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Maritime Accidents Analysis Using Maritime Human Factors and Analysis Model

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Abstract

Purpose: *The majority of global trade is still carried out by the commercial shipping sector although it lags behind other transport sectors in terms of safety and accident reduction. Human error is recognized as the most likely cause of maritime accidents. As such, the literature focuses on the impact of human error on maritime safety. Human Reliability Analysis (HRA), Human Error Identification (HEI), and accident analysis are the most common techniques used to examine the human error. The initial goal of this paper is to give a general overview of the various types of analysis models and methods that are accessible. The goal is not to give a thorough overview of analysis methods. Instead, it serves to inform the readers of the broad ideas that underlie each category and to offer them a point of reference for any further research they choose to conduct. So, the paper focuses on the accident analysis division of accident investigation techniques.*

Design/Methodolgy/Approach: *In particular, this paper thoroughly examines the Human Factors Analysis and Classification System (HFACS) as a qualitative analytic model to assess active and latent failures reported in maritime accident reports. A collision accident is taken as a case study, a step-by-step analysis is undertaken, and human error causal factors are singled out.*

Findings: *The HFACS-MA approach was assessed for its potential as a way of analyzing maritime accidents in the current research, and it was determined to be quite suitable.*

Key-words:
Maritime Accidents, Accident analysis, Human Factors Analysis and Classification System (HFACS), HFACS maritime version.

BACKGROUND

Accidents normally happen due to negligence, but their consequences are permanent and lasting. The impact includes not only humans but also marine life, as well as marine environment and ecosystems. There are several causes of maritime accidents.

A significant proportion of maritime accidents can be directly related to human error. This means that crew members must be well-trained and alert to dangerous situations. Some of the causes of human error that lead to accidents at sea are (i) lack of sleep leading to fatigue, (ii) lack of experience and preparation, (iii) long voyages, (iv) personal relationships on board, (v) reckless behavior, including abuse of drugs and alcohol, (vi) bad decision-making and/or neglect, and (vii) pressure and stress during the service, among others.

LITERATURE REVIEW

Inshore and offshore workers face many dangers. The specific dangers that must be faced depend largely on the type of work their ship is doing. The crew who work at sea for an extended period of time faces hazards other than those on an offshore oil rig. One thing remains the same, working at sea is dangerous. Examples of typical maritime accidents include explosions, fires, relocation of improperly secured cargo, leading to injuries, skid, and fall, poor/misplaced equipment, control/navigation failures, grounding, collisions with other vessels or fixed structures, and many more (Shaw, 2021).

Akyuze et al. (2016) proposed a methodological approach by integrating Human Factors Analysis and Classification System (HFACS), Analytic Hierarchy Process (AHP), and majority rule to quantify the Error-Producing Conditions (EPCs) for the marine industry. Furthermore, Chan et al. (2016) investigated past research on maritime accidents attributed to human error with emphasis on the accident of MV Sewol that occurred in 2014 due to overloading. They concluded that human error could be reduced by increasing control and survey, increasing the usage of alert signs, using accurate working standards, improving Standards of Training, Certification, and Watch-keeping (STCW), implementing International Safety Management (ISM) Code, installing more alert tools, having more onboard hierarchical risk assessment system, and increasing the simulator-based training.

Another approach based on a safety assessment theory was introduced by Islam et al. (2017a) which identified the most important factors that influence seafarers to make an error during maintenance activities in marine and offshore operations. The factors are extreme weather, extreme workplace temperature, high ship motion, high level of noise and vibration, work overload and stress, which increase the likelihood of human error as well as potential accidents. To do so, they revised and modified the conventional Human Error Assessment and Reduction Technique (HEART) to estimate the Human Error Probabilities (HEPs) for the maintenance procedures in marine operations during various environmental and operational conditions.
Another study was performed by Islam et al. (2017b) which developed a monograph for assessing the likelihood of human error in marine operations that can be applied to instant decision-making. That monograph supports the decision-making process in a short period of time and enables chief engineers or captains to select the most suitable seafarers to complete maintenance tasks successful. It can also help them to be better prepared and to prioritize marine operation activities. Besides, it can help tackle the frequency of human error and serves to increase the overall safety of maintenance procedures in marine operations through the use of the Success Likelihood Index Method (SLIM) to estimate the (HEPs).

Furthermore, Islam et al. (2018) highlighted the concern associated with human performance during maintenance operations on ships as a part of maritime quantitative risk assessment by studying the generalization of data identifying the relative importance of the performance-affecting factors, collecting data to develop human error assessment techniques for more accurate (HEPs) estimation in marine environmental conditions, identifying the relative importance of performance-affecting factors for the maintenance operations of marine systems by structured questionnaire method, and then analyzing the collected data for normality and for a pairwise significance test.

In addition, Nosov et al. (2019) noted that the subjective entropy or lack of order or predictability, gradually falling into disorder, is an indication of negative human error in maritime transportation. They introduced the development of a data system to identify negative manifestations of human error to use the proposed formal methods, patterns, and algorithms to ensure maritime safety. These methods form the basis of navigator behavior analysis in emergency situations and determine the mathematical expectations of navigator behavior in emergency situations. The formal methods have been confirmed by the simulation patterning using the navigation simulator "Navi-Trainer Professional 5000" NTPRO 5000.

