AN ANALYSIS OF CAUSES RELATED TO HUMAN FACTORS IN MARITIME ACCIDENTS

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SUMMARY

Safety is the most critical job of any Mariner. Recently, the maritime industry has embedded automated systems onboard ships to reduce workload and improve safety. This study explores several recent marine incidents generated by human errors resulting from improper use of technology and the loss of situational awareness. Accidents within three categories of vessels illustrate findings, small passenger vessels, a container ship, and military vessels, using the official accident reports and agency findings. The results indicate that three categories of errors were identified: competence-based, regulatory-based, and perception-based. By sharing this information, Governments, Educators, Mariners, Admiralty Lawyers, and vessel owners can work together to improve maritime safety. This research article proposes academic Maritime Education and Training (MET) strategies and administrative systems to recognise the deficiencies between human factor errors and digital innovation to prevent such accidents from reoccurrence.

KEYWORDS

Maritime accidents, Human-technology interaction, Maritime education and training

NOMENCLATURE

AIBN	Accident Investigation Board Norway
AIS	Automatic Identification System
ARPA	Automatic Radar Plotting Aid
COLREGS	Convention on the International Regulations for Preventing Collisions at Sea
ECDIS	Electronic Chart Display, Information System
IMO	International Maritime Organisation
MET	Maritime Education and Training
NTSB	National Transportation Safety Board
SOLAS	International Convention for the Safety of Life at Sea
STCW	International Convention on Standards of Training, Certification, and Watchkeeping for Seafarers
TAIC	Transportation Accident Investigation Commission, NZ
USCG	United States Coast Guard
VTS	Vessel Traffic Service

1. INTRODUCTION

There have been accidents from the first time a person built a boat and sailed it. Human beings have researched preventing accidents ever since! Notably, a large number of previous studies concluded that between 80 and 90% of all maritime accidents and casualties are due to human error (Uğurlu et al., 2015a; Sánchez-Beaskoetxea et al., 2021). As a result, nations and industries formed alliances to prevent maritime accidents. Specifically, the International Maritime Organisation (IMO) plays a vital role in establishing rules and conventions for dealing with maritime safety issues. As waterborne commerce expanded, several treaties (conventions) were implemented with the intent to mitigate accidents and ensure the maritime safety of the environment, cargo, vessel, and life at sea. The SOLAS and STCW are predominantly known as crucial measures to improve maritime safety from the perspectives of a ship and human, respectively (IMO, 2002; Uğurlu et al., 2015b).

Recently, the awareness of the economics of scales and environmental protection has accelerated the industry towards digitalisation, and the shipping industry is no exception. Digitalisation further accelerates the application of automated systems to steer even mega-size ships for sustainable development (Del Giudice et al., 2021). Thus, shipowners are exploring how they can leverage the cost advantages of enterprises' economies of scale in the new digital technologies within the maritime industry through the introduction of autonomous vessels to create new avenues and opportunities for a more prosperous future. The emergence of vessel upsizing, and autonomous ships has a substantial impact on ship operations and the safety of navigation. Fortunately, the incidents are the lowest in the past 19 years and are down by roughly 70 percent (Allianz Global Corporate, 2020). The current total global losses that have improved from 2010 to 2019 were 951 vessels of greater than 100 gross tons with the cost of claims $1.5bn value of claims from ship linking/collision incidents. Notably, the region encompassing South China, Indochina, Indonesia, and the Philippines had the most significant shipping losses ranking first in shipping losses over the past decade (Lloyd, 2020).

In order to improve maritime safety, not only safety policy or safety management system was adopted, but innovative technologies were also applied in the shipping industry. Several automated technology systems, such as marine radar with ARPA, ECDIS, and AIS, have been embedded onboard ships to improve navigation and help avoid accidents. However, Seafarers are operating in a changing social-technical environment (Fonseca et al., 2019). Accordingly, accidents continue to happen due to overreliance on technology and crew members being on their phones and using pads when accidents occur. Previous research has discovered that technology led to accidents in more than a third of the instances (31%) (Acejo et al., 2018). That is because no matter how advanced and autonomous the ship is, it is definitely operated by humans (Sánchez-Beaskoetxea et al., 2021). Accordingly, regardless of how much the sector is digitalised, the avoidance of marine accidents remains a critical problem for maritime interests (Celik et al., 2010).

