comparison between officers and cadets, with cadets scoring the training lower; officers were less divided along those lines. Curiously, although instructors were more experienced, no distinction was found in the perceptions of instructors compared to students. Finally, since these skills had lower satisfaction ratings, the study highlights the importance of simulator training focusing more on non-technical skills such as stress control and leadership. Hence, the present study suggests a mixed educational approach that prepares maritime professionals by integrating both simulator training and onboard exposure.

Conclusions.

There is a high "gap" between simulator usage and real-life situations. More experienced seafarers (over six months on ship) transferred skills to a greater degree, showing higher satisfaction and better transfer of learning. The finding of the present work highlights how invaluable onboard training is, even when simulation training is included. This study focuses on the quantitative impact of maritime simulator training on effectiveness with respect to maritime safety and human error minimization, which is highly relevant for shipping companies within STCW standard measures.

While statistically significant differences in satisfaction existed between ranks, the primary difference was between officers and cadets, with cadets in particular rating the effectiveness of the training lower. Thus, there is a need for experience-based training strategies. Specifically, the instructors' perceptions did not differ significantly from those of the students, indicating that their perspectives may be aligned due to their regular exposure to the simulator. The present study concludes by highlighting the need to reinforce non-technical skills, namely the human factors of stress management and leadership, which were assessed with lower ratings.

Thus, the study recommends a blended training approach that encompasses both simulator and onboard experiences in order to enhance overall maritime safety and better prepare maritime specialists for the challenges of the marine field.

References.

Angelique Bosker. (2021). *Assessment of soft skills in inland navigation simulator training.* 1–72. Tampere University of Applied Sciences.

B. Ćorović, P. D. (2013, 05 23). Research of marine accidents through the prism of human factors. *Research of Marine Accidents through the Prism of Human Factors*, pp. 369–378.

Carine Dominguez-Péry, L. N. (2021, 09 24). Reducing maritime accidents in ships by tackling human error: a bibliometric review and research agenda. *Journal of Shipping and Trade*, pp. 1–32.

Cho Thet Maung. (2019). *Simulation training and assessment system on maritime education and training.* Malmö, Sweden: World Maritime University.

E. Demirel, T. A. (2022). Evaluation of simulator use in maritime education and training (MET) institutes. *Proceedings of the International Scientific Conference* (pp. 1–22). Constanta: MBNA Publishing House Constanta.

Elsayed, A. M. (2023). The outcome of implementing structured SOFTES model as a post simulation debriefing strategy among marine trainees. *The International Maritime and Logistics Conference "Marlog 12"* (pp. 1–18). Alexandria, Egypt: Arab Academy for Science, Technology, and Maritime Transport.

Francis A. Alterado, A. A. (2018). Effectiveness of Kongsberg simulations through maritime education technology. pp. 1–10.

Inger Johanne Kristensen. (2023). *Human factors in maritime accidents: a bibliometric review.* Norway: University of South-Eastern Norway, Faculty of Technology, Natural Science & Maritime Science, Institute of Maritime Operations.

International Maritime Organization. (2002). *Model course 2.07, Engine room simulator*, 2002 Edition.

International Maritime Organization (IMO). (2017). *STCW – International convention on standards of training, certification and watchkeeping for seafarers.* IMO.

Kimmo Tarkkanen, J. S. (2023). Pragmatic and hedonic experience of virtual maritime simulator. *7th International GamiFIN Conference 2023 (GamiFIN 2023)* (pp. 106–112). Lapland, Finland.

Lech Kasyk, A. E. (2023, 06 02). The analysis of social and situational systems as components of human errors resulting in navigational accidents. *Applied Sciences*, pp. 1–25.

Mohammud Hanif Dewan, R. G. (2023, 01 07). Immersive and non-immersive simulators for the education and training in maritime domain—A review. *J. Mar. Sci. Eng.*, pp. 1–17.

Muidun Nabi Chowdhury, S. S. (2024, 02 29). Navigating human factors in maritime safety: A review of risks and improvements in engine rooms of ocean-going vessels. *International Journal of Safety and Security Engineering*, pp. 1–14.

Suzanna Razali Chan, N. A. (2016). A theoretical review of human error in maritime accidents. *Advanced Science Letters*, pp. 2108–2112.

Toni Bielić, N. H. (2017, 05 20). Preventing marine accidents caused by technology-induced human error. *Scientific Journal of Maritime Research*, pp. 33–37.

W. Gyldensten, A. C. (2023, 06). *The International Journal on Marine Navigation and Safety of Sea Transportation*, pp. 1–8.