More recently, Zogorsky (2020) presented the validity of the Human Factors Analysis and Classification System - Fishing Vessel (HFACS-FV), using ten-year data documenting the causes of fatal accidents in the commercial fishing industry, by developing and evaluating a version of Wiegmann and Shappell's (2003) HFACS, that is the analysis of human factors for the causes of marine accidents and retrospective analysis of accidents using advanced human error methodology in commercial fatal accidents on fishing vessels.

The aim of the paper is to bring to the readers a panoramic picture of maritime accident techniques, but not to give a detailed rundown of these techniques. In doing so, the different techniques will first be categorized, and a general understanding of the concepts that underlie each category will be furnished, thus providing a point of reference for any forthcoming research in this field.

METHODOLOGY

An analytical descriptive methodology is used herein. The open literature on accident investigation and analysis, with particular emphasis on maritime accidents, is first reviewed and relevant sources are collected. The general classification of accident investigation models is first presented briefly and the most important models in each class are singled out. Then, a closer focus is made on accident analysis models. Salient features, as well as points of strength and weakness of each model, are discussed. Application of potential models of this class is highlighted and a particular model for further use in maritime accident analysis is selected. Reasons behind this selection are given and a detailed procedure for applying the model to analyze a maritime collision accident is furnished. A typical collision accident is taken as a case study and human error factors, whether active or latent and likely to have caused the accident, are singled out.

Techniques to Investigate Human-error-based Accidents

Based on the above literature review it becomes possible to classify techniques used to investigate maritime accidents caused by human error into three main categories: (i) Human Reliability Assessment (HRA) such as (CREAM - HEART), (ii) Human Error Identification (HEI) such as (ATHEANA - SHERPA), and Accident Analysis (AA) such as (HFACS - STAMP) Zohorsky (2020).

The HRA is the probability of humans conducting specific tasks with satisfactory performance. Tasks may be related to equipment repair, equipment or system operation, safety actions, analysis, and other kinds of human actions that influence system performance. Further details can be found in HSE (2009), Calixto (2016), Bai and Jin (2016), and Alexander (2019).

The HEI provides a proactive strategy for studying human errors in complex sociotechnical systems, identifying potential errors and determining their causative factors, consequences, and recovery strategies. For more details, the reader is advised to consult Salmon et al. (2010), and Alexander (2019).

The third category includes the AA models, which are dealt with herein in greater detail, since one of the main objectives of this endeavor is to select a suitable AA model for application in the maritime field, particularly in the analysis of human-error-based maritime accidents. The most important models used in accident analysis included human errors count to some (29) models. According to Hollnagel and Goteman's (2004), these models are divided into three subcategories, some which are shown in Figure 1.

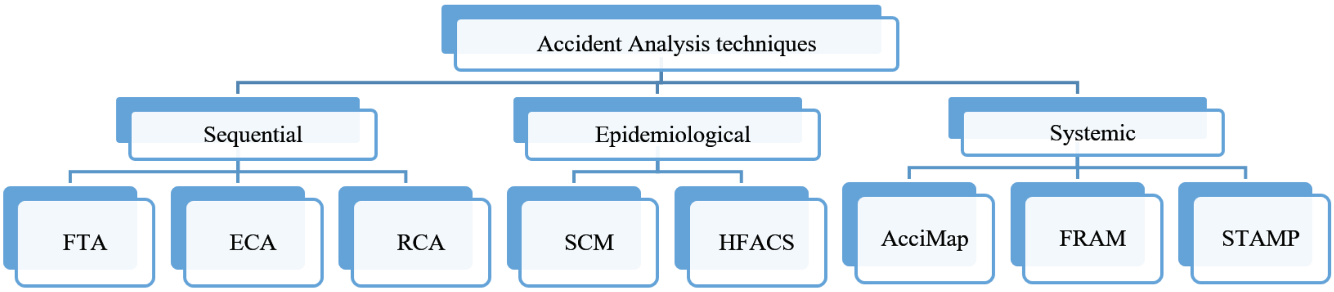

Fig 1: Examples of different techniques used in accident analysis
Source: Hollnagel and Goteman (2004)

1- Sequential techniques that evaluate the cause and effect of a linear accident, and include (a) fault tree analysis, (b) event/consequence tree analysis, and (c) root cause analysis.
2- Epidemiological techniques, which take into account latent and active contributions
to accidents and were named for their similarities to the distribution of illness
and disease as compared to how latent factors adversely affect the organizational and supervisory conditions within the system. Examples of epidemiological techniques are (a) The Swiss cheese model (SCM) and (b) HFACS.
3- Systemic techniques, which evaluate the interaction between system components as a systematic approach, which is essential to understanding how a system works or fails (Underwood, Peter, 2019). Examples of Systemic techniques are (a) the AcciMap model, (b) the FRAM model, and (c) the STAMP model.
To increase safety, one must first understand why accidents happen and how to avoid them in the future. The accident analysis techniques are a crucial tool for achieving this insight. Therefore, in this paper, only the accident analysis techniques will be studied.

Hulme et al. (2019) outlined HFACS research statistics in literature reviews through July 31, 2018. After searching four databases (PubMed, ScienceDirect, Scopus, Web of Science), a total of 690 articles were identified. After removing 197 duplicates and examining 493 titles and summaries, a total of 43 HFACS studies were included; 14 studies were published between 2000 and 2009 (9 years), and 29 studies were published between 2010 and July 31, 2018 (8 years and 6 months). Utilization of the HFACS model in studies approximately doubles over the same period. They also noted that more than 60% of the studies used HFACS in a modified form to analyze how a network of interacting latent and active factors contributed to the occurrence of an accident.