The human factor has been treated as the most critical factor in causing maritime accidents. These factors generally could be identified as communication errors, the lack of training, and inadequate or lack of knowledge to operate the navigational equipment and aids (Sharma et al., 2013; Sánchez-Beaskoetxea et al., 2021). Despite a growing body of research on safety policy (Kuronen & Tapaninen, 2010), safety training (Besikci et al., 2019), safety culture and climate (Lu & Tsai, 2008; Nævestad et al., 2019), risk assessment and mitigation (Chang et al., 2019; Chang et al., 2021; Zhou et al., 2022), and technology adoption (Yousefi, 2007; Fonseca et al., 2021) for the purpose of improving maritime safety, it seems to have the same types of accidents and maritime incidents. In order to contribute to the research literature and to further enhance the quality of maritime education and training in this digital edge, this study thus aims to ask the research questions as follows:

RQ1. What has been the impact of lessons learned from maritime incidents? In other words, “Have mariners learned from their mistakes in the past”?
RQ2. Which factors contribute to the interrelationship of technology and situational awareness?

The increased capabilities and the high level of automation of navigation systems present a challenge for monitoring, integrating, and interpreting information provided by automation. Another issue is the difficulty of maintaining track of several systems simultaneously, especially when poorly designed displays and inadequate feedback limit observability. One factor that may lead to complacent behaviour is over-reliance on new technology (Parasuraman & Manzey, 2010). It is frequently ignored that Mariners are confronted with various industry-related specifics concerning technology assimilation, ranging from a lack of technological know-how, a lack of situational awareness, and appropriate training in the use. Thus, this study aims to analyse the causes of maritime incidents based on different vessel types. Specifically, incidents caused by human factors and automation were summarised and identified. The policy for maritime training can be proposed to implement autonomous ships.

After introducing the research motivation and purposes in Section 1, the remainder of the paper is organised as follows: the method explaining how to select the accident cases was described in Section 2. The analysis of selected maritime incidents was presented in Section 3. Section 4 is the research findings and recommendations. The conclusions and suggestions were introduced in the last section.

2. QUALITATIVE CASE STUDY METHOD

To investigate RQ1 and RQ2, the official reports of the national and international governmental accident investigating agencies and services, and court documents (NTSB, AIBN, and the USA and foreign Coast Guards) were reviewed. After a preliminary filter, based on their level of similarities, 21 best-know and critical incidents with the highest number of fatalities ever recorded in four classifications, shown in Table 1, were selected to compose this paper’s theoretical reference.

To limit the paper’s scope, 7 of the 21 incident reports presented in Section 3 were selected to illustrate the research findings and the merchant marine’s current state and lessons learned. The selection criteria for the initial 21 cases included violations of rules and regulations, use or improper use of technology, required licensure, crewing requirements, training requirements, years of service, area of operations, the significance of the incident related to loss of life, countries, and factors related to cultural differences. In addition, to comprehensively survey the incident reports from different types and sizes of vessels, incidents used in this study were classified into three groups, namely military vessels, small passenger vessels, and merchant ship vessels.

Table 1. A list of selected official maritime accident reports

	Date	Vessel	Remarks
Large Commercial Vessels			
1	17 June 2013	M/V MOL Comfort	Suffered a crack amidships in bad weather
2	5 October 2011	M/V Rena	Ship grounding, spill volume up to 2,500 barrels (400 m^3)
3	7 November 2007	M/V Cosco Busan*	Allision with the San Francisco Bridge
4	18 January 2007	M/V MSC Napoli	Fate: Damaged in a storm; beached on 19 January 2007; broken up on 20 July
5	11 November 2002	M/V Hanjin Pennsylvania	Explosions at sea, aerial fireworks shells
6	24 March 1989	M/V Exxon Valdez	Grounding of the oil Tanker Exxon Valdez Volume 10.8 ×106 U.S. gal (260,000 bbl; 41,000 m^3)
7	10 June 2018	M/V Leda Maersk*	Grounding, no injuries or damage
8	28 March 2020	M/V Key Bora*	Grounding, no injuries or pollution, flooding of ballast tanks
9	25 October 2021	M/V Chem Alya	Grounding, no injuries or pollution, re-floated
Large Passenger Vessel > 100 Gross Tons			
10	20 December 1987	M/V Doña Paz	Collided with the M.T. Vector caught fire and sank, deaths 4,386, 24 total survivors
11	14 April 1912	RMS Titanic	2,224 people were onboard when striking an iceberg, deaths 1,490–1,635
12	27 April 1865	S/W Sultana	Boiler Explosion and Fire killing an estimated 1,200 to 1,800 Union prisoners
Small Passenger Vessels < 100 Gross Tons			
13	02 September 2019	M/V Conception*	Fire killed 34 of the 39 persons on board (33 passengers and 1 crew)
14	05 February 1987	M/V Fish – N – Fool	Capsizing and sinking killed 10 of the 13 persons on board, 1 passenger and 1 crew member survived)
Military Vessels			
15	08 November 2018	HNoMS Helge Ingstad*	Collision M/V Sola TS and sinking of the Ingstad.
16	