Yisi Liu, X. H. (2016). Human factor study for maritime simulator-based assessment of cadets. *ASME*, pp. 1–6.

Yisi Liu, Z. L. (2020). *Psychophysiological evaluation of seafarers to improve training in maritime virtual simulator.* Singapore: Singapore Maritime Institute and the National Research Foundation, Prime Minister's Office.

Appendix 1: Questionnaire.

USER SATISFACTION SURVEY QUESTIONNAIRE

DATE (YYYY/MM/DD): ____________________

GENDER: ☐ MALE ☐ FEMALE AGE: _________ SEMESTER OF STUDY: _______________

POSITION: ☐ STUDENT ☐ TEACHER

RANK: ☐ 1st CAPTAIN/ENGINEER
☐ 2nd CAPTAIN/ENGINEER
☐ 3rd CAPTAIN/ENGINEER
☐ STUDENT CAPTAIN/ENGINEER

MARITIME EXPERIENCE: ☐ UP TO 6 MONTHS ☐ MORE THAN 6 MONTHS

MARINE SIMULATOR TRAINING: _____ SEMESTER

NECESSARY TO COMPLETE THE QUESTIONNAIRE:

I. PREVIOUS SIMULATOR TRAINING
II. PERFORMING A TRAINING TRIP OR SEA SERVICE FOR MORE THAN SIX MONTHS

I. EVALUATION INDEX OF THE CONTRIBUTION OF SIMULATOR TRAINING IN AVOIDING THE MAIN MISTAKES THAT LEAD TO A MARINE ACCIDENT

No.	SATISFACTION	Strongly disagree	Agree	Neither disagree nor agree	Agree	Strongly agree
1	Did the simulator training help you gain a better understanding of the ship's bridge/engine room work environment?	☐	☐	☐	☐	☐
2	Did the simulator training help you acquire the necessary skills to perform routine actions and tasks and avoid related mistakes on the ship's bridge/engine room?	☐	☐	☐	☐	☐
3	Did the simulator training help you make decisions and avoid mistakes on the ship's bridge/engine room?	☐	☐	☐	☐	☐

II. EVALUATION INDEX OF THE CONTRIBUTION OF SIMULATOR TRAINING TO AVOIDING HUMAN BEHAVIORS/ACTIONS LEADING TO MARINE ACCIDENTS

No.	SATISFACTION	Strongly disagree	Agree	Neither disagree nor agree	Agree	Strongly agree
1	Has simulator training helped you cope with sea duty fatigue and stress?	☐	☐	☐	☐	☐
2	Did the training in the simulator contribute positively to the acquisition of the required technical knowledge in the bridge/engine room on the real ship?	☐	☐	☐	☐	☐
3	Did the training in the bridge/engine room simulator contribute positively to the understanding of the real ship automations?	☐	☐	☐	☐	☐
4	Did the training in the simulator contribute positively to the use of the communication systems on the real ship?	☐	☐	☐	☐	☐
5	Did the training in the simulator contribute positively to dealing with dangerous situations (through indications, alarms, etc.) on the real ship?	☐	☐	☐	☐	☐
6	Did the simulator training help you develop leadership skills to deal with difficult situations on board?	☐	☐	☐	☐	☐

III. EVALUATION INDEX OF THE CONTRIBUTION OF SIMULATOR TRAINING TO THE CORRECTION PROCESS OF ERRORS LEADING TO A MARINE ACCIDENT

No.	SATISFACTION	Strongly disagree	Agree	Neither disagree nor agree	Agree	Strongly agree
1	Did the simulator training help you improve your ability to find out errors/malfunctions on the real ship?	☐	☐	☐	☐	☐
2	Did the simulator training help you after identifying the error/wrong action to describe it and communicate it immediately to your superiors on board?	☐	☐	☐	☐	☐
3	Did the simulator training help you take the required actions and work together to fix the error?	☐	☐	☐	☐	☐

IV. GENERAL EVALUATION INDEX OF SIMULATOR TRAINING AS A FACTOR IN REDUCING MARINE ACCIDENTS

No.	SATISFACTION	Strongly disagree	Agree	Neither disagree nor agree	Agree	Strongly agree
1	Do you think that overall simulator training helps to avoid and correct human errors that can lead to marine accidents?	☐	☐	☐	☐	☐
2	Do you think training in modern VR marine simulators would help reduce human errors/actions that could lead to a marine accident?	☐	☐	☐	☐	☐
3	Do you think increasing training hours in marine simulators would help reduce human error/effort that could lead to a marine accident?	☐	☐	☐	☐	☐