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RESEARCH ARTICLE

An evaluation of the effects of human factors on potential ship accidents under pilotage

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ABSTRACT

In recent years, despite the technological advances, and increasing security measures in the maritime industry, it is observed that the effect of the human factor in the marine accidents has not changed. Most of the accidents occur in narrow canals, straits, rivers and entering port areas, resulting in environmental pollution, economical casualties and injury/loss of life. Pilotage is set compulsory in order to maintain safe passage at such confined waters. The purpose of this study is to investigate the effect of critical human factors on the potential ship accidents under pilotage operations. To explore the identified human factors, depth interviews and a questionnaire study were conducted with masters and pilots. The obtained data was analysed using DEMATEL (Decision Making Trial and Evaluation Laboratory) method to identify the most important and influential factors. The DEMATEL method is used to investigate interaction among human factors and to visualize them with help of causal-effect relation diagram. The results show that master experience, pilot experience and crew training are significant factors compared to other human risk factors. As a result of the findings of this research, it is also thought that improving the collaboration and communication between the master and the pilot will be effective in preventing the accidents. Moreover, understanding casual relations among human factors is important to prevent marine accidents. Furthermore, sensitivity analysis was performed for testing reliability of the experts' evaluation and being clear certainty of the main results/findings in the DEMATEL method. It is found that expert considerations to the casual relationship between human factors are objective and sufficient. The findings of this article provide a critical overview of the research literature on the development of preventive measures for policy makers, shipping companies and port authorities.

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Introduction

Shipping, as a massive international mode of transportation, is becoming increasingly important to global trade and economic development. This increase in marine operations raises the risk of potential ship accident. It is defined by IMO as death, serious injury or loss of a person from ship, loss or abandonment of a ship, material damage to a ship, contact with land, collision of ships and severe damage to the environment directly in connection with the operation of a ship (International Maritime Organization, 2008). Studies on marine accidents indicate that over 75 % of marine accidents occur due to human error (Berg et al., 2013; Wróbel, 2021). Despite building ships equipped with modern technology and setting new rules and regulations to increase the safety, marine accidents still occur (Erol & Başar, 2015). As effects of accidents may be catastrophic to environment, economy and lives, quantification of human error contribution which is accepted as the main cause of marine accidents is of vital importance for maritime domain. As the industry adopts to the autonomous vessels which is expected to reduce human intervention to maritime transportation, the topic is particularly crucial to examine in the maritime domain recently (Hoem et al., 2019). The main goal of the autonomous ships is announced as improving the maritime transportation safety by means of reducing human error, which indicates importance of the subject (Ahvenjärvi, 2016). Although autonomous ships can navigate safely in open seas, it is thought that navigation in confined waters will need human support for safe navigation.

Navigation is more complicated at confined waters such as canals, rivers, straits and port areas due to difficulties like heavy ship traffic, proximity to dangers and many other complications (van Westrenen, 1995). The rapid expansion of marine transportation, particularly in recent decades, has resulted in congested marine traffic in confined waters (Wu et al., 2020). Growing ship size has also been highlighted as a navigation and manoeuvring difficulty in previous research (van Westrenen, 1996). All these complications are pointing out that support of professionals who are aware of the dangers at local waterways is crucial for safe navigation of ships at confined waters. Maritime pilotage is a profession that provides this support to the ships navigating at confined waters in order to ensure safe passage of ships from these dangerous waterways. With the knowledge and experience it provides, pilotage has vital role on risk reducing during passage from dangerous fairways (Uğurlu et al., 2017).

