HUMAN FACTOR ANALYSIS OF CONTAINER VESSEL'S GROUNDING ACCIDENTS

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SUMMARY

Investigation on maritime accidents is a very important tool in identifying human factor-related problems. This study examines the causes of accidents, in particular the reasons for the grounding of container ships. These are analysed and evaluation according to the contribution rate using the Monte Carlo simulation. The OpenFTA program is used to run the simulation. The study data are obtained from 46 accident reports from 1993 to 2011. The data were prepared by the International Maritime Organization (IMO) Global Integrated Shipping Information System (GISIS). The GISIS is one of the organizations that investigate reported accidents in an international framework and in national shipping companies. The Monte Carlo simulation determined a total of 23.96% human error mental problems, 26.04% physical problems, 38.58% voyage management errors, and 11.42% team management error causes. Consequently, 50% of the human error is attributable to human performance disorders, while 50% team failure has been found.

NOMENCLATURE

AHP	Analytic Hierarchy Process
ATSB	Australian Transport and Safety Bureau
BRM	Bridge Resource Management
ECDIS	Electronic Chart Display and Information System
ENC	Electronic Navigation Chart
ETSC	European Transport Safety Council
FTA	Fault Tree Analysis
GISIS	Global Integrated Shipping and Information System
GPS	Global Positioning System
GT	Gros Tonnage
HFACS	Human Factor Analysis and Classification System
IMO	International Maritime Organization
ISM	International Safety Management
MAIB	Marine Accident Investigation Branch
STCW 78/95	Standards of Training Certification and Watchkeeping
UNCTAD	United Nations Conference on Trade and Development
US	United States
WTO	World Trade Organization
VHF R/T	Very High Frequency Radio Telephone

1. INTRODUCTION

Maritime transport is the lifeblood of the world's economy (WTO, 2010). Approximately 80% of the global trade by volume and over 70% by value are carried by sea and handled by ports worldwide (UNCTAD, 2012). The growing need for transport boosted by the global economic development has led to an increase in the number and size of ships in the world fleet. The world merchant fleet consists of 1.75 billion deadweight tons, with a total of 89,464 vessels as of 2015. The world fleet by principal vessel types consist of 27.98% oil tankers, 43.47% bulk carriers, 4.39% general cargo ships, 11.14% other vessel types and 13.02% container ships (UNCTADStat, 2015). The role of container ships for the global trade is more important than its tonnage share would suggest. Accordingly, 52% of the maritime trade in dollar terms is containerized (World Shipping Council, 2013).

Lu and Tsai (2010) recognised that shipping is one of the world's most dangerous professions. It is generally accepted that container ships are different and more often difficult to operate from other ship types in terms of working conditions and challenges. For instance, personnel fatigue resulting from frequent voyages and manoeuvres, high-speed navigation, non-stop watches between passages and ports and short stay at ports present various risks to safety of life and property based on human factors and environmental pollution. A company governing with the highest level of safety perception of their ships according to this understanding has triggered the research subject selection. The remarks received during the interviews conducted with the representatives of a container shipping company, which operates in the global transport and owns over 30 ships, stated that their ships consecutively undergo grounding accidents in spite of the fact that the ships in their fleet are modern, and the captains and officers are experienced and decent sailors with academic backgrounds.

Research on maritime accidents leads to the process of taking new measures and establishing new rules. The scope of the study was kept within specific limits because of the lack of research studies that concomitantly focus on the accident type and human error in grounding accidents of container ships. This study aims to determine the most significant failures by running the algorithm composed by collecting and combining accident root causes from real accident reports in a Monte Carlo simulation. The results express the causes and failure modes with the maximum likelihood obtained by running the algorithm in the simulation for a hundred thousand times. The aim is to contribute to raising awareness as regards accident prevention and develop proposals to create preventive measures by detecting and evaluating the root causes and failure modes.

2. LITERATURE REVIEW

Ship operations present numerous risks in various fields, such as social and personal issues, environment, property, operations and corporate image. Ships that are out of their safe courses pose a series of dangers along with accidents, including collision and grounding (Martins & Maturana, 2010). The databases containing descriptions of worldwide accidents state that fire, grounding and collision are the most frequent types of sea accidents (Soares & Teixeira, 2001). According to an investigation involving Greek flagged vessels between 1993 and 2006, the most frequent type of accident was grounding (46.9%), followed by technical failures at a much lower rate (28.7%). Other types of accidents (e.g. fire, explosion, collision and flooding) accounted for 21.6% of the total and less than 10% separately (Tzannatos, 2010). Grounding and ship fires are the dominant types of ship accidents worldwide (Akten, 2006). The most frequent types of accidents with the highest rate are grounding (32%), contact (24%), and collision (16%) (ETSC, 2001). Collision and grounding-related maritime disasters may pose serious problems for the environment, human life, and property (Committee V.1, 2006). Possible maritime accidents mean risks for life, economy and the environment. Therefore, analysing these accidents and evaluating results to take necessary actions for ensuring safe navigations and mitigating the risks of maritime accidents are essential (Hollnagel, 2002; Antao & Soares, 2006).

