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Identification and Prioritization of Human Error Factors Related to Maritime Accidents

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ABSTRACT

Maritime accidents associated with its consequences, such as loss of people, huge financial compensations, pollution disasters, and environmental damage, are real threats to maritime transport industry. Many factors have a direct or an indirect effect on marine accidents; however, the Human Error Factors (HEFs) are the main contributor to those accidents, as confirmed by many investigations and databases concerning this issue.

Purpose: *This paper aims to study, identify, and prioritize the most important human error factors related to maritime accidents, in an attempt to control and reduce their potentiality in future, and to consequently increase the maritime safety level.*

Approach/Design/Methodology: *The paper presents a systematic literature review on the human error factors that affect maritime safety. Additionally, the study depends on collecting quantitative data using a specially designed questionnaire, which is based on the Analytic Hierarchy Process (AHP) of Multi-Criteria Decision Making (MCDM). The questionnaire targeted around 80 maritime experts working in the maritime industry and academia. The final sample size ended up with 51 respondents.*

Findings: *The participants gave the Competency Factors (CFs) group first rank and priority over the other factor groups. Then, the Psychological Factors (PSFs) group, the Team Factors (TFs) group, the Application Factors (AFs) group, the Voyage Management Factors (VMFs) group, and the Physical Factors (PHFs) group followed in descending order. Moreover, the factors included in each group, totaling 32 factors, were similarly ranked and prioritized.*

Recommendations: *The findings of this paper could serve as a milestone for further studies to trace and identify more factors that contribute to the occurrence of maritime accidents. Thus, to consider the best alternatives to reduce their potentiality and, consequently, to increase the overall maritime safety level.*

Key-words:
Maritime accidents, Human Error Factors (HEFs), Maritime safety, Analytic Hierarchy Process (AHP).

INTRODUCTION

The maritime industry is crucial for global trade and economic growth, but it faces significant safety challenges due to complex operations and an unpredictable marine environment (Arslan et al., 2016). Understanding Human Error Factors (HEFs) is essential for enhancing maritime safety through reducing maritime accidents' rate. Human error factors are broadly categorized into competency factors, physical factors, team factors, psychological factors, voyage management factors, and application factors.

Competency factors relate to personnel skills that encompass knowledge and experience of maritime personnel, influencing their ability to navigate and respond effectively to dynamic and challenging situations at sea (Skorupski and Wiktorowski, 2015). Psychological factors explore the cognitive and emotional aspects that may affect decision-making processes, reaction times, and overall performance during maritime operations (He et al., 2021; Fan et al., 2023). Team factors delve into the collaborative dynamics within maritime crews, examine how effective communication, coordination, and teamwork contribute to or mitigate human errors (Tavakoli and Nafar, 2021). Application factors consider the role of technological equipment in influencing the occurrence and severity of human errors in maritime settings (Morais et al., 2022). Voyage management factors extend the focus to the planning, execution, and monitoring of maritime journeys, exploring how these aspects impact safety outcomes (Graziano et al., 2016). Lastly, the physical factors investigate the environmental and ergonomic elements that may act as contributing or mitigating factors to human errors in the maritime context (Morais et al., 2022).

Maritime accidents result from various factors, including human errors, engine failures, and environmental conditions (Galić et al., 2014). Human error is responsible for more than 85% of maritime accidents and 30-50% of oil spills. Despite this, there is a startling lack of research in the management literature on human errors in the maritime domain and how they affect the maritime safety (Dominguez-Péry et al., 2021). The current endeavor, therefore, is concerned with human-error-related accidents only.

According to the European Maritime Safety Agency report, human factors were the main reason behind most of the maritime accidents which were traced from 2014 until 2020 (EMSA, 2021). Furthermore, the navigation accidents assessment conducted by EMSA in 2022 revealed that nearly 78% of the navigation incidents that have been investigated had some sort of "human factor" component. By focusing on the intricacy of human mistakes, it was demonstrated that marine casualty is not explained by the variability of the major actors' performance. On the other hand, human activity results from complex, non-linear, and dynamic socio-technical interactions between individuals onboard, organizations onshore, policies, procedures, and machinery (EMSA, 2022).

Due to complexity and lack of standardization in maritime accident reporting, determining particular causation factors can be difficult and time-consuming. Despite this, human error has been identified as a primary cause in more than 75% of maritime accidents. A review of 177 marine accident reports revealed that one component of human error, namely a lack of situation awareness, is a serious concern in the maritime realm. In particular, there are failings in the cognitive psychology paradigm of perception, cognition, and future event prediction since human error resulted from a failure to anticipate future actions, a failure to correctly perceive information, and a failure to correctly integrate or comprehend information and/or the system. These human failures are deemed hinderances in the context of advancing onboard digital systems because they suggest that if the crew becomes overly reliant on new technologies, the problems of situational awareness may worsen and may have a greater detrimental influence on safety (Dominguez-Péry et al., 2021).

Several individual factors contribute to navigation accidents as shown in Table 1.