Many researchers studied ship accidents and their reasons in the last decades. Mutual point of these studies is presenting human error as the major reason of maritime accidents. The most popular technique used in maritime domain for human error identification is the Human Factors Analysis and Classification System (HFACS) which is developed from Reason's Swiss Cheese model (B. Wu et al., 2022). Chen et al. (2013) proposed HFACS for maritime accidents (HFACS-MA) in line with HFACS, Hawkins' SHEL and Reasons' Swiss Cheese Models. HFACS has four main causal categories for classifying human errors; unsafe acts, preconditions for unsafe acts, unsafe supervision and organizational influences. In the framework proposed in their study, external factors are integrated in the main causal factors of traditional HFACS. In the study, authors analysed capsizing reasons of a ship in the port and found out that preconditions are the primary factors with 34.8% frequency which are followed by unsafe acts (26.1%), unsafe supervisions (21.7%), organizational influences (13%), and external factors (4.3%), respectively (Chen et al., 2013). Uğurlu et al. (2018) recommended HFACS for passenger vessel accidents (HFACS-PV), and examined 70 ship collision and contact accidents involving passenger vessels by using their proposed framework. In the framework, operational conditions are integrated in the main four causal categories of HFACS structure. Findings of the study reveal that unsafe acts are the primary factors contributing to accident occurrence with 35.01% frequency which are followed by preconditions for unsafe acts (30.37%), operational conditions (19.92%), organizational influences (11.21%), and unsafe supervision (3.48%), respectively (Uğurlu et al., 2018). Yıldırım et al. (2019) studied collision and grounding incidents by using HFACS. This study demonstrated that decision errors, resource management failures, violations, skill-based errors and communication errors are the main human errors leading to accidents (Yıldırım et al., 2019). Erdem & Akyuz (2021) used Success Likelihood Index Method (SLIM) and interval type-2 fuzzy sets (IT2FSs) to evaluate the potential impact of human errors in maritime domain. Due to the significant threats to the marine environment, a loading procedure onboard a containership was evaluated in the study. The results revealed that safety culture, fatigue, time limitation, and experience are deeply influential on crew performance (Erdem & Akyuz, 2021). Uflaz et al. (2022) outlines the principles of fuzzy-based shipboard operation human reliability analysis (SOHRA), which is used to quantitatively assess human error during ship preparation procedures for navigation. The overall human error probability for preparing the ship for sailing is found to be 1.49E-01. It is stated that the study will provide practical contributions to shore-based safety professionals, ship managers and masters of the ship (Uflaz et al., 2022).

Though human factors in maritime accidents are studied frequently, effects of human factors on accidents under pilotage are very limited. For instance, Graziano et al. (2016) classified human errors in collision and grounding accidents by the Technique for the Retrospective and Predictive Analysis of Cognitive Errors (TRACEr) taxonomy. A total of 52 accident reports involving 64 ships were analysed and 289 obtained task errors were classified by TRACEr. The results revealed that 28.7% of the task errors are classified under navigation tasks and pilotage errors has the highest share with 43.6% among navigation subtasks. This result indicates that 12.5% of the task errors are related to pilotage activities among the grand total (Graziano et al., 2016). Park et al. (2019) investigated the relation between pilots' age and accidents under pilotage. The study indicated that after pilot retirement age was increased from 65 to 68, ship accidents under pilotage increased seriously. They also underlined that fatigue is one of the main contributors to human errors thus, resting hours of the pilots should be rescheduled to reduce the fatigue (Park et al., 2019). Ernstsen & Nazir (2020) studied a systematic human error reduction and prediction approach (SHERPA) to investigate the types of errors and error remedies encountered in pilotage operations. Analysis of SHERPA results revealed that action omission is the most frequent human error contributing to accidents where communication error is the second most frequent one (Ernstsen & Nazir, 2020).

International Group of P&I Clubs (IGP&I) published a report about P&I claims involving vessels under pilotage between years 1999-2019 (IGP&I, 2020). As reported, there are 1,046 incidents resulting liabilities in excess of 1.82 billion USD. These numbers indicate that ship accidents which occur under pilotage has an average liability of 1.74 million USD per incident, demonstrating fatality of the results in case of failure at maintaining safety of navigation during pilotage waters. Incident categories and statistics for the years between 1999-2018 are shown in Table 1, however, since the data for 2019 are limited, they are not included in the Table 1. The report also points out that general cause of the incidents is insufficient performance of the bridge team and suggests that effective master-pilot exchange and good bridge resource management are crucial for the safe navigation under pilotage. At the loss prevention poster published by West of England P&I Club for navigation with pilot, it is highlighted that navigation in pilotage waters is mutual task of the bridge team and the pilot (IGP&I, 2020). Potential risks listed in the poster while navigating with pilot are failures at communication, cooperation and situation awareness which are connected to human element. All this information leads us conclude that the majority of accidents under pilotage are caused by human error which is also the major cause for shipping accidents in general (Erol & Başar, 2015; Macrae, 2009; Sánchez-Beaskoetxea et al., 2021).

Table 1. Categorization of the incidents occurred during pilotage (IGP&I, 2020)