HFACS Model

The Human Factors Analysis and Classification System (HFACS) model was first developed by Shappell and Wiegmann (2000) and further modified by them (2003) to include four stages of failure based on Reason's (1990) idea of latent and active failures as illustrated in Figure 2.

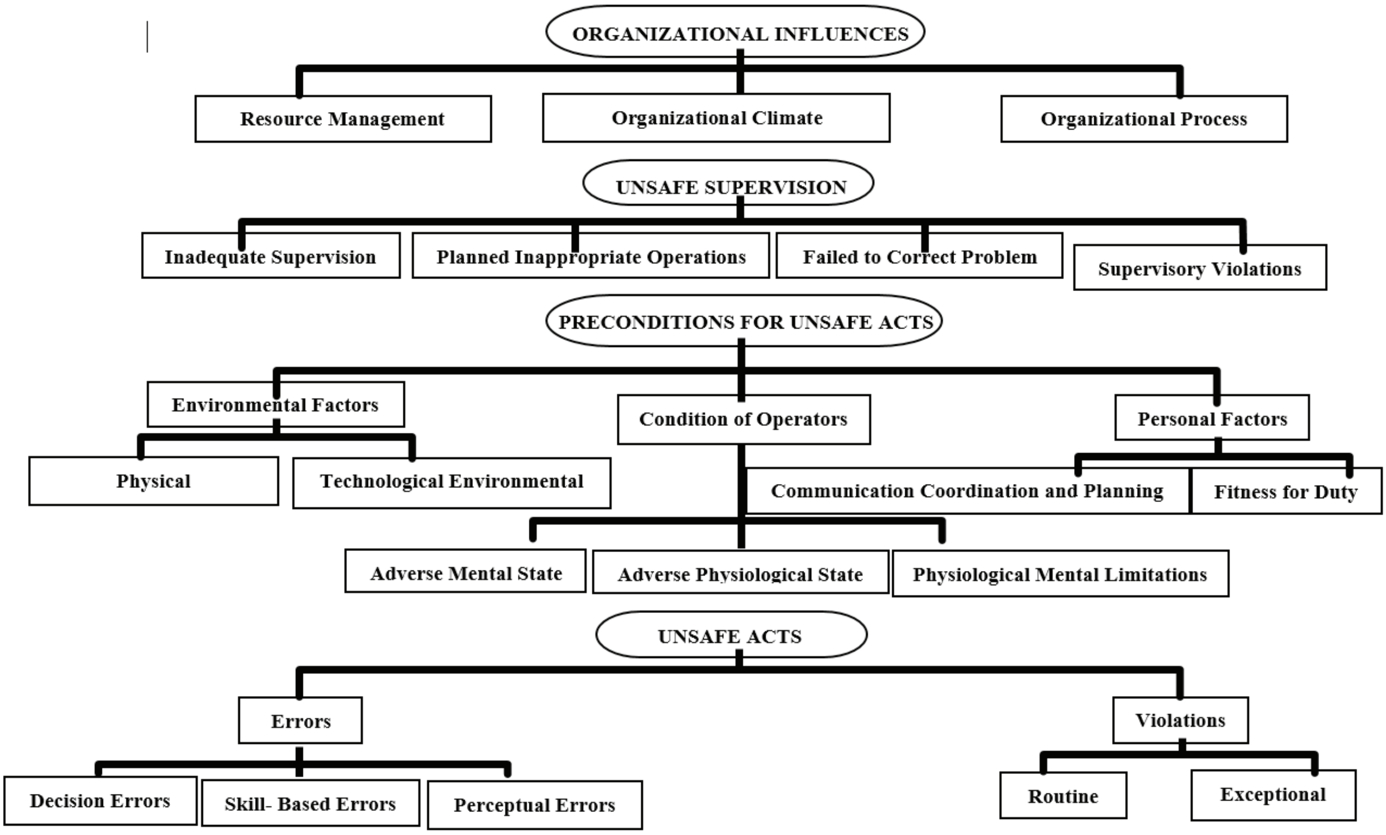

Fig 2: HFACS Framework

Source: Shappell and Wiegmann (2003)

Over the years, new versions of HFACS have been developed; some of which are of particular importance to maritime accident investigation specialists, such as the HFACS-MA model, which is considered herein. Details of these versions can be found elsewhere, Scarborough and Ponds (2001), Krulak (2004), U.S. Department of Defense (2005), Reinach and Viale (2006), Li and Harris (2006), Australia Government Department of Defense (2008), Patterson and Shappell (2010), Schröder-Hinrichs et al. (2011), Kim et al. (2011), Chen et al. (2013), Chauvin et al. (2013), Mazaheri et al. (2015), Soner et al. (2015), Theophilus et al. (2017), Cohen et al. (2018), Ugurlu et al. (2018), Zohorsky (2020), J. Wang et al (2020), Sarıalio˘glu et al (2020), Lin et al (2021), and Yang and Kwon (2022).

HFACS-MA Version

In this paper, the HFACS-MA framework, recently developed by Kim et al. (2011), was used to analyze human factors related to towing vessel accidents. As shown in Figure 3, the HFACS-MA model divides into three stages: organizational influences, preconditions for unsafe acts, and unsafe acts.