Table 1: Factors contributing to navigation accidents

Ser. No.	Factor	Description
1	Fatigue	Both physical and cognitive functions are impaired by lack of sleep, long hours, and circadian rhythm disorders, leading to poor performance
2	Misperception/Misinterpretation/Distraction	Refer to inadequate operator performance resulting from misreading or misinterpreting information supplied by tools or instruments or other input from the environment, also due to operator's distractions and interruptions
3	Situational Awareness	Failures in processing available information, often due to interruptions, and improper attention-redirections that lead to errors
4	Physical and Mental Incompetence	The operator's physical stamina and coordination were not sufficient to meet the demands of the duties. The majority of incidents listed in EMCIP have been connected to operator performance being hampered by alcohol use

5	Cognitive Workload	This is a result of cognitive processing being negatively influenced by the rapid operational pace of the developing scenario, which results in dangerous operator performance
6	Lack of Awareness of Actual Risks	A false sense of security causes operators to dismiss or underestimate dangers
7	Overconfi-dence	Poor operator assessment of one's own, others', or equipment's capabilities results in incorrect performance at work, such as approaching the port without a pilot's help

Source: EMSA (2022)

Through a systematic examination of these human error factor groups, this research endeavors to clarify the complicated interplay between human actions and maritime safety levels. By identifying patterns, correlations, and dependencies, this study aims to provide valuable insights for industry stakeholders, regulatory bodies, and maritime professionals.

While significant strides have been made in understanding the intricate relationship between human error and maritime safety, there exists a noticeable research gap regarding the comprehensive examination of specific human error factor groups and their collective impact on maritime safety levels. The existing body of literature often addresses isolated aspects of human error in maritime contexts, but a holistic investigation into competency factors, psychological factors, team factors, application factors, voyage management factors, and physical factors is notably lacking. This gap presents an opportunity for further exploration and in-depth analysis to contribute to a more comprehensive understanding of the dynamics at play.

The complexity and the interactions of the human behaviors, responses, and perceptions, make it so difficult and important at the same time to trace and identify the most important HEFs that have a significant impact upon maritime accidents. Thus, the urgency of this paper lies in its potential to identify and prioritize more accurately the most important human error factors that have an impact on marine accidents in order to study the suitable preventive actions to reduce them in future. The paper aims to provide a perspective that can guide the development of effective strategies to enhance the seafarers' performance and skills, thus enhancing the maritime safety level. The findings of this study have the potential to significantly contribute to the overall safety and elasticity of maritime operations, ensuring the well-being of maritime personnel, the protection of valuable cargo, and the sustainability of global trade.

METHODOLOGY

The current study depends on adopting a deductive approach, which explains the causal relationships between the variables of the study, depending on collecting quantitative data. A specially designed questionnaire has been distributed to maritime experts from the industry, with at least 15 years of experience, academic experts, with at least 10 years of experience, and maritime officers working onboard ships, with at least 10 years of experience. The questionnaire was designed to be clear, unbiased, easy to understand, and interesting to maintain the participant's interest, and motivation. It is based on the Analytic Hierarchy Process (AHP) of Multi-Criteria Decision Making (MCDM) (Saaty, 1980), which is based on pairwise comparisons of parameters and subsequent calculation of their weights.

Returned questionnaires were subsequently used to prioritize the different human error factors. The questionnaire provides perfectly consistent pairwise comparison matrices by asking the participants to complete the first row only, that is (a_{1j} , j = 1, 2,...n), where n is the number of factors. Then the remaining elements of the matrix are obtained as follows: (i) the diagonal elements a_{ij} , i = j are all equal to 1, (ii) the upper off-diagonal elements, except for those of the first row, are obtained applying the property $a_{ij} = a_{1j} / a_{1i}$, where i , j = 1, 2, ..., n, and (iii) the lower off-diagonal elements are obtained from the property $a_{ij} = 1/ a_{ji}$, where i , j = 1, 2, ..., n.

The questionnaire targeted around 80 maritime experts, while the final sample size ended up with 51 respondents. Statistical analysis of the data provided by the respondents and completed by the authors was done by using the SPSS to check their frequencies; also, quantitative analysis of the data was attempted using the AHP method. A specially designed computer program was constructed to accommodate the chosen parameters, based essentially on the use of Excel spreadsheets (Microsoft, Excel 2016).

Selection of Factor Groups

Six main HEFs groups were considered as follows: (a) Competency Factors (CFs) group, (b) Physical Factors (PHFs) group, (c) Team Factors (TFs) group, (d) Psychological Factors (PSFs) group, (e) Voyage Management Factors (VMFs) group, and (f) Application Factors (AFs) group.

These groups totaled a number of 32 human error factors as listed in Table 2. The relative significance or preference of each factor is then calculated using the priority or relative importance of each factor. The factor with the highest weight value was taken as the most important factor, followed by the lower-weight factors in descending order.