Year	No. of Incidents	Total Coast	Average Cost Per Incident	Allision & Contact	Collision	Grounding	Navigation
1999	33	$21,761,748	$659,447	26	6	1	0
2000	47	$35,371,471	$752,584	29	13	5	0
2001	70	$51,090,973	$729,871	45	21	4	0
2002	52	$41,662,008	$801,192	38	9	4	1
2003	56	$106,305,096	$1,898,305	35	16	3	2
2004	59	$76,596,850	$1,298,252	29	20	10	0
2005	46	$39,563,866	$860,084	20	20	5	1
2006	54	$112,306,540	$2,079,751	29	20	5	0
2007	57	$306,538,481	$5,377,868	30	20	6	1
2008	57	$50,811,280	$891,426	31	22	4	0
2009	38	$149,212,660	$3,926,649	26	10	2	0
2010	32	$70,436,063	$2,201,127	23	7	2	0
2011	59	$76,077,997	$1,271,310	32	25	2	0
2012	74	$130,646,688	$1,765,496	49	21	4	0
2013	42	$107,118,832	$2,550,448	25	13	4	0
2014	79	$144,241,993	$1,825,848	39	32	7	1
2015	70	$134,125,800	$1,916,083	40	25	4	1
2016	42	$66,593,613	$1,585,562	27	9	6	0
2017	45	$42,425,808	$942,796	32	10	2	1
2018	34	$58,769,271	$1,728,507	25	8	1	0
Totals	1,046	$1,821,657,039	$1,741,545	630	327	81	8

In all the studies mentioned above, realizing that human factors contributing to maritime accidents during pilotage are not studied comprehensively is our main motivation to conduct this study. Within this scope, critical factors and causal relations among them that cause maritime accidents with presence of pilot are determined by using multi-criteria decision-making methods (MCDM), Decision Making Trial and Evaluation Laboratory (DEMATEL). Moreover, preventive actions are proposed based on determined critical factors.

DEMATEL Method

DEMATEL (The Decision Making Trial and Evaluation Laboratory) is one of the Multi Criteria Decision Making (MCDM) methods, and was developed in 1972 by the Battelle Memorial Institute of Geneva Research Center to visualize the structure of complicated causal relationships through matrixes or digraphs (Gabus & Fontela, 1972). In the terms of the structural modelling approach, DEMATEL method has many advantages and capabilities such as analysing causal relations between criteria of the system, converting the interdependency relations into cause and effect group, detecting most critical criteria, reflecting relative relation of the criteria, and so on (Si et al., 2018). Thanks to its advantages and capabilities, DEMATEL method is used to solve complicated problem in many application areas such as engineering (Zhang vd., 2020), social science (Demirci & Uygur, 2021), and energy (Büyüközkan & Güleryüz, 2016).

The main steps applied of the DEMATEL method are introduced as follows and its flowchart is presented in Figure 1.

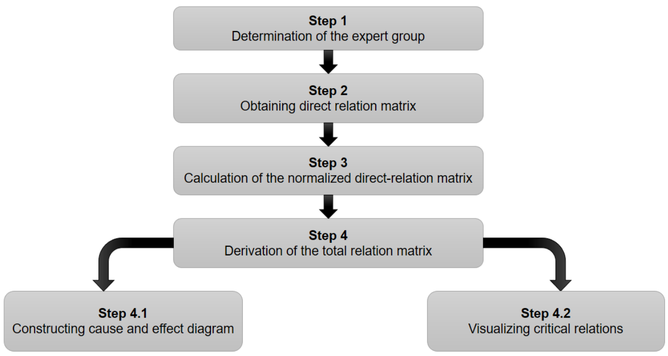

Figure 1. Flowchart of the DEMATEL method

Step 1: Determination of the Expert Group

This step includes the determination of experts who know the problem well and can evaluate it from different perspectives for problem-solving. These experts should be people who have experienced or observed the problem.

Step 2: Obtaining Direct Relation Matrix (A)

Secondly, each experts' evaluation for criteria comparison is obtained by using scale between 0 and 4, presented in Table 2 (Akyuz & Celik, 2015). Arithmetic means of expert evaluations for each comparison which shown in Eq. (1) is used as the direct relation matrix.

Table 2. Corresponding relationship of evaluation criteria

Linguistic terms	Numerical values
No impact (No)	0
Very low impact (VL)	1
Low impact (L)	2
High impact (H)	3
Very high impact (VH)	4

$$A = \begin{bmatrix} 0 & a_{12} & \cdots & a_{1n} \\ a_{21} & 0 & \cdots & a_{2n} \\ \vdots & a_{32} & 0 & a_{3n} \\ a_{n1} & a_{42} & \cdots & 0 \end{bmatrix} \tag{1}$$

Step 3: Calculation of the Normalized Direct-Relation Matrix (S)

The normalization of matrix A can be achieved with following Eq. (2) and Eq. (3), respectively (Si et al., 2018). Thus, each element of matrix S should be in the range of 0 to 1.

$$K = \frac{1}{max_{1 \le i \le n}} \sum_{j=1}^{n} a_{ij} \tag{2}$$

$$S = K \times A \tag{3}$$

Step 4: Derivation of the Total Relation Matrix (M)

Total relation matrix M is derived using Eq. (4) from S. In this Equations, I denotes the identity matrix (Soner, 2021).