Human error is generally the primary factor in maritime accidents. Around 75% to 96% of these accidents involve human error to a certain extent (Baker & McCafferty, 2005; Hetherington et al., 2002; McCafferty & Baker, 2006; Toffoli et al., 2005; Dabra & Casal, 2004; Rothblum, 2000, Uğurlu et al., 2015a, Uğurlu et al., 2015b, Uğurlu et al., 2015c). Therefore, many academic studies have aimed at reducing human error in ships.

Amrozowicz et al. (1997) investigated the grounding accident occurring in tanker vessels. They determined the following factors in reducing the potential risk of grounding: checking publications for changes, properly determining the waypoint, master verifying the passage plan, accurate planning information, properly taking fixes, recognizing the difference errors and providing accurate and reliable navigation equipment. Human error embodies a lack of knowledge and experience, technical incompetence, poor look-out, inattention to rules, procedures and shipboard control, misinterpretation of radar signals, fatigue and lack of alertness, overworking, exhaustion and insufficient rest periods. Errors made by humans, which are fallible as ever, will clearly continue to be the dominant cause of accidents in navigable waters (Akten, 2006). Macrae (2009) reviewed 30 accident reports investigated by the Australian Transport Safety Bureau (ATSB). He determined that inadequate communication between bridge team members and non-preparation or faulty passage plan are common reasons. Chauvin et al. (2013) made a systematic and multi-component analysis of accidental maritime collisions using a human factor analysis and classification system (HFACS) method. They examined dates related to 27 reported accidental collisions involving a total of 39 ships between 1998 and 2012. Their analysis showed that the majority of collisions had resulted from poor decisions. Their study also compared the reasons behind recent accidents with those identified for previous accidents. Ugurlu et al. (2015a) used the fault tree analysis (FTA) method to evaluate the risk of collision and grounding in the case of oil tankers. The database used in the study was based on a research of accidents involving oil tankers between 1998 and 2010 and according to the Global Integrated Shipping Information System (GISIS). The authors identified the factors for reported accidents within the scope of the study. They also observed these causal factors through the FTA, which revealed the level of importance of the causal factors in the initial accident stage. Akhtar & Utne (2015) determined the differences for collision and grounding between fatigue factors. The collision accidents related to fatigue include wrong/badly made decisions, misconceptions and poor communication between vessels. The grounding accidents related to fatigue include monotony, and the navigating officer either overlooking the upcoming seabed or simply falling asleep. Uğurlu et al. (2015b) analysed grounding accidents using the analytic hierarchy process. Their results suggested that the most significant causes of these types of accidents are the lack of communication and coordination, position-fixing application errors, lookout errors, interpretation errors, use of improper charts, inefficient use of bridge navigation equipment and fatigue. The preventive measures proposed in their papers were about education and training, ECDIS, bridge resource management, number of seafarers, and working–rest hours.

Lu & Tsai (2008) study experimentally assessed the impact of safe environments in sea accidents from the seamen's perspectives particularly as part of container shipping. Lu & Tsai (2010) also introduced and tested a model on the relationship between safe behaviours and safe environments. Zheng et al. (2016) estimated fatal and non-fatal crew injuries in container vessel accidents using probit regression equations. They also used the US Coast Guard database, including container vessel accidents between 2001 and 2008.

The Monte Carlo simulation is a modelling technique that transfers causal relationships of a system to computers and enables behaviours of the real system to be observed as part of a computational model. It is an effective technique widely employed in optimization, numeric integration, sampling from probability distributions, and solving complicated problems (Murphy & Perera, 2001; Tür & Balas, 2010). The simulation is one of the types of risk analysis or assessment methods along with the sensitivity analysis and moment methods (Balas et al., 2004).

The Monte Carlo simulation offers alternatives to analytical mathematics in understanding the statistical sampling distribution among random samples and assessing their behaviours. In a majority of studies, researchers define the virtual simulation population as computational algorithms. Computer algorithms create artificial data by simulating a social phenomenon of the real world. Researchers can use virtual population-related information to ensure a better understanding of the statistical estimations based on real data (Mooney, 1997).

Goerlandt & Kujala (2011) suggested a method called traffic simulation based on the collision probability modelling to determine the probability of ship–ship collisions. Their method provided input for the relevant models into determining the number of expected accidents along with locations, frequency, and expected results. These authors applied the Monte Carlo simulation to estimate collision-related factors in a statistically significant manner.