Table 2: Human error groups and pertinent factors included in the analysis

Group	Code	Factor
Competency Factors (CFs)	CF1	Technical Knowledge
	CF2	Training
	CF3	Skills
	CF4	Attitude
	CF5	Response
	CF6	Experience
	CF7	Perception
Physical Factors (PHFs)	PHF1	Fatigue
	PHF2	Fitness
	PHF3	Sensitivity to Temperature
	PHF4	Sensitivity to Noise
	PHF5	Sensitivity to Ship's Motion/Vibration
Team Factors (TFs)	TF1	Communication
	TF2	Team Management
	TF3	Multi-Cultural Team
	TF4	Watchkeeping
	TF5	Safety Awareness
Psychological Factors (PSFs)	PSF1	Risk Tolerance
	PSF2	Stress Resistance
	PSF3	Panic Resistance
	PSF4	Motivation
	PSF5	Complacency
Voyage Management Factors (VMFs)	VMF1	Passage Plan/Voyage Planning
	VMF2	Decision Making
	VMF3	Procedures and Checklists
	VMF4	Look Out
	VMF5	Situation Awareness
Application Factors (AFs)	AF1	Position Fixing
	AF2	Usage of Bridge Equipment
	AF3	Maneuvering
	AF4	Interpretation Adequacy
	AF5	Ship Speed

DATA ANALYSIS

As stated in the previous section, a questionnaire has been specifically designed to collect data for the current study. More than 80 experts were contacted in order to complete the questionnaire and participate in the analysis. After excluding the biased and incomplete ones, the final sample size ended up with 51 respondents, approximately representing 64% of the targeted sample, and were grouped as follows: (a) 31 experts from AASTMT (~ 61%), and (b) 20 experts from different organizations and companies in the maritime field (~ 39%).

The experts' age ranged from less than 40 years to more than 70 years, and their years of experience ranged from 10 years to more than 40 years. Table 3 shows the descriptive analysis of the respondents. It is clear that the group with the age range from 41 to 55 are 21 respondents (41.2%), while the group with 15 to 20 years of experience are 19 respondents (37.3%).

Table 3: Descriptive analysis of the respondents' profile

Age			Experience		
Range	Frequency	Percent	Range	Frequency	Percent
Less than 40	16	31.4	From 10 to 14	16	31.4
From 41 to 55	21	41.2	From 15 to 20	19	37.3
From 56 to 70	9	17.6	From 21 to 34	10	19.6
More than 70	5	9.8	From 35 to 40	4	7.8
Total	51	100.0	Above 40	2	3.9
			Total	51	100.0

RESULTS

Table 4 displays a typical pairwise comparison matrix of factor groups provided by the experts involved in the analysis. The weight of the individual groups is also shown in the same table. According to the experts, group CFs has the highest weight, followed by groups PSFs, TFs, AFs, VMFs and finally PHFs.

Table 4: Pairwise comparison matrix of the factor groups

Group	CFs	PHFs	TFs	PSFs	VMFs	AFs	GM	W	Rank
CFs	1.000	3.157	1.943	1.618	2.723	2.118	1.963	0.304	1
PHFs	0.317	1.000	0.616	0.513	0.863	0.671	0.622	0.096	6
TFs	0.515	1.625	1.000	0.833	1.401	1.090	1.010	0.156	3
PSFs	0.618	1.951	1.201	1.000	1.683	1.309	1.213	0.188	2
VMFs	0.367	1.159	0.714	0.594	1.000	0.778	0.721	0.112	5
Afs	0.472	1.491	0.917	0.764	1.286	1.000	0.927	0.144	4
Sum	3.289	10.383	6.390	5.322	8.956	6.966	6.456	1.000	

The weight of the individual groups is depicted in Figure 1. It could be observed that the CFs group is ranked first, while the PSFs group comes in the second rank; the third one is the TFs group; the fourth rank goes to AFs group, while VMFs group comes in the fifth rank, and finally the PHFs group is ranked sixth.

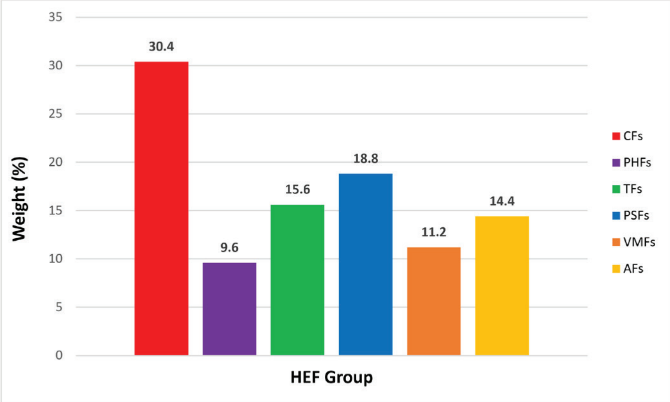

Fig. 1. Weight of the HEF Groups

Table 5 displays another typical pairwise comparison matrix of the seven factors of the CFs group. The weight of each individual factor is calculated in Table 4. According to the experts, Technical Knowledge CF1 is given the highest weight, followed by Experience CF6, Training CF2, Skills CF3, Response CF5, Perception CF7, and finally Attitude CF4.