$$M = S(I - S)^{-1} \tag{4}$$

Step 4.1: Constructing cause and effect diagram

In this step, the sum of row and columns of total relation matrix are calculated by using Eq. (5) and Eq. (6), respectively (Xia et al., 2015). In these equations, while r_i denotes all direct and indirect influence given by criterion i to all other parameters, c_j denotes the degree of influenced impact.

$$r_i = \left[\sum_{j=1}^{n} m_{ij}\right]_{nx1} \tag{5}$$

$$c_j = \left[\sum_{i=1}^{n} m_{ij}\right]_{1xn} \tag{6}$$

$$M = m_{ij}, \quad i,j = 1,2,\cdots n.$$

where r_i denotes sum of rows in total relation matrix and refers all direct and indirect influence given by criterion i to all other criteria. Similarly, c_j denotes sum of columns in total relation matrix and refers all direct and indirect influence received by criterion j from others.

To construct cause – effect diagram, $r_i + c_j$ and $r_i - c_j$ values are calculated. In the diagram, these values define coordinates of criteria and refer horizontal and vertical axis values, respectively. $r_i - c_j$ value is named as relation and if relation value is positive, criterion j can be grouped into cause group, otherwise it can be grouped into effect group. When $i=j$, $r_i + c_j$ value shows importance of criterion and is called as prominence. While the visualization of relation among criteria with cause-effect diagram, all relation which have indirect and direct effect between criteria are taken into account.

Step 4.2: Visualizing critical relations

The total relation matrix contains all direct and indirect relations between criteria. For this reason, with the aim of filtering some minor effects between criteria and exploring critical relations between criteria, the threshold value (θ) can be defined with summation of standard deviation and mean of m_{ij} figures from total relation matrix (Xia et al., 2015). The values over threshold value shows critical relations. These values present effects of criteria on each other.

Application and Results

Over one-third of the total human population lives within 60 miles of coastal areas. For this reason, maritime accidents happened in near coastal areas excessively affect people, environment and property. To prevent accidents in coastal areas, many preventive measures has been taken by government and private sector organisations. Some of the major and well-known measures are pilotage service, navigation aids, vessel traffic service (VTS), traffic separation scheme. Among all these measures, the pilotage service stands out as the first and most effective measure in terms of directly intervening in the ship's manoeuvre to prevent the accident. Therefore, when examining the human factor in accidents that occurred under pilotage, the relationship between pilots and ship crew should be considered. In this study, to begin the analysis, critical human-related criteria that have vital role in maritime accident under pilotage area were determined with the help of accident investigation reports published by GISIS and expert opinions. Criteria determined are presented in Table 3.

In the first step, initially, professionals who are considered to be directly influential in ship control and have at least 15 years of experience were selected as experts. Information about the experts consulted in this study is given Table 4.

Table 3. Human criteria

Codes	Criteria
C_1	Master Experience
C_2	Pilot Experience
C_3	Bridge Team Management
C_4	Maneuvering Team
C_5	Communication
C_6	Fatigue
C_7	Understanding & Application of Instructions
C_8	Crew Training

Table 4. Information about the experts

Experts	Competency	Current Position	Experience in Year
Expert 1	Oceangoing Master	Master	15 Years
Expert 2	Oceangoing Master	Pilot	17 Years
Expert 3	Oceangoing Master	Harbour Master	21 Years
Expert 4	Oceangoing Chief Officer	Port Captain	18 Years
Expert 5	Oceangoing Chief Officer	VTS Operator	15 Years

Table 5. Direct-relation matrix

Criteria	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8
C_1	0.000	3.000	4.000	3.800	4.000	4.000	4.000	4.000
C_2	3.200	0.000	3.800	3.200	3.600	4.000	3.600	2.200
C_3	3.800	3.400	0.000	3.400	4.000	3.800	4.000	3.400
C_4	4.000	3.400	2.800	0.000	4.000	3.800	4.000	3.800
C_5	3.600	3.400	4.000	4.000	0.000	4.000	4.000	3.000
C_6	3.600	3.400	4.000	4.000	4.000	0.000	4.000	3.400
C_7	3.600	2.800	4.000	4.000	3.000	3.000	0.000	3.400
C_8	4.000	3.400	4.000	4.000	3.600	4.000	4.000	0.000

Table 6. Normalized direct relation matrix

Criteria	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8
C_1	0.000	0.111	0.148	0.141	0.148	0.148	0.148	0.148
C_2	0.119	0.000	0.141	0.119	0.133	0.148	0.133	0.081
C_3	0.141	0.126	0.000	0.126	0.148	0.141	0.148	0.126
C_4	0.148	0.126	0.104	0.000	0.148	0.141	0.148	0.141
C_5	0.133	0.126	0.148	0.148	0.000	0.148	0.148	0.111
C_6	0.133	0.126	0.148	0.148	0.148	0.000	0.148	0.126
C_7	0.133	0.104	0.148	0.148	0.111	0.111	0.000	0.126
C_8	0.148	0.126	0.148	0.148	0.133	0.148	0.148	0.000