The Monte Carlo simulation analyses are applicable to the risk analysis of ship manoeuvring and traffic models (Aarsæther & Moan, 2010). Goerlandt et al. (2012) summarized the risk assessment methodology of ship collisions. They also analysed a draft for their existing collision case scenario models, and employed the Monte Carlo simulation to devise collision scenarios.

An examination of the accident studies in the literature showed that special grounding studies for container vessels were not performed. Therefore, the present study is very important to fill the gap in this area. The main objective of this study is to demonstrate the significance level of accident causes and failure modes.

3. METHOD

Feedback from maritime accident investigation reports provides enormous guidance to preventing prospective shipping accidents. Hence, the literature shows many studies on accident and human errors. A total of 46 container ship's grounding accidents that occurred between 1993 and 2011 were investigated in this study. The accident data herein included accident reports mainly recorded on the Marine Accident Investigation Branch (MAIB), ATSB, a private company, and the GISIS. The GISIS provides public access to selected data collected by the Secretariat. Its aim is to allow online access to information supplied to the IMO Secretariat by the Maritime Administrations in compliance with IMO's instruments. Accordingly, registration is required. The GISIS casualty module contains information related to marine casualties and incidents as well as full marine safety investigation reports submitted to the International Maritime Organization by reporting administrations. The module also contains analyses of these reports, which aimed to identify the overall trends or issues of potential concern to marine transportation (or to the shipping industry).

The casualty module contains two kinds of information collected on ship casualties. The first category of information is made of factual data collected from various sources. The second data category is made up of more elaborate information based on the reports of investigations on casualties received at the IMO, which may be full investigation reports to be analysed by the organization or reporting forms annexed to MSC-MEPC.3/Circ.3 (IMO, 2014).

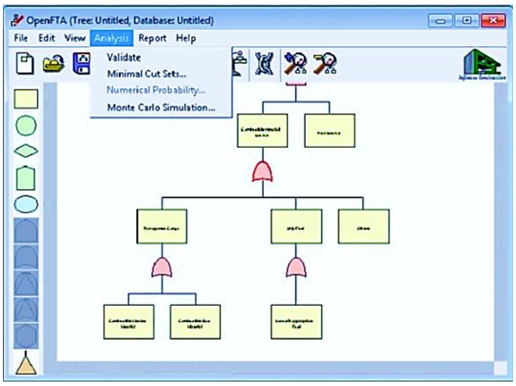

Figure 1. Notation of the Monte Carlo simulation in the OpenFTA program

The present study only focuses on grounding caused by human error. The root causes of accidents were identified after analysing the accident reports of container ship groundings from databases. The probability values were calculated, and an algorithm was designed. The Monte Carlo simulation was then initiated. The simulation randomly distributes the probabilities of accident causes using a number of tests. Real-life probabilities utilised for establishing a theorem rendered a more realistic analysis. The principle behind the Monte Carlo methodology is to simulate the occurrences of primary events (component failures) using a random number generator. Each primary event for each trial is simulated by generating a (pseudo-) random real number inclusive of the 0 to 1 range. The event is deemed to have occurred and its value is set to TRUE if this number is less than or equal to the probability of the primary event. Otherwise, it is deemed not to have occurred and its value is set to FALSE. The fault tree is then evaluated with these values for the primary events to see if the top event occurs (system failure). The number of top event occurrences is stored together with the corresponding failure mode (the list of primary events that occurred to cause the top event) (OpenFTA Manual, 2005). The accident causes stated in the relevant reports and the probability values calculated were used in this simulation. The Monte Carlo simulation employed herein is one of the analysis modes on the OpenFTA program developed by the Auvation Company (Figure 1) (OpenFTA, 2013). This program places data to reasonableness test after defining the root causes and devising an appropriate algorithm. A target analysis can then be conducted, unless any logic error or defect in the algorithm is detected.

4. APPLICATION

The algorithms of the logic related to the accident causes from the relevant accident reports should first be established. In other words, a qualitative analysis should be conducted to analyse the human error factor using the OpenFTA program. Flowcharts were used to show the accident causes in the logical arrays in an algorithm employed to analyse these causes. Causal relationships, such as initial event and gate, or gate, priority and gate, transfer and conditioning event, and their symbols used in a fault tree analysis (FTA) are utilised in the program's algorithm. The algorithm established using the FTA elements demonstrates the relationship between the causes, and can be used in the OpenFTA software for Monte Carlo. The simulation was an attempt to ensure that the algorithm represents the real world. The Monte Carlo simulation is a type of simulation that creates the probability distribution of accident causes by performing a desired number of trials running in a random fashion. The simulation yields the failure modes consisting of single or multiple causes, likelihood estimates and significance value of primary events. Each root cause should be defined in the system to place causes of grounding accidents into the system. The full names, abbreviations, and probability values of these causes are used to define them in the system.