Application of HFACS-MA

An example will show how to use the HFACS-MA model to analyze maritime accidents, as shown in Figure 4.

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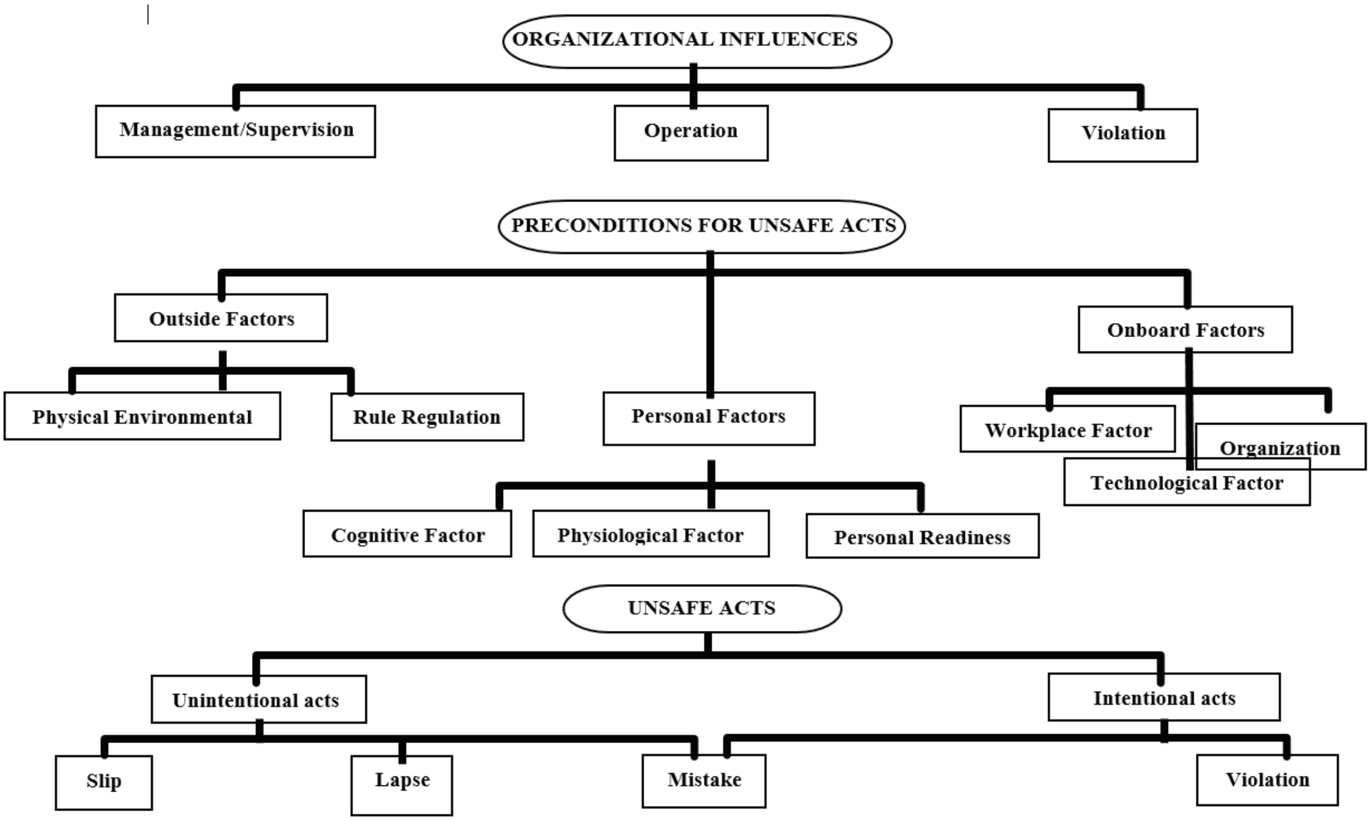

Fig 3 : HFACS-MA framework - Source: Kim et al. (2011)