Table 7. Total direct-relation matrix

Criteria	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8
C_1	2.382	2.231	**2.572**	**2.557**	2.541	**2.567**	**2.657**	2.307
C_2	2.226	1.897	2.298	2.271	2.265	2.299	2.368	2.014
C_3	2.422	2.168	2.358	2.460	2.457	2.476	**2.569**	2.213
C_4	2.430	2.170	2.455	2.350	2.459	2.478	**2.570**	2.226
C_5	2.431	2.181	2.501	2.491	2.343	2.496	**2.584**	2.214
C_6	2.463	2.210	2.535	2.525	2.505	2.400	**2.618**	2.256
C_7	2.262	2.012	2.328	2.319	2.272	2.295	2.275	2.072
C_8	2.524	2.254	**2.586**	**2.575**	2.543	**2.580**	**2.671**	2.190

To solve complex relations among criteria presented in Table 3, experts were asked to compare these criteria by using the linguistic terms in Table 2. After the comparison, direct relation matrix in Table 5 is achieved by calculating the average of each experts' opinion (Step 2).

Normalization of the direct-relation matrix, Step 3, Eq. (2) and Eq. (3) have been used respectively and normalized direct-relation matrix is presented in Table 6.

To obtain total relation matrix, as the Step 4, Eq. (4) have been utilized and the matrix presented in Table 7. Threshold value is calculated from this matrix (Step 4.1). In this matrix, mean of the all elements and standard deviation are calculated as 2.379 and 0.169, respectively. Threshold value (2.548) has been determined by adding one standard deviation to mean of elements. In Table 7, bold numbers indicate elements over threshold value and refer critical relations. These relations are visualized with the help of chord diagram and presented in Figure 2. The chord diagram is built by using "*circlize*" package in R programming language.

In the application of the Step 4.2, with the help of Eq. (5) and Eq. (6), relation (r_i - c_j) and prominence (r_i + c_j) values has been derived in Table 8 and thus, DEMATEL diagram has been constructed as shown in Figure 3. In this figure, red and green points denote cause and effect criteria, respectively.

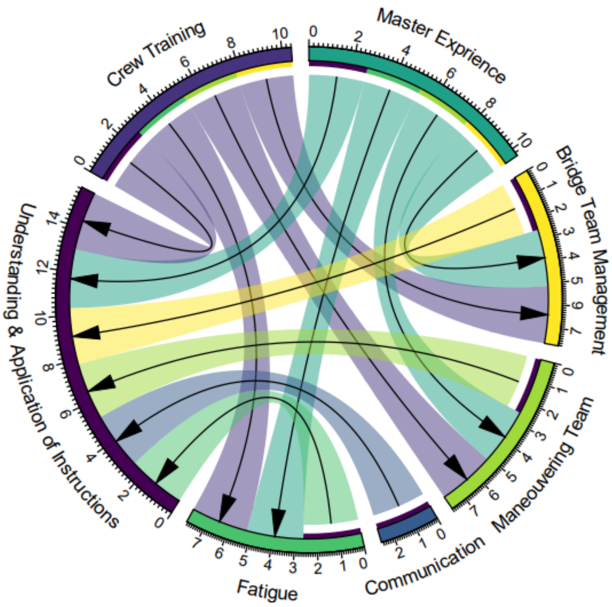

Figure 2. Critical relation between criteria

Table 8. Values of r_i, c_j, $r_i + c_j$ and $r_i - c_j$.

Criteria	$\tilde{r}_i$	$\tilde{c}_j$	$\tilde{r}_i + \tilde{c}_j$	$\tilde{r}_i - \tilde{c}_j$
C_1	19.814	19.141	38.955	0.673
C_2	17.640	17.123	34.762	0.517
C_3	19.123	19.633	38.756	-0.510
C_4	19.138	19.548	38.687	-0.410
C_5	19.241	19.385	38.626	-0.144
C_6	19.511	19.592	39.103	-0.081
C_7	17.836	20.311	38.147	-2.476
C_8	19.923	17.492	37.416	2.431