We calculated the extent to which human errors led to accidents and the means in which they occurred along with their probability values. In this study's algorithm, human errors as accident causes were classified under two main groups: team errors and failures in human performance (Yıldırım, 2012). Figures 2a and b show the FTA Algorithm generated for the human error. Figures 2a and b are related to team failures and human performance. The Monte Carlo simulation produces failure modes, including one or more than one error, estimation probabilities and importance values of root causes.

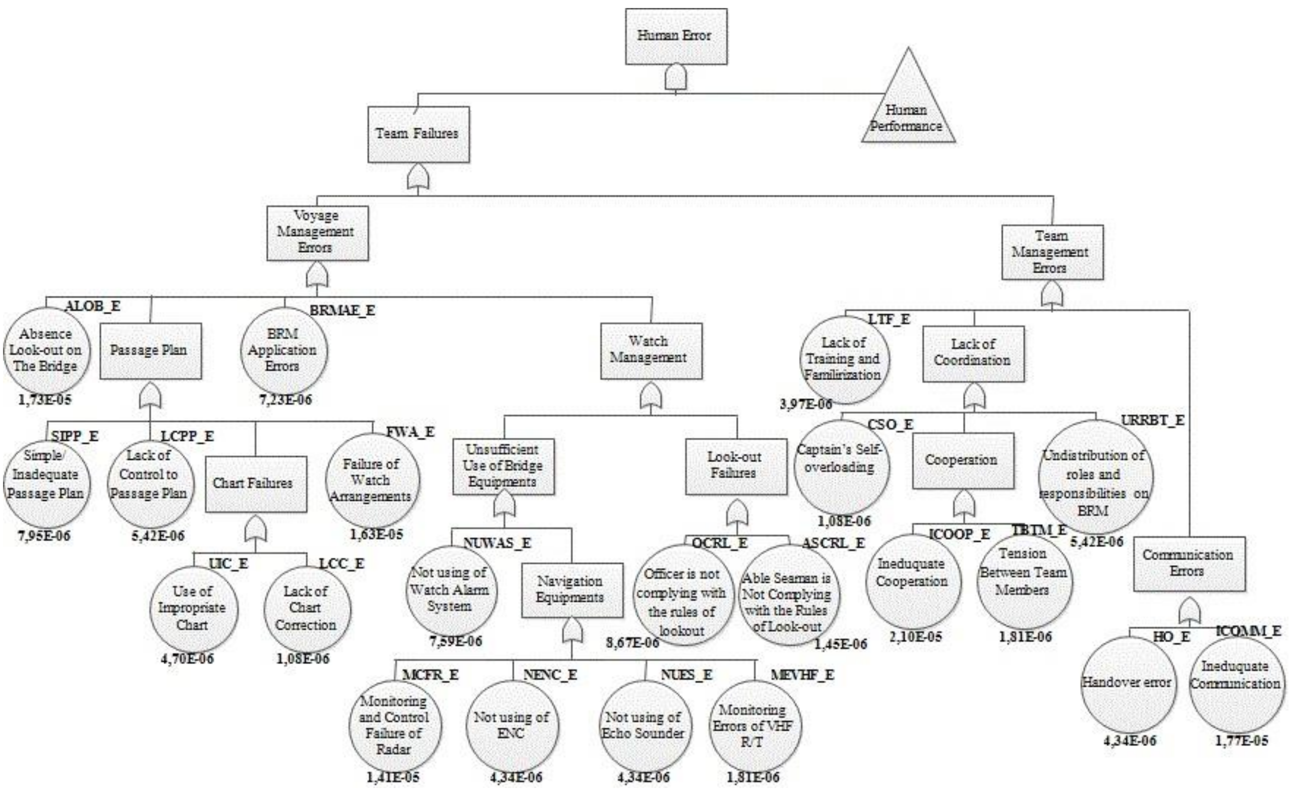

Figure 2.a. Algorithm for human error

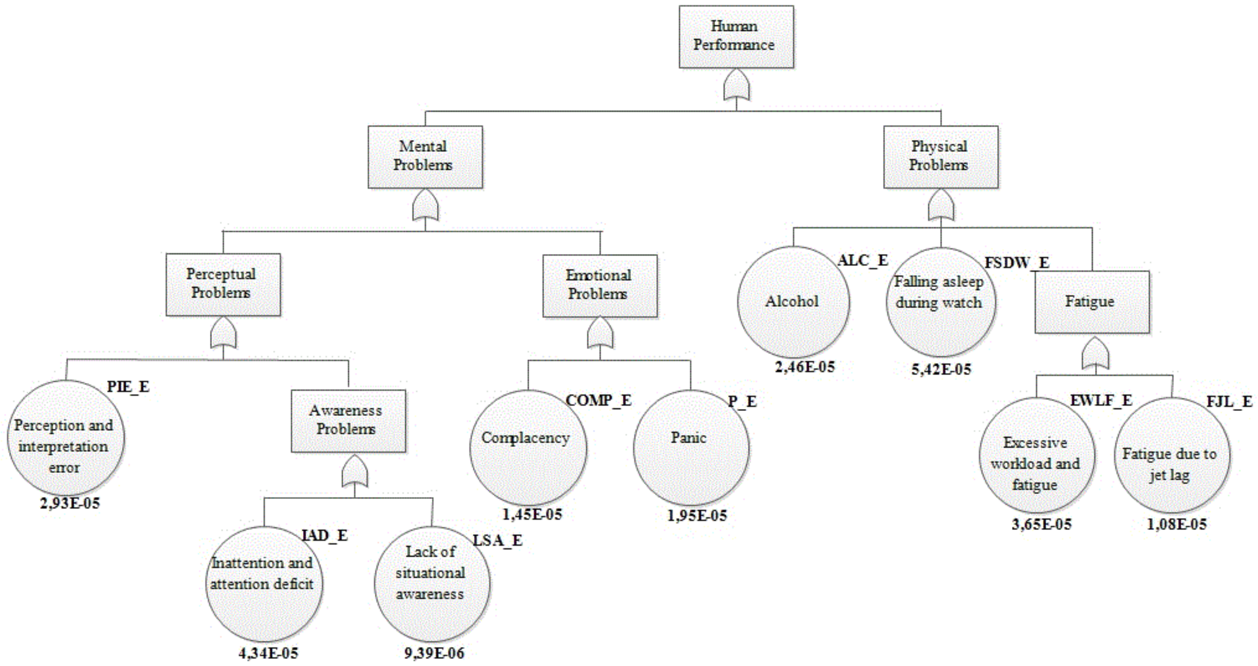

Figure 2.b. Algorithm for human error

4.1. DATA CALCULATION

The probability values of accident causes are entered into the program to run it after establishing an algorithm of logic and abbreviations of accident causes. The probability values of the root causes (i.e. initial events) are put into the OpenFTA program as data. One or more than one cause is attributable to a grounding accident. Thus, the value of each contributing factor in an accident was calculated by standard division using Eq. (1) while computing the extent to which these factors in total contributed to the relevant accident.

The contributions of each factor were calculated for each ship. Eq. (2) was used to seek the presence of the same root cause in all accidents. The resulting rates were added. Moreover, the total contribution of the relevant cause was found.