Table 5: Pairwise comparison matrix of CFs

HEFs	CF1	CF2	CF3	CF4	CF5	CF6	CF7	GM	W	Rank
CF1	1.000	1.575	1.648	2.429	1.712	1.180	1.824	1.567	0.216	1
CF2	0.635	1.000	1.046	1.542	1.087	0.749	1.158	0.995	0.137	3
CF3	0.607	0.956	1.000	1.474	1.039	0.716	1.107	0.951	0.131	4
CF4	0.412	0.648	0.678	1.000	0.705	0.486	0.751	0.645	0.089	7
CF5	0.584	0.920	0.963	1.419	1.000	0.689	1.065	0.915	0.126	5
CF6	0.847	1.335	1.397	2.058	1.451	1.000	1.546	1.328	0.183	2
CF7	0.548	0.863	0.904	1.332	0.939	0.647	1.000	0.859	0.118	6
Sum	4.633	7.297	7.636	11.254	7.933	5.467	8.451	7.262	1.000	

Similarly, Tables 6 to 10 were constructed to calculate the weight of the factors of each of the remaining groups and to subsequently prioritize them. It is worthy to mention that in Table 6, PHF4 (Sensitivity to noise) and PHF5 (Sensitivity to ship motion) come in the same level as they have the same weight of the third rank. Also in Table 8, PSF3 (Panic Resistance) and PSF5 (Complacency) share the second rank as they have equal weights.

Table 6: Pairwise comparison matrix of PHFs

HEFs	PHF1	PHF2	PHF3	PHF4	PHF5	GM	W	Rank
PHF1	1.000	2.303	3.227	2.844	2.848	2.269	0.409	1
PHF2	0.434	1.000	1.401	1.235	1.237	0.985	0.177	2
PHF3	0.310	0.714	1.000	0.881	0.883	0.703	0.127	4
PHF4	0.352	0.810	1.135	1.000	1.001	0.798	0.144	3
PHF5	0.351	0.809	1.133	0.999	1.000	0.797	0.144	3
Sum	2.447	5.636	7.896	6.959	6.969	5.553	1.000	

Table 7: Pairwise comparison matrix of TFs

HEFs	TF1	TF2	TF3	TF4	TF5	GM	W	Rank
TF1	1.000	2.687	1.841	2.377	1.531	1.783	0.335	1
TF2	0.372	1.000	0.685	0.885	0.57	0.663	0.125	5
TF3	0.543	1.46	1.000	1.291	0.832	0.968	0.182	3
TF4	0.421	1.13	0.775	1.000	0.644	0.75	0.141	4
TF5	0.653	1.755	1.202	1.553	1.000	1.164	0.219	2
Sum	2.989	8.032	5.503	7.106	4.577	5.329	1.000	

Table 8: Pairwise comparison matrix of PSFs

HEFs	PSF1	PSF2	PSF3	PSF4	PSF5	GM	W	Rank
PSF1	1.000	2.318	1.891	2.062	1.887	1.763	0.336	1
PSF2	0.431	1.000	0.816	0.890	0.814	0.761	0.145	4
PSF3	0.529	1.226	1.000	1.090	0.998	0.933	0.178	2
PSF4	0.485	1.124	0.917	1.000	0.915	0.855	0.163	3
PSF5	0.530	1.228	1.002	1.093	1.000	0.935	0.178	2
Sum	2.975	6.896	5.626	6.135	5.614	5.247	1.000	

Table 9: Pairwise comparison matrix of VMFs

HEFs	VMF1	VMF2	VMF3	VMF4	VMF5	GM	W	Rank
VMF1	1.000	1.769	1.791	1.82	1.447	1.529	0.297	1
VMF2	0.565	1.000	1.012	1.029	0.818	0.864	0.168	3
VMF3	0.558	0.988	1.000	1.016	0.808	0.853	0.166	4
VMF4	0.549	0.972	0.984	1.000	0.795	0.84	0.163	5
VMF5	0.691	1.223	1.238	1.258	1.000	1.056	0.205	2
Sum	3.363	5.952	6.025	6.123	4.868	5.142	1.000	

Table 10: Pairwise comparison matrix of AFs

HEFs	AF1	AF2	AF3	AF4	AF5	GM	W	Rank
AF1	1.000	1.916	1.772	1.644	1.612	1.552	0.302	1
AF2	0.522	1.000	0.925	0.858	0.841	0.810	0.157	5
AF3	0.564	1.081	1.000	0.928	0.910	0.876	0.170	4
AF4	0.608	1.165	1.078	1.000	0.981	0.944	0.183	3
AF5	0.620	1.189	1.099	1.020	1.000	0.963	0.187	2
Sum	3.314	6.351	5.874	5.450	5.344	5.144	1.000	

DISCUSSION

Based on the previous pairwise comparison matrices, the participants gave the Competency Factors (CFs) group first rank and priority over the other factor groups. Then, the Psychological Factors (PSFs) group, the Team Factors (TFs) group, the Application Factors

(AFs) group, the Voyage Management Factors (VMFs) group, and the Physical Factors (PHFs) group followed in a descending order, as has been shown in Figure 1.