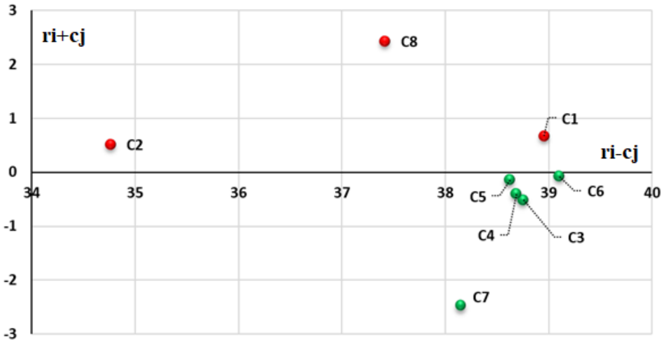

Figure 3. The cause-effect relation diagram

Sensitivity Analysis

Testing reliability of the experts' evaluation and being clear certainty of the main results/findings in the DEMATEL method, sensitivity analysis is conducted. Sensitivity analysis makes it possible to verify whether the results of the DEMATEL are varied by experts' evaluation (Seker & Zavadskas, 2017). In the analysis, experts' evaluations are weighted within the various scenarios in order to detect the effect of criteria compared by experts on the results. According to six scenarios given in Table 9, firstly, equal weights (Scenario 1) are given for each experts' evaluation as applied in Step 1. Then, different weights are given for each expert in the five scenarios to analyse the evaluations how much effect to causal relation between criteria. With the given weights in each scenario, direct relation matrix is calculated by using weighted arithmetic mean.

Afterwards, other steps explained in the section 2 are applied in MS Excel to obtain final DEMATEL results, ($r_i + c_j$) and ($r_i - c_j$) values. Obtained results are given in Table 10 and presented in Figure 4.

The results obtained from the sensitivity analysis for each scenario show that the overall effect on the cause-and-effect criteria remained the same, even if the experts' evaluations were weighted differently. The fact that the lines connecting the criteria are parallel or overlapped for each scenario in Figure 3 shows that the experts are of the similar or same opinion in pair-wise comparison of the criteria. As a result, the approaches of experts to the causal relationship between human factors are unbiased and adequate for this study.

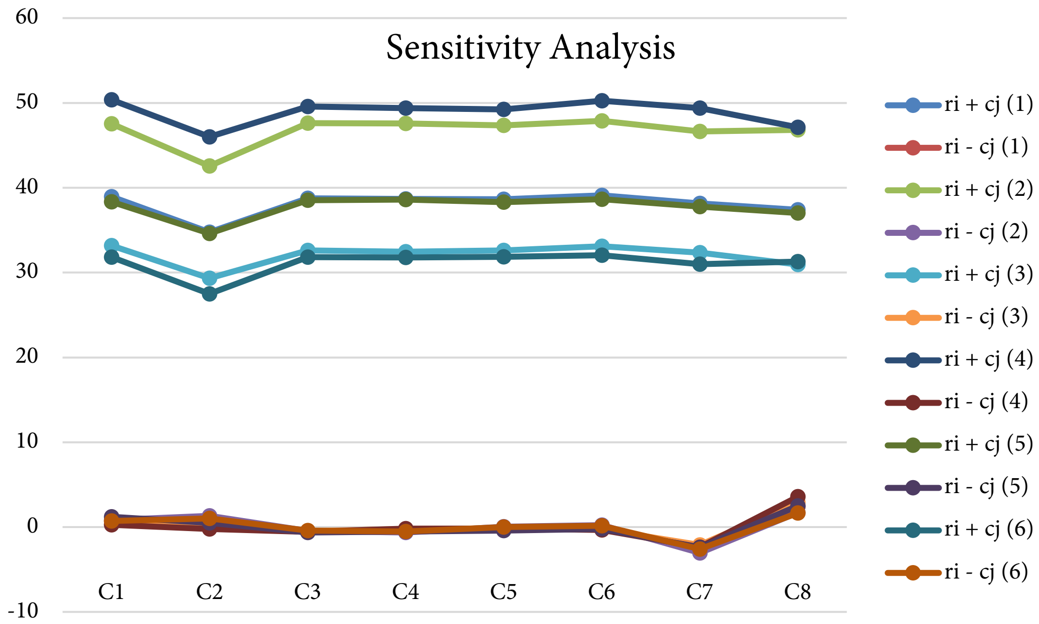

Figure 4. Cause and Effect diagram of sensitivity analysis for each scenario

Table 9. Given weights in each scenario

Experts	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6
Expert 1	0.20	0.10	0.30	0.25	0.20	0.15
Expert 2	0.20	0.15	0.10	0.30	0.25	0.20
Expert 3	0.20	0.20	0.15	0.10	0.30	0.25
Expert 4	0.20	0.25	0.20	0.15	0.10	0.30
Expert 5	0.20	0.30	0.25	0.20	0.15	0.10