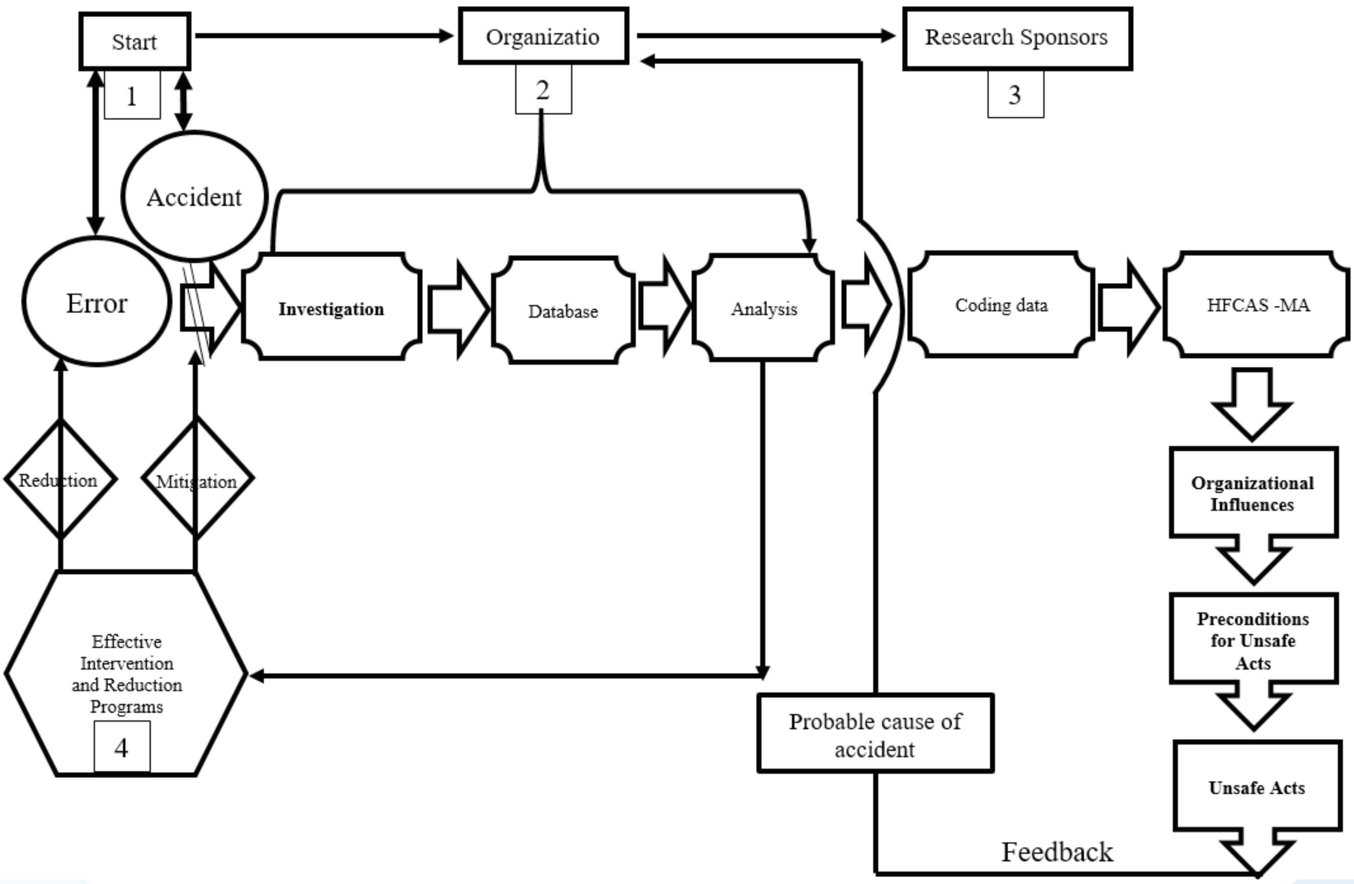

Fig 4: Flowchart of HFACS-MA application prepared by the authors

Identification of human errors

At the start, human errors which may have caused the accident are singled out and the accident report is prepared and analyzed by the organization. The report should usually include the sequence of events gathered data and analysis.

Investigation/ Database/ Analysis

A maritime accident report that was created by the National Transportation Safety Board (NTSB) in the U.S.A. is considered the sequence of events. In this example, a maritime collision accident between the offshore supply vessel Cheramie Bo Truc No. 22 and the articulated tug and barge (ATB) Mariya Moran/ Texas is considered, brief description is shown in table 1. The accident report prepared by the NTSB (2019) is available; a detailed sequence of events, data selection, and data analysis are explained in the report, which is not included here for brevity.

Table 1: Brief description of collision of towing vessel Maryia Moran

Owner/operator	Moran Towing Corp.
Port of registry	Wilmington, Delaware
Year built	2015
Official number (US)	1257668
Persons on board	9
Accident time	At 0415 on November 14, 2019
Accident location	Sabine Pass Jetty Channel, Port Arthur, Texas 29°40.90′ N, 093°50.12′ W
The number of injuries	None
Property damage	1,854,572 dollars est.
Environmental damage	Estimated 6,641 gallons of diesel oil released
Weather	Visibility 6 miles, light rain, winds northeast-by-north 6 knots, gusts 8 knots, ebb current 0.16 knots, air temperature 44°F.

Research sponsors

The authors of this article will play the role of research sponsor, using the HFACS-MA framework classified into three levels of organizational influences, precondition for unsafe acts, and unsafe acts are sought then make a relation of causal factors between levels to extract the results. In terms of the Maryia Moran accident, 13 accident causation factors are identified according to the authors' experience, and the accident causation factors are listed in Tables 2 and 3.

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Table 2: Description of categories involved in the HFACS-MA framework

		Latent Failures		Category	Code	Authors' identification
HFACS-MA	Precondition for Unsafe Acts	Outside factor	Physical environment	Weather	a.1	
				Vessel over-traffic	a.2	
				VTS failures	a.3	✓
				Obstacle	a.4	
				Inappropriate navigation aid	a.5	✓
				Poor navigation aid	a.6	
				Inappropriate Notice to Mariner	a.7	
				Mismanagement of waterway	a.8	✓
				Inappropriate port facilities	a.9	
				Shallow water	a.10	
				Narrow waterway	a.11	
				Strong current	a.12	
				Frozen condition	a.13	
				Drift ice area	a.14	
				Pilot failures	a.15	
				Etc.	a.16	
			Rule regulation	Local special navigation regulations	b.1	
				International regulations & Codes	b.2	✓
				Flag State regulations	b.3	
				Port State regulations	b.4	
				Others	b.5	
		Personnel factors	Cognitive factor	Complacency	c.1	
				Mental fatigue	c.2	
				Nerves	c.3	
				Haste, Flustration	c.4	
				Distraction	c.5	
				Negative affectivity	c.6	
				High-self confidence	c.7	
				Low-self confidence	c.8	
				Low work satisfaction	c.9	
				Immoderate reliance on automated system	c.10	
				Personality	c.11	
				Mental disease	c.12	
				Others	c.13	
			Physiological factor	Physical fatigue	d.1	
				Physical disease	d.2	
				Alcohol, Drugs	d.3	✓
				Sight or hearing disability	d.4	
				Body condition	d.5	
				Motor ability	d.6	
				Age, Sex	d.7	
				Others	d.8	