The total contribution of the root cause was divided by the total number of ships and the time period of an accident to calculate the probability value of an accident cause using Eq. (3) (Uğurlu et al., 2015a). The time period refers to the difference of the time between the first and last accidents analysed. The value of time period in days, months, and years was calculated as 17.51 in year mode.

Human error incorporates failures in human performance and team errors. The human performance failures were addressed under mental and physical problems. The team errors were addressed under voyage and team management. Table 1 was created using the root causes of accidents, total contributions of these causes calculated by Eq. (2), and their probability values computed according to Eq. (3). A total of 39 human errors in accidents were found under the analysis. These causes were observed for a total of 125 times.

$$\text{Contribution Rate} = \frac{1}{\text{Number of Root Causes}} \qquad \text{(eq.1)}$$

$$\text{Total Contribution Rate} = \frac{(\text{Vessel 1})}{(\text{Number of Root Cause})} + \frac{(\text{Vessel 2})}{(\text{Number of Root Cause})} \dots + \frac{(\text{Vessel 46})}{(\text{Number of Root Cause})} \qquad \text{(eq.2)}$$

$$\text{Probability value} = \frac{\text{Total Contribution Rate of Root Cause}}{\text{Number of accidents x Time Period}} \qquad \text{(eq.3)}$$

Table 1. Table of accident causes, incidence numbers, total contributions and probability values