Table 10. ($r_i + c_j$) and ($r_i - c_j$) values obtained in each scenario

Scenario 1		Scenario 2		Scenario 3		Scenario 4		Scenario 5		Scenario 6	
$r_i + c_j$	$r_i - c_j$	$r_i + c_j$	$r_i - c_j$	$r_i + c_j$	$r_i - c_j$	$r_i + c_j$	$r_i - c_j$	$r_i + c_j$	$r_i - c_j$	$r_i + c_j$	$r_i - c_j$
38.955	0.673	47.527	0.834	33.178	0.333	50.362	0.273	38.355	1.199	31.803	0.710
34.762	0.517	42.560	1.330	29.337	-0.042	46.008	-0.211	34.611	0.504	27.498	1.012
38.756	-0.510	47.632	-0.458	32.600	-0.497	49.579	-0.576	38.546	-0.633	31.813	-0.414
38.687	-0.410	47.573	-0.625	32.463	-0.207	49.376	-0.173	38.611	-0.529	31.774	-0.517
38.626	-0.144	47.360	0.023	32.607	-0.144	49.235	-0.182	38.313	-0.411	31.860	0.000
39.103	-0.081	47.887	0.232	33.111	-0.246	50.244	-0.345	38.653	-0.213	32.045	0.155
38.147	-2.476	46.625	-3.042	32.337	-2.106	49.370	-2.363	37.779	-2.414	31.003	-2.593
37.416	2.431	46.837	1.706	30.948	2.908	47.109	3.577	37.039	2.498	31.292	1.646

Findings

The significant relationships of each factor are explained using a cause-effect diagram which created according to Table 8. The findings obtained from the model created by using expert opinions are divided into two different groups as follows; cause and effect factors.

Cause Factors

In order to clearly assess the most common and critical human factors on accidents during navigation under pilotage, it is essential to focus on the cause factors that have positive value of $\tilde{r}_i - \tilde{c}_j$. As shown in cause-effect diagram (Fig. 1), C_1, C_2 and C_8 are in cause group. In cause group, C_8 (Crew Training) has the highest $\tilde{r}_i - \tilde{c}_j$ value (2.43) among the all factors. This means that C_8 has a more significant impact on the whole of the process. Furthermore, C_8 has the highest $\tilde{r}_i$ value (19.92) among the causal factors from the point of influential impact degree. Following that, C_1 (Master Experience) has the second highest $\tilde{r}_i - \tilde{c}_j$ value (0.67) and is the second most important causal factor among all factors. C_1 has the second highest degree of influential impact ($\tilde{r}_i$) value which is 19.81. Therefore, it has a great influence on the entire process. Also, C_8 and C_1 have critical effect on C_3, C_4, C_6, and C_7. Moreover, C_2 is found as the third most critical factor which means that it had a considerable influence on the entire process ($\tilde{r}_i - \tilde{c}_j$ = 0.52).

Effect Factors

In Figure 1, the factors below the horizontal x-axis are considered as the effect group. As can be clearly seen from Figure 1, it shows that influential factors can be easily affected by other factors. According to the cause-effect diagram, C_6 (Fatigue) has the highest $\tilde{r}_i + \tilde{c}_j$ value (39.10) among the effect factors. In addition, $\tilde{r}_i - \tilde{c}_j$ value of C_6 is very high (-0.08). This means that C_6 is the least affected factor among the whole process and has significant effect on the other factors. Moreover, it has the highest degree of influential impact index ($\tilde{r}_i = 19.51$). Considering $\tilde{r}_i + \tilde{c}_j$ value, the other parameters are sorted by C_3, C_4, C_5 and C_7, respectively and they had also great impacts on the entire process as effect factors. Furthermore, C_7 (understanding & application of instructions) has the lowest $\tilde{r}_i - \tilde{c}_j$ value (-2.48) and this means that C_7 is easily affected from other factors. Specifically, C_7 is critically affected by C_1, C_3, C_4, C_5, C_6 and C_8. It is also observed that Bridge Team Management (C_3) has the second highest $\tilde{r}_i + \tilde{c}_j$ value (38.76) among the other effect factors.

Discussion

The human factor is accepted the primary cause of the majority of marine accidents. The human factor, which accounts for 75-96% of maritime accidents involving modern ships, is a major issue that must be recognized and addressed. One of the most difficult tasks for investigators is determining the reasons of human error because the role of human influence in these errors is revealed by the combination of many parameters that are ignored after an accident. However, it is possible to determine the source of human errors that occur in many accidents by analysing them with the right people who are experts in their fields. That is why this study is of essential importance. In this study, the human factor in accidents that may occur with pilot onboard was investigated by using the DEMATEL method by taking expert opinions. In the report published by the Canadian Transportation and Safety Board (CTSB), it is seen that 273 incidents that occurred in the Canadian pilotage waters from 1987 to 1992. CTSB also reported that 42% of incidents involving misunderstandings or lack of communication between the pilot and the captain or watch officer. Hetherington et al. (2006) stated that the term "misunderstanding" represents a lack of situation awareness and poor team working as well as inadequate communication (Hetherington et al., 2006). In this context, many companies have implemented Bridge Team Management (BTM) courses because they are recommended by the IMO. Although BTM courses are compulsory for deck officers, there is still lack of skills, which increases the possible accident risks. According to MSC-MEPC.2/Circ.13, the rules and regulations that implemented to seafarers should be simple, clear and comprehensive.