In the same manner, the factors included in each one of these groups, were also weighed and prioritized according to their importance based on the participants' judgements, as has been shown in Tables 5 – 10. The results in the previous section, from Table 5 to Table 10, are concerned with the ranking of the factors of each group. However, to reveal the overall significant importance of each factor regarding all factors (32 factors), weight of each factor has been multiplied by its related group weight, so the overall weight of all 32 factors amounts to 100%. Thus, all of the 32 factors have been ranked and prioritized, as shown in Figure 2.

The figure reveals that the technical knowledge ranks first, with a relative importance of 6.57%, followed by risk tolerance, experience, communication, position fixing, training, skills, fatigue, response, perception, safety awareness, complacency, panic resistance, passage plan, motivation, multi-cultural team, stress resistance, attitude, ship speed, interpretation adequacy, maneuvering, situation awareness, usage of bridge equipment, watch keeping, team management, decision making, procedures and checklists, look out, fitness, sensitivity to ship motion, sensitivity to noise, and finally comes sensitivity to temperature, ranking last with a relative importance of 1.22%.

Moreover, it could be observed that six factors from the Competency Factors (CFs) group are within the first ten factors; these are the technical knowledge, experience, training, skills, response, and perception. On the contrary, four factors from the Physical Factors (PHFs) group take the lowest four ranks; these are the fitness, sensitivity to ship motion, sensitivity to noise, and finally sensitivity to temperature. Nonetheless, fatigue, which is related to the same group, comes in the eighth rank.

To make the picture clearer, the previous results are reproduced in Figure 3, where the groups are prioritized, together with their pertinent factors. It could be observed in this figure, that two groups acquire low weights in groups' prioritization; these are the Application Factors (AFs) group and Physical Factors (PHFs) group, but on the contrary, they compromise two factors having high weights among the overall factors; these are position fixing with a relative importance of 4.35%, acquiring the fifth rank, and fatigue with a relative importance of 3.93%, occupying the eighth place.

The figure also reveals that the top-ranked group, i.e. Competency Factors (CFs), comprises a factor with a significant low weight, which is attitude, with a relative importance of 2.71%, occupying the eighteenth place. Similarly, the Psychological Factors (PSFs) group occupies the second place though it comprises the stress resistance factor with a relative importance of 2.73%. Likewise, Team Factors (TFs) group has the third rank, while it includes the team management factor, with a significantly low relative importance of 1.95%, thus occupying the twenty fifth place.

The results of the current study were compared with similar results of other investigators as follows: Uğurlu et al. (2015) prioritized HEFs behind grounding accidents and confirmed that application errors were the most common type. This study, however, confirmed that the competency factors are the most important type of factors behind maritime accidents. They classified HEFs and groups to Voyage Management Errors: Faulty or inadequate passage plan, Inappropriate route selection, Use of improper chart; Team Management Errors: Lack of communication and coordination in bridge resource management, Lack of external communication, Improper look-out, Deficiency in safety management system, Failure of watch arrangements; Application Errors: Position Fixing Application Errors, Inefficient usage of bridge navigation equipment, Faulty maneuvering, Interpretation Errors, Unsafe speed; and Individual Errors: Fatigue, Alcohol, Stress, Lack of training and education, Watch-keeping officer who is unfamiliar with bridge.

Uğurlu et al. (2015) stressed the importance of enhancing education and training to prevent grounding accidents in maritime operations, focusing on competency, shore-based, and onboard training. They also emphasized the need for competency training in team management, communication, and navigation equipment use, alongside promoting Electronic Chart Display and Information Systems (ECDIS) usage. Additionally, they addressed the impact of increased workload due to reduced crew numbers, advocating for increased seafarer numbers and proper rest hours, and recommended improvements in Safety Management Systems (SMS) concerning passage planning, chart applications, and team management.

Figure 4 represents a comparison of results between the current study and Uğurlu et al. (2015) study concerning prioritization of factors according to its relative importance. For comparison reasons, the common HEFs in both studies were selected and their relative weights adjusted (normalized) such that the sum in each case is 100%. In doing so, six factors suffered from some kind of deviation in terminology between the two studies. To get around this difficulty and to conduct the comparison more accurately Uğurlu et al. names of factors have been adjusted to match the same terminology of the current study, as shown in Table 11. It is important to state here that one of the problems that encountered this study in its early stages was concerned with the variation and diversity in terminology regarding the human error factors among the different studies found in the literature, which makes the process of identifying such factors more difficult.

Table 11: Adjusted names of Uğurlu et al. (2015) factors to match current study

Uğurlu et al. (2015) factors	Current study factors
Communication and coordination in bridge resource management	Team management
Use of improper chart	Technical knowledge
Safety management system	Safety awareness
Route selection	Decision making
Alcohol	Fitness
Unfamiliarity with bridge	Experience

Figure 4 reveals that team management and position fixing factors in Uğurlu et al. (2015) study have significant high weights, with a relative importance of 18.7% and 17.2%, respectively. On the contrary, in the current study, team management has low weight with a relative importance of 3.3%, while position fixing has a higher weight with a relative importance of 7.4%. Technical knowledge has the highest weight with a relative importance of 11.2%, then comes experience with a relative importance of 9.4%.

Özdemir et al. (2018) used fuzzy AHP technique to identify important elements that contribute to occupational accidents involving sailors onboard and provided alternative remedies. The research ranked the following variables as the primary causes of these mishaps: environmental factors, shipborne problems, cargo problems, human issues, and poor management. The main reasons were found to be human issues, such as exhaustion, ignorance, and a lack of training. Results of Özdemir et al. (2018) and those of the current study are generally in good agreement, as they both emphasize that the main reasons that contribute to accidents are related to human error. However, the former study stresses on exhaustion, ignorance, and lack of training. In the current study, these factors are called fatigue, lack of technical knowledge, and also lack of training, and have the weights of 3.93%, 6.57%, and 4.16%, respectively, in good agreement with their counterparts in Özdemir et al. (2018).

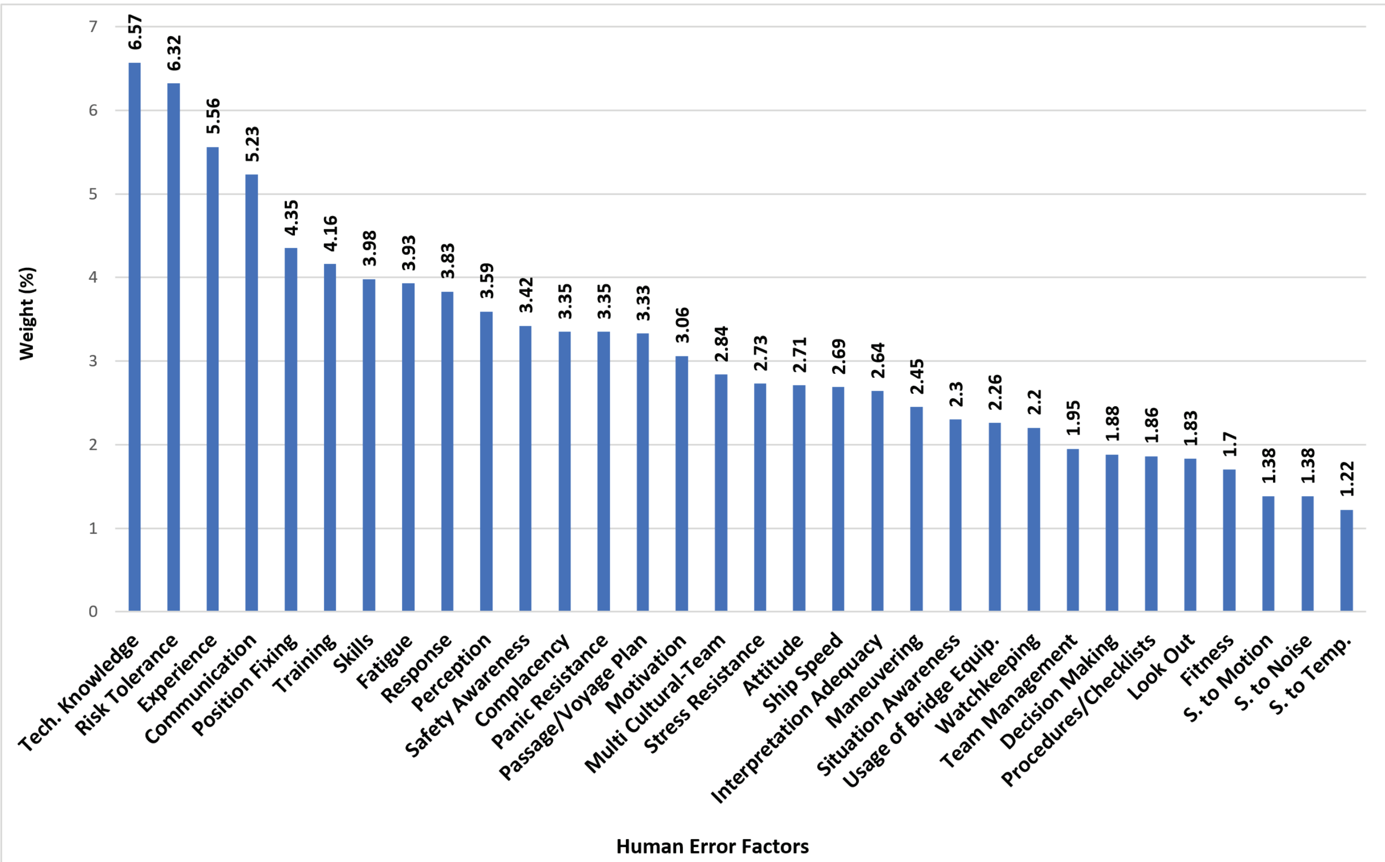

Fig. 2. Weights of human error factors

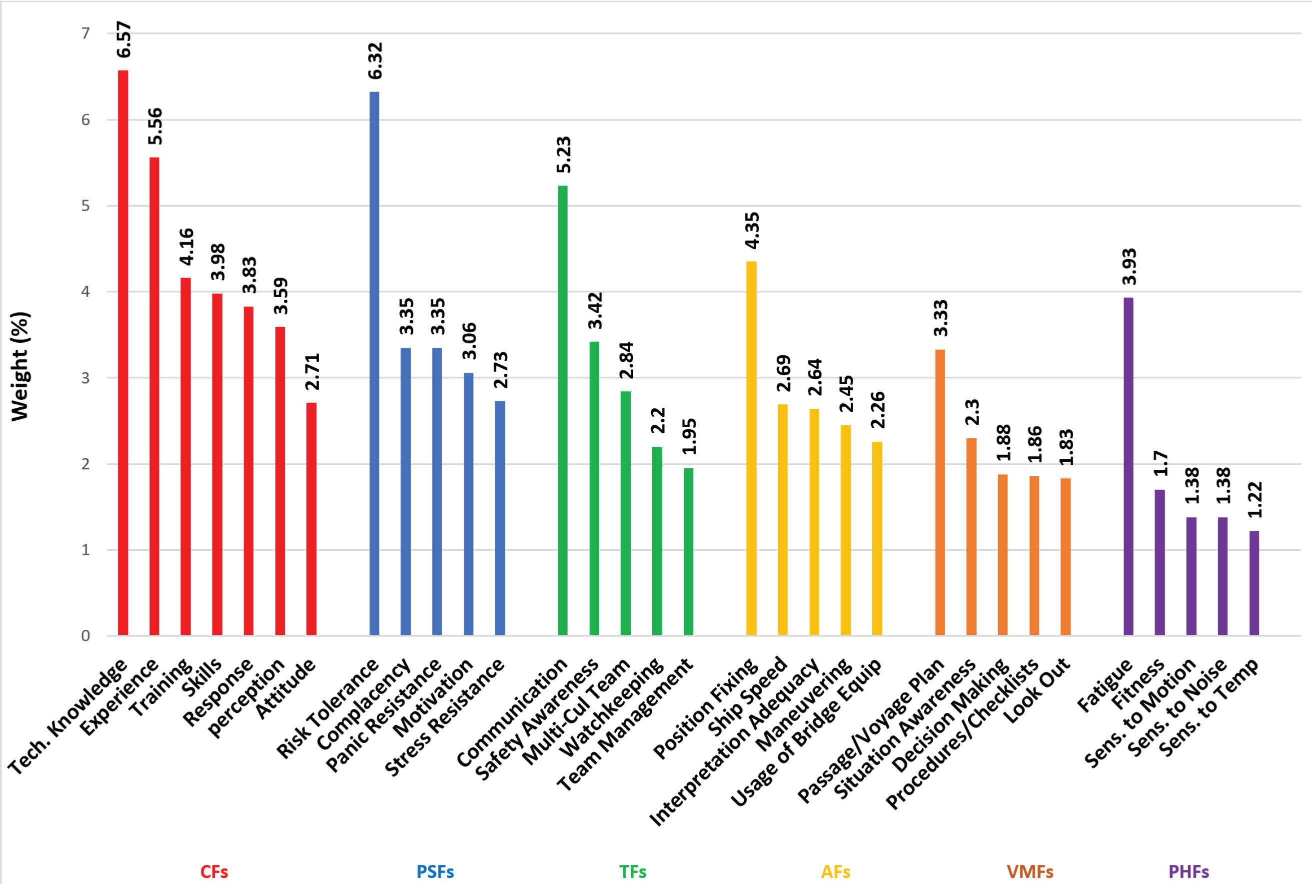

Fig. 3. Prioritization of groups and factors

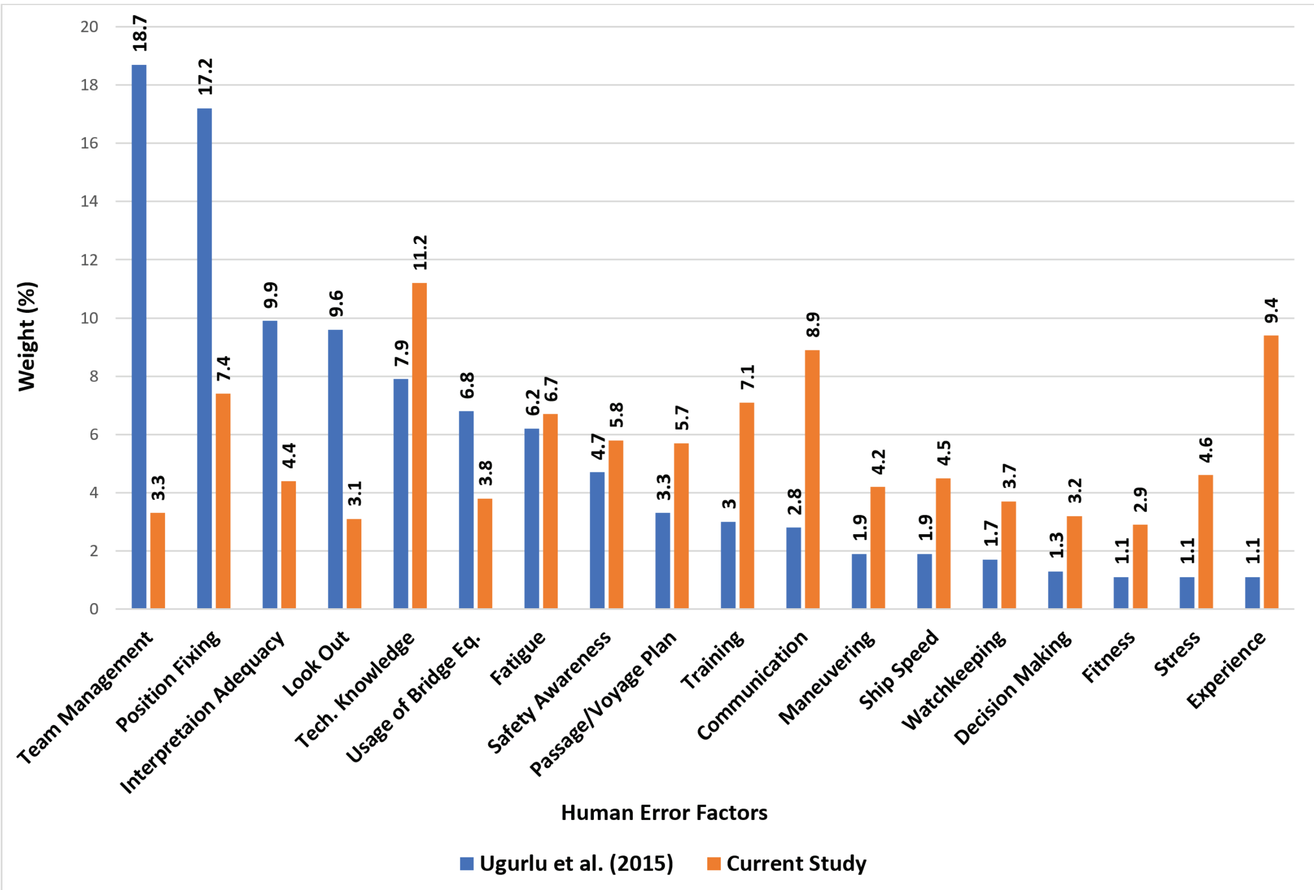

Fig. 4. Comparison between Uğurlu et al. (2015) and the current study corresponding factors' weight

CONCLUSION

The aim of this paper was to study, identify, and prioritize the most important human error factors related to maritime accidents in an attempt to control and reduce their potentiality in the future by considering the suitable preventive measures and to consequently increase the maritime safety level. Motivated by this aim, the study presented a specially designed questionnaire, completed by 51 experts from the maritime field to identify the most important HEFs related to maritime accidents. Based on their judgements, this questionnaire was analyzed using AHP technique. The results showed the most influential factors on maritime accidents based on the participants' perspective; which are technical knowledge, risk tolerance, experience, communication, position fixing, training, skills, and fatigue factors that have scored significantly high weights, agreeing with several studies and researches that investigate human error factors related maritime accidents, e.g. Özdemir et al. (2018), EMSA – EMCIP (2020), and EMSA – EMCIP (2022). This could help the decision makers to adopt the most suitable solutions to neutralize those factors and to subsequently enhance the skills and performance of seafarers towards achieving higher safety levels. However, the results reported herein cannot be generalized without taking the limitations encountered during conducting this research into consideration. Two such limitations were dictated by the time available to finish the research and the availability of a large number of experts to participate in the data collection process via the questionnaire.

RECOMMENDATIONS

Based on the present findings, it is verified that the lack of technical knowledge, inefficient communication skills, inappropriate risk tolerance and inaccurate risk assessment are the most important human error factors that have a significant impact on maritime accidents, in addition to the need for more technical training to enhance the seafarer's skills and experience. Therefore, Maritime Education and Training (MET) should focus more effectively upon the improvement of seafarers' technical and non-technical skills. In this regard, the following recommendations can be singled out:

- Providing periodical effective learning and training sessions to seafarers, in order to continuously enhance their technical and non-technical skills.
- Training programs should encompass maneuvering under emergency situations, whether critical environmental conditions or maneuvering in restricted areas; this improves the seafarer's risk tolerance, response, and perception. Also, the practical training should include working under stress and pressure; so, it could reduce seafarers' panic when facing critical situations.
- Regularly evaluating the emergency response protocols in high-risk regions to guarantee that all affected crew members are aware of them.
- Sticking to the following rules to reduce the risks of collision and grounding in high-risk locations: (i) keeping a close eye on the situation of a vessel and to conduct bridge watch constantly, and (ii) minimizing the chance of making poor or late decisions.

The findings of this paper could serve as a milestone for further studies to trace and identify more factors such as mechanical failure, environmental and weather conditions, that have an influential impact on maritime accidents and to adopt the best alternatives to reduce their potentiality, thus increasing the overall maritime safety level. Moreover, the impact of new technologies, such as artificial intelligence and virtual reality, on maritime safety deserves a separate investigation to augment the current endeavor.

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