			Personal readiness	Inadequate qualification (physical, aptitude, etc.)	e.1	
				Lack of knowledge	e.2	
				Mis-knowledge	e.3	
				Lack of skills	e.4	
				Estimate of the situation inability	e.5	✓
				Erroneous assumption, prediction, prejudice	e.6	✓
				Inappropriate habit	e.7	
				Previous accident experience	e.8	
				Others	e.9	
		Onboard Factor	Organization	Inappropriate custom regulation	f.1	
				Organizational pressure (workload, workhour)	f.2	
				Inaccurate responsibility & duty	f.3	✓
				Aberrant communication	f.4	
				Improper duty handover	f.5	
				Inappropriate placement of human resources	f.6	
				Chilling effect of seafarers	f.7	
				Seafarers' interaction	f.8	
				Leadership problem (superior supervision)	f.9	
				Immoderate authoritarianism	f.10	
				Lack of authority	f.11	
				Inappropriate procedure, regulations, instructions	f.12	✓
				Education-training onboard	f.13	
				Staffing of seafarers (nationality, qualification)	f.14	
				Others	f.15	
			Technological factor	Ship design	g.1	
				Equipment & tool (utility, reliability)	g.2	
				Maintenance check-up	g.3	
				Cargo property	g.4	
				Cargo handling management	g.5	

				Draft (loadage, overload)	g.6	
				Kinds of ship certification	g.7	
				Others	g.8	
			Workplace factor	Lighting	h.1	
				Noise	h.2	
				Temperature, humidity	h.3	
				Vibration	h.4	
				Cleanliness	h.5	
				Atmosphere (stench, fumes, gases)	h.6	
				Ergonomic design of workplace	h.7	
				Work characteristics	h.8	
				Influence by others in workplace	h.9	
				Absence or misarrangement of equipment	h.10	
				Automation level of ship	h.11	
				Diet suitability	h.12	
				Others	h.13	
	Organizational Influences	Management / Supervision		Boarding inappropriate seafarers	i.1	
				Insufficient management of eligibility of seafarers	i.2	
				Education-training absence	i.3	
				Education-training deficiency	i.4	
				Inappropriate education-training contents	i.5	
				Inappropriate education-training procedure	i.6	
				Insufficient assessment or development of education-training	i.7	
				Mismanagement of equipment & supplies	i.8	
				Others	i.9	
		Operation		Operation tempo	j.1	
				Inappropriate operating system	j.2	
				Inappropriate ship operation plan	j.3	
				Absence of safety culture	j.4	✓

				Management environment (economic, political, legal, social condition, etc.)	j.5	
				Budget problem	j.6	
				Inappropriate reward and punishment system	j.7	
				Poor working condition (vacation, shift system)	j.8	
				Hiring policy	j.9	✓
				Accident emergency countermeasures	j.10	
				Others	j.11	
		Violations		Boarding unqualified seafarers	k.1	
				Onboard standards violation	k.2	
				Violate behavior connivance	k.3	
				Others	k.4	
	Unsafe Acts	Active Failures		Category	Code	
		unintentional acts	Slip	Skill-Based Errors (SBE), Momentary attention failure	l.1	
			Lapse	Skill-Based Errors (SBE), Momentary memory problem	m.1	
		intentional acts	Mistake	Knowledge-Based Errors (KBE)	n.1	
			Violation	Routine Violations (RV)	o.1	✓
				Exceptional Violations (EV)	o.2	✓