The results also emphasize the significance of collaboration once again. Crew training, master and pilot experiences were found to be associated with the occurrence of marine accidents with presence of pilot. In order to minimize the effect of such human factors on the occurrence of accidents, it is necessary to continually improve the quality of maritime training and standards to meet the constantly changing needs, and to provide regular knowledge by updated trainings to all crew. Akyuz & Celik (2014) emphasized the need for routine and special training to lead personnel and all crew members in order to improve ship safety standards. Additionally, it is recommended that the safety training officer on board implement an effective training program coordinated with the Master (Akyuz & Celik, 2014). The significance of pilot experience is found to be low in maritime accidents with presence of pilot, however errors originated by pilots are considered to be caused by fatigue and communication failures instead of pilot experience. Fatigue is not only a problem to be prevented in order to improve the individual well-being of seafarers but it is also one of the most important human factors that can increase the risk of accidents and fatal disasters. Crew member performances are affected by fatigue due to its effects of reducing situation awareness, causing planning deficits/errors, leading to inability to adapt to new knowledge, frequent forgetfulness and concentration difficulties. Moreover, crew performance is directly related to management policies, cultural factors, experience, training and so on (MSC-MEPC.2-Circ.13, 2013). Rothblum et al. (2002) stated that human factors such as fatigue, stress, health, situation awareness, and cultural diversity might cause to unsafe situations (Rothblum et al., 2002). Moreover, extended hours on duty are contributed to marine accidents that could be attributable to fatigue (Raby & McCallum, 1997). The authors also examined 98 ship casualty reports and found that fatigue was effective in 23% of cases. One of the most common human factors is seafarer fatigue. Several factors such as working hours, extended work, the short period of rest between working hours and excessive workload can contribute to fatigue (Smith et al., 2007). Therefore, work rest hours of both pilot and ship crew should be reconsidered and revised in order to provide effective work/rest periods and minimize fatigue. In order to reduce the possibility of human error as much as possible, preventive actions should be proposed and discussed with all stakeholders in light of the findings. Our observations are in agreement with previous studies regarding the human factor is an important factor in marine accidents (Trucco et al., 2008; Tzannatos, 2010; Fan et al., 2018).

Conclusion

Ship accidents have caused global ecological, environmental, and economic problems, posing a hazard to human life. Especially, accidents in confined waters in recent years (Ever Given) have seriously damaged global trade and powerful economies around the world. Therefore, to prevent accidents in these areas, many preventive measures has been taken by government and private sector organisations. Although pilotage is taken as one of the major preventive measures in coastal areas, accidents still occur in coastal areas such as canal, strait, and port area. In addition, preventive measures are taken with national and international rules and regulations in order to minimize the effect of other human-induced factors that have a significant impact on accidents.

In present study, the DEMATEL method was used to solve the complex relationships among human factors considered as affecting accidents with presence of pilot at confined waters. As a result of the study, it is found that master experience (C_1) and crew training (C_8) have influential role on the other factors. Furthermore, understanding & application of instructions (C_7) is most affected by other factors. As an interesting result of the study is that pilot experience (C_2) is among the influential factors and is less impressive than the others. This imply that the main cause of maritime accidents is caused by human factors originating from the ship and points out the importance of seafarer's competences and skills in safe ship management. To ensure the reliability of the obtained results, sensitivity analysis was performed and it is revealed that the experts' evaluations on the human factors are consistent in case of different weights too.

With the help of DEMATEL results, we believe that the maritime stakeholders can determine their policies for the prevention of accidents and regulate relation between critical human factors. In future studies, the scope of the study can be expanded by considering the environmental and ship-related factors that are thought to have an effect on the maritime accident under pilotage.

Compliance With Ethical Standards

Authors' Contributions

SMED: Conceptualization, Methodology, Software, Original draft preparation.
RC: Conceptualization, Methodology, Original draft preparation.
HE: Supervision, Writing- Reviewing and Editing.

Conflict of Interest

The authors declare that there is no conflict of interest.

Ethical Approval

For this type of study, formal consent is not required.

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