I.Human Error				
No	Root Causes	Quantity	Contribution Rate (Total)	Probability Value
A.Human Performance Disorders				
i. Mental Problems				
1	Complacency	2	0,375	4,66E-04
2	Inattention and attention deficit	6	1,208	1,50E-03
3	Lack of situational awareness	1	0,333	4,13E-04
4	Perception and interpretation error	5	1,074	1,33E-03
5	Panic	1	0,5	6,21E-04
ii. Physical Problems				
1	Excessive workload and fatigue	6	1,052	1,31E-03
2	Fatigue due to jet lag	2	0,342	4,25E-04
3	Alcohol	2	0,75	9,31E-04
4	Falling asleep during watch	4	1,583	1,97E-03
B.Team Failures				
i. Voyage Management Errors				
1	Absence look-out on the bridge	6	1,658	2,06E-03
2	Failure of watch arrangements	3	1,533	1,90E-03
3	Simple/ inadequate passage plan	5	1,2	1,49E-03
4	Lack of control to passage plan	2	0,5	6,21E-04
5	Poor tracking of the ship's position	14	3,118	3,87E-03
6	Only position fixing with GPS	5	1,05	1,30E-03
7	Position fixing application errors	2	0,483	6,00E-04
8	Inadequate brifing and deliberation	2	0,583	7,24E-04
9	Officer is not complying with the rules of look-out	4	0,8	9,93E-04
10	Able seaman is not complying with the rules of look-out	1	0,125	1,55E-04
11	Not using of watch alarm system	3	0,625	7,76E-04
12	Not using of ENC	2	0,5	6,21E-04
13	Not using of echo sounder	2	0,366	4,54E-04
14	Monitoring and control failure of radar	6	1,309	1,63E-03
15	Monitoring errors of VHF R/T	1	0,142	1,76E-04
16	Not monitoring of helmsman	1	0,166	2,06E-04
17	Helmsman failure	2	0,7	8,69E-04
18	Faulty steering order	1	0,21	2,61E-04
19	Use of impropriate chart	2	0,5	6,21E-04
20	Lack of chart correction	1	0,111	1,38E-04
21	BRM application errors	3	0,616	7,65E-04
22	Judgement error of captain	3	0,525	6,52E-04
23	Excessive confidence to pilot and not monitoring of pilot	3	0,611	7,59E-04
ii. Team Management Errors				
1	Inadequate communication	9	1,699	2,11E-03
2	Inadequate cooperation	4	1,582	1,96E-03
3	Undistribution of roles and responsibilities on bridge team	3	0,498	6,18E-04
4	Handover error	2	0,450	5,59E-04
5	Lack of training and familiarization	2	0,392	4,87E-04
6	Tension between team members	1	0,111	1,38E-04
7	Captain's self-overloading	1	0,25	3,10E-04
	Total	125		

5. RESULTS

5.1. MONTE CARLO SIMULATION ROOT CAUSE FINDINGS

The Monte Carlo simulation runs the algorithm in the predetermined number of tests to determine the extent to which root causes contributed to an accident. As a result of 100,000 tests, the simulation concluded that all 39 root causes contributed to accidents.

Table 2 shows the simulation results. The most significant causes of accidents were: 1) sleeping of the watch-keeping officer; 2) inattention, attention deficit and absent-mindedness among the bridge team, including the captain and look-out; and 3) poor and incomplete tracking of the ship's position or the failure to regularly determine the ship's position. Other important causes included excessive workload, fatigue and perception errors.

Table 2**.** Monte Carlo Simulation contribution rates

No	Root causes	Abbreviations	Contribution Rate to Error	Importance Values	% Ratio
1	Falling asleep during watch	FSDW_E	5,42E-05	22.66	11,19
2	Inattention and attention deficit	IAD_E	4,34E-05	18.13	8,96
3	Poor tracking of the ship's position	PTSP_E	3,76E-05	15.71	7,76
4	Excessive workload and fatigue	EWLF_E	3,65E-05	15.26	7,54
5	Perception and interpretation error	PIE_E	2,93E-05	12.24	6,05
6	Alcohol	ALC_E	2,46E-05	10.27	5,07
7	Inadequate cooperation	ICOOP_E	2,10E-05	8.76	4,33
8	Panic	P_E	1,95E-05	8.16	4,03
9	Inadequate communication	ICOMM_E	1,77E-05	7.40	3,66
10	Absence look-out on the bridge	ALOB_E	1,73E-05	7.25	3,58
11	Failure of watch arrangements	FWA_E	1,63E-05	6.80	3,36
12	Complacency	COMP_E	1,45E-05	6.04	2,98
13	Monitoring and control failure of radar	MCFR_E	1,41E-05	5.89	2,91
14	Only position fixing with GPS	OPFG_E	1,19E-05	4.98	2,46
15	Fatigue due to jet lag	FJL_E	1,08E-05	4.53	2,24
16	Lack of situational awareness	LSA_E	9,39E-06	3.93	1,94
17	Excessive confidence to pilot and not monitoring of pilot	ECPMP_E	9,39E-06	3.93	1,94
18	Officer is not complying with the rules of look-out	OCRL_E	8,67E-06	3.63	1,79
19	Simple/ inadequate passage plan	SIPP_E	7,95E-06	3.32	1,64
20	Not using of watch alarm system	NUWAS_E	7,59E-06	3.17	1,57
21	BRM application errors	BRMAE_E	7,23E-06	3.02	1,49
22	Helmsman failure	HF_E	5,78E-06	2.42	1,20
23	Position fixing application errors	PFAE_E	5,78E-06	2.42	1,20
24	Judgement error of captain	JEC_E	5,42E-06	2.27	1,12
25	Lack of control to passage plan	LCPP_E	5,42E-06	2.27	1,12
26	Undistribution of roles and responsibilities on bridge team	URRBT_E	5,42E-06	2.27	1,12
27	Inadequate brifing and deliberation	IBD_E	5,42E-06	2.27	1,12
28	Use of impropriate chart	UIC_E	4,70E-06	1.96	0,97
29	Not using of ENC	NENC_E	4,34E-06	1.81	0,89
30	Hand-over error	HO_E	4,34E-06	1.81	0,89
31	Not using of echo sounder	NUES_E	4,34E-06	1.81	0,89
32	Lack of training and familirization	LTF_E	3,97E-06	1.66	0,82
33	Not monitoring of helmsman	NMH_E	2,17E-06	0.91	0,45
34	Monitoring errors of VHF R/T	MEVHF_E	1,81E-06	0.76	0,38
35	Tension between team members	TBTM_E	1,81E-06	0.76	0,38
36	Able seaman is not complying with the rules of look-out	ASCRL_E	1,45E-06	0.60	0,30
37	Lack of chart correction	LCC_E	1,08E-06	0.45	0,22
38	Captain's self-overloading	CSO_E	1,08E-06	0.45	0,22
39	Faulty steering order	FSO_E	1,08E-06	0.45	0,22
				Total	100

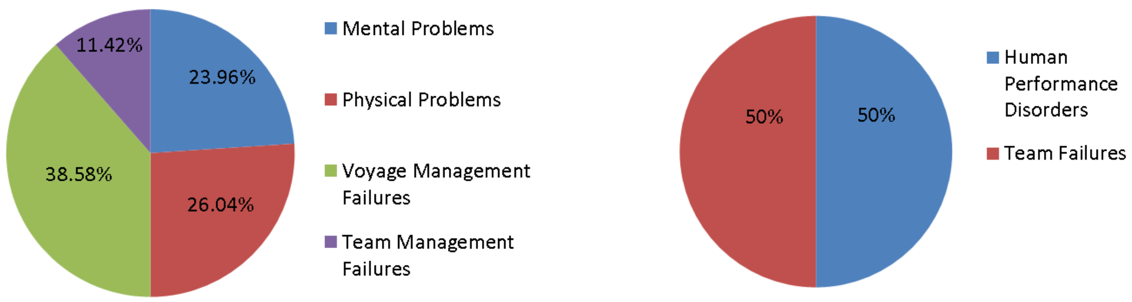

Figure 3. Distribution of human error on grounding accidents according to the Monte Carlo simulation results

As per the simulation results, human errors comprise voyage management failures in 38.58%, mental problems in 23.96%, physical problems in 26.04% and team management failures in 11.42% (Figure 3). As regards the distribution, failures in human performance and team errors were both found to have contributed 50% (Figure 3). The results of the study are similar to those of Macrae (2009), Akhtar & Utne (2015), and Uğurlu et al. (2015a, 2015b). The human performance disorders were extremely important for the container vessels' grounding accidents.

5.2. MONTE CARLO SIMULATION FAILURE MODES FINDINGS

At least two or more causes were observed to lead to a cause in failure modes. As a result of the 100,000 tests conducted on 39 root causes, 200 failure modes were found as part of the Monte Carlo simulation. Regarding the most important failure modes in the simulation, poor tracking of the ship's position, irregular determination of the ship's position and sleeping of the watch-keeping officer led to 27 accidents. Misperception and misinterpretation along with poor tracking of the ship's position contributed to 18 accidents. Inattention and attention deficit along with poor tracking of the ship's position led to 16 accidents. A lack of attention and attention deficit along with poor bridge team cooperation led to 13 accidents. Meanwhile, a lack of attention and attention deficit along with failures in watch management led to 13 accidents.

Figure 4 displays the first 25 failure modes in order. The simulation results showed that the coexistence of some root causes increased the probability of grounding of container vessels. Different from other studies, the present study generally shows that the lack of position tracking, together with sleepiness, perception, carelessness, alcohol consumption and tiredness, poses a greater risk. Carelessness, together with coordination, watch duty arrangements, lack of lookout, overconfidence to a single device and lack of radar control, poses a greater risk.

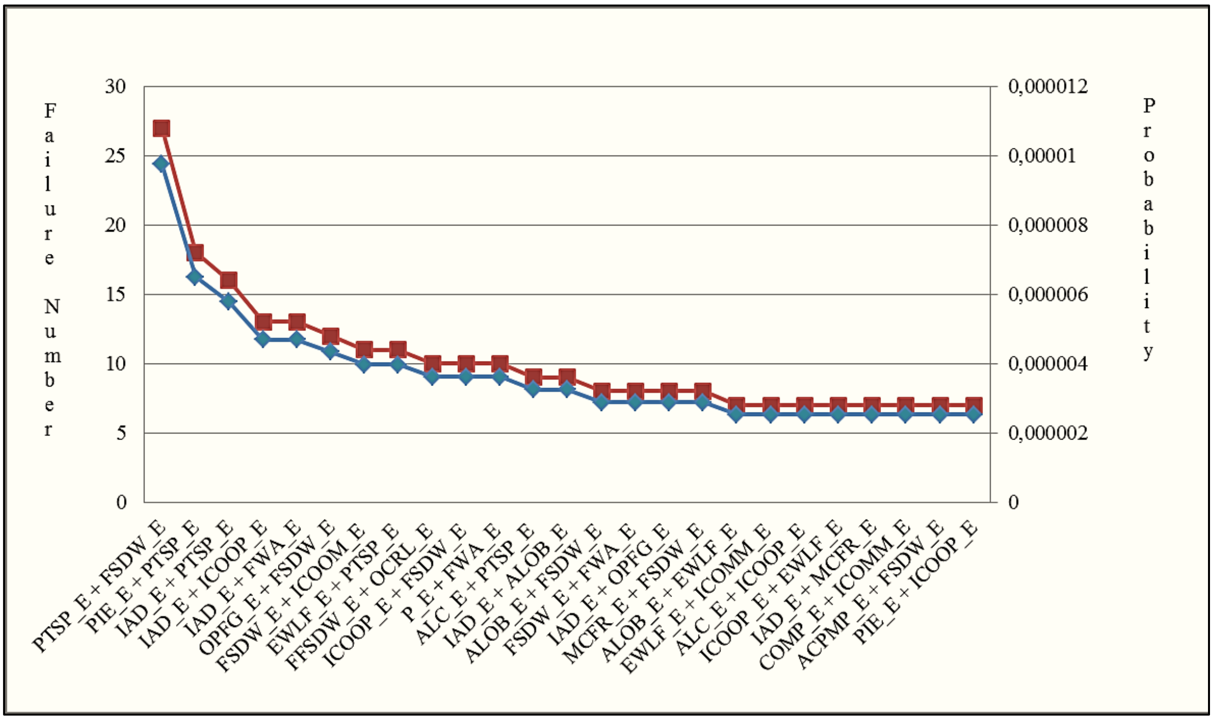

Figure 4. Highest 25 failure modes

6. CONCLUSIONS

Analysing and assessing accident reports are important for developing safety measures and preventing recurrence of such accidents. This study assessed the causes of groundings that involved container ships between 1993 and 2011 using the Monte Carlo simulation. The simulation determined 23.96% of human error mental problems, 26.04% physical problems, 38.58% management errors and 11.42% team management error causes. Consequently, 50% of the human error represented the human performance failure, while 50% team failure has been found.

Similar to the study results, Amrozowicz et al. (1997) and Antao ve Soares (2006) also found, according to the failure mode results of a Monte Carlo simulation, that grounding accidents most often occur when the ship's position is not properly tracked; when the watch-keeping officer faces problems, such as lack of sleep, misperception, inattention and fatigue; and when basic bridge duties are not performed. Therefore, improvement of the working conditions of the watch officers, who render overworking hours or have inadequate resting hours, will be effective in preventing grounding accidents. Therefore, the most important measure for container vessels would be to increase the number of watch-keeping officers. Moreover, the effective use of ECDIS will decrease carelessness and perception errors. The use of BNWAS dead man alarm should also be implemented to avoid falling asleep because of tiredness and excessive workload. An effective use of the other bridge devices is also part of the preventive actions.

Unaccompanied watch keepers on the bridge are a significant risk factor that raises accident occurrence. The watch system should be organized according to the STCW 78/95 and ISM Code requirements and in such a way that the efficiency, perception, and interpretation skills of the watch-keeping officers are not undermined by fatigue. The working times should be inspected and ensured to be respected to reduce human-related errors.

The share of human error in the causes of accident correspondingly increases as the amount of devices and technology used in ships increases. Therefore, human error should be a focus of training, safety culture, and bridge resource management to mitigate its share in maritime accidents. Training sessions should target not only the seamen's professional progress, but also behaviours and opinions related to safety. A culture of safety should be reinforced in topics like voyages, manoeuvring, watch and team management while maintaining efficiency, quality and professional attitudes

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