Table 3: Causation factors associated with the Maryia Moran accident

S/N	Code		Accident Causes	Data quality
1	a.3	VTS failures	The VTS watch stander noticed the Cheramie Bo Truc No 22's "course had changed abruptly," placing the vessels on a collision course. He reached out to the Cheramie Bo Truc No 22 once, on channel 1A (which vessels were required to monitor while transiting the area), with no answer.	5
2	a.5	Inappropriate navigation aid	After narrowly avoiding the jack-ups, automatic identification system (AIS) and VTS data showed the Cheramie Bo Truc No 22 crossed the channel at 0400 at a near right angle, then followed the east side of the channel.	
3	a.8	Mismanagement of waterway	The Maryia Moran/Texas was in the center of the channel, making 8 knots over ground against an ebb tide, according to the chief mate.	
4	b.2	International regulations & Codes	Inland Navigation Rules require either a port-to-port passage or communication either by radio or whistle signal for an agreed-upon alternate passage between two vessels.	
5	d.3	Alcohol, Drugs	The Cheramie Bo Truc No 22-captain used saliva swab test kits, and the mate's results indicated a blood alcohol concentration of at least 0.02 grams per deciliter (g/dL). The regulatory limit for commercial mariners is 0.04 g/dL.	
6	e.5	Estimate of the situation inability	The Maryia Moran/Texas pilot hailed the Cheramie Bo Truc No 22 on channel 13, to which the mate answered. During the radio call, believing a collision was imminent on the Cheramie Bo Truc No 22.	
7	e.6	Erroneous assumption, prediction, prejudice	Attempting to use the autopilot in a channel, nearly colliding with stationary jack-ups, weaving across the channel, ignoring the warnings from the on-watch AB and engineer in the wheelhouse, and suddenly turning in front of the ATB all indicate a degree of misjudgment, impairment, and/or incompetence.	
8	f.3	Inaccurate responsibility & duty	The Cheramie Bo Truc No 22 AB and engineer recognized the developing hazardous situation as the mate started the turn toward the ATB and again advised the mate to steer to port. The mate ignored their concern. They did not take further action despite the hazardous situation.	
9	f.12	Inappropriate procedure, regulations, instructions	The Cheramie Bo Truc No 22 AB and engineer stated they had to correct the mate's steering in the channel twice (before the turn in front of the ATB), but they did not summon the captain.	
10	j.4	Absence of safety culture	Although both vessels were aware of each other, no VHF radio passing arrangement or maneuvering signals were made. Contributing to the accident was a lack of early communication from both vessels.	
11	j.9	Hiring policy	The Cheramie Bo Truc No 22 was crewed with a master, mate, unlicensed engineer, and two able seamen (ABs).	
12	o.1	Routine Violations (RV)	L&M Botruc Rental's Alcohol, Firearms, and Controlled Substances Policy prohibited alcohol from being consumed or brought on company property.	
13	o.2	Exceptional Violations (EV)	The manual for the Cheramie Bo Truc No 22's autopilot specifically warned users not to use autopilot in a "harbor entrance or narrow channel." Despite this warning, the mate attempted to use the autopilot after getting under way on the accident voyage.	

After that, the authors classified the code table for latent factors of Levels 1 and 2 specified in the guideline for maritime accident investigation. After all the data were coded, the contributing factors were classified under the three levels of the HFACS-MA. For the next step, the factors in each category were subdivided into sub-categories depending on their attribute. This stage allowed the authors to confirm the contributory factors under each level of the HFACS-MA framework by the different types of accidents. After the classification was completed, the process of the relational analysis of contributing factors between each level was performed by accident type.

Encoding causal factors

Table 4 illustrates the frequency of causal factors of one accident investigation report as well as the percentage, which represents the frequency of occurrence to the total 9 contributory factors. The category of the highest proportion of HFACS-MA category is the pre-conditions for unsafe acts (69.2 %), followed by the organizational Influences (15.4 %) and the unsafe acts (15.4 %). The 15 subcategories of contributing variables assigned to each HFACS-MA category are then further categorized. At level 1 of pre-conditions for unsafe acts, outside factors show the highest ratio in the accident reports, accounting for (23 %). The physical environment in outside factors and rule regulation in personnel factors were the highest at (23 %) and (7.7 %), in sequence. Among level 2 of the organizational influences category, the factors related to the company's operation were higher than operation, with (15.4 %) and (0 %), in sequence. In level 3 of the category of the unsafe act, the proportion of violations accounted for (7.7 %), as mistakes (7.7 %). However, none of the reports referred to the causal factors involved in the unintentional acts of seafarers.

One accident report of collision have found 13 contributory factors. Figure 5 shows a diagram of the relationships in which the contributing factors identified at each level are affecting contributing factors in 3 levels, in terms of collision accidents. The accident reports indicated that the latent failure of the collision, was due to a strong current, an estimate of the situation's inability, and erroneous assumption, prediction, and prejudice due to the captain or pilot or the relief captain. The active failure of the collision accidents was caused by routine violations and exceptional violations.

Table 4: Distribution of casual factors of HFACS-MA category

Levels	Category	Sub-category	Frequency	Percentage
Level 1	Pre-conditions for unsafe acts (69.2 %)			
(9)	Outside factors (4)	Physical environment	3	23 %
		Rule Regulation	1	7.7 %
	Personnel factors (3)	Cognitive Factor	0	0 %
		Physiological Factor	1	7.7 %

Table 4: Distribution of casual factors of HFACS-MA category (Cont'd.)

Levels	Category	Sub-category	Frequency	Percentage
Level 1	Pre-conditions for unsafe acts (69.2 %)			
(9)	Personnel factors (3)	Personal Readiness	2	15.4 %
	Onboard factors (2)	Organization	2	15.4 %
		Technological Factor	0	0 %
		Workplace Factor	0	0 %
Level 2	Organizational Influences (15.4 %)			
(2)		Management / Supervision	0	0 %
		Operation	2	15.4 %
		Violations	0	0 %
Level 3	Unsafe acts (15.4 %)			
(2)	unintentional acts	Slip	0	0 %
		Lapse	0	0 %
	intentional acts (3)	Mistake	1	7.7 %
		Violation	1	7.7 %
Total			9	100.0%

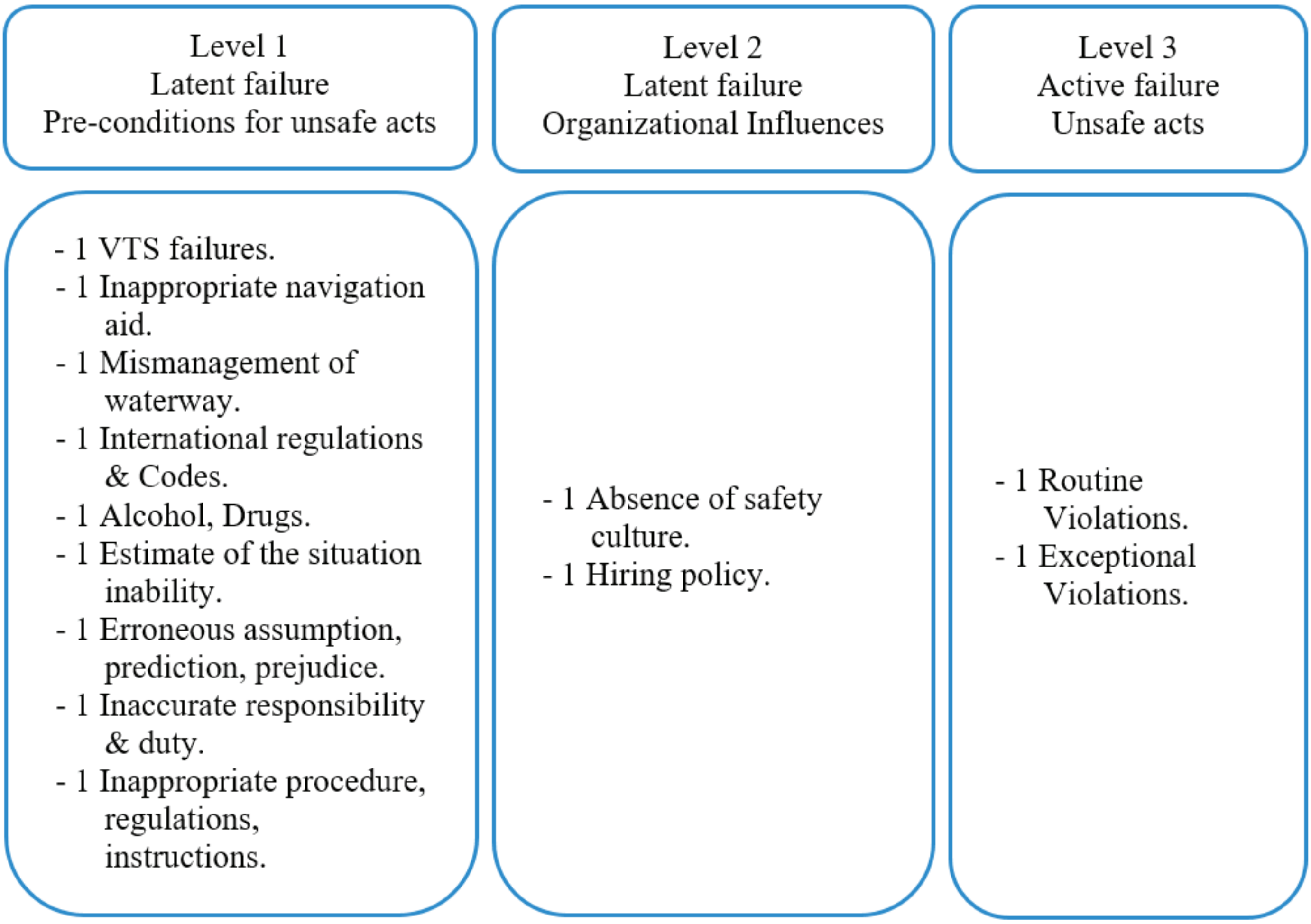

Figure 5: Relations of casual factors among levels

Effective intervention and reduction programs

This final step explored the specific pattern of the accidents and the contributing factors that need further inquest. The evaluation of investigative records assists in establishing the reason for the towing vessel accident pattern. Based on the relationships of contributing factors at each level by accident type, six patterns with active failure and latent failure have been discovered. Table 5 shows the ways to countermeasure the failure.

Table 5: The pattern of towing vessel accidents causes and countermeasure

Accident Type	Pattern #	Active Failure	Latent Failure	Implications	countermeasure
Collision	#1	Routine Violations (RV)	Boarding unqualified seafarers	Estimate of the situation inability	Commitment with the code of U.S. Federal Regulations
	#2	Exceptional Violations (EV)	Violation of the use of equipment	Unable to control the ship	Commitment with the international Standards by putting equipment operating instructions clearly on the equipment

Conclusion and Recommendations

One of the most difficult tasks accident analysts confront is to choose the appropriate, most effective technique to use. The current endeavor has assessed the potential of the HFACS-MA technique as means of analyzing maritime accidents and found it rather suitable for the following reasons: (a) Compared to other accident analysis methods, it has salient features and sound capabilities to extract the results and is easy to use in the analysis of maritime accidents, (b) It represents a reliable tool to analyze comprehensive accident investigation reports and to identify errors and adverse events underlying organizational systems, (c) It assists accident investigators in systematically identifying the active and latent organizational failures that lead to an accident, and (d) It can be used as a framework that reviews and analyses historical accidents.

The preceding arguments are supported by the results of earlier studies that compared a variety of accident investigation models and concluded that the HFACS-MA model is the best match for accident prevention and reduction strategies. The current work can be further augmented by investigating negative issues associated with the use of the HFACS-MA model, proposing suitable modifications to get around them and examining the reliability and accuracy of the modified model by comparing its results with those of other HFACS versions as well as with other competitive accident analysis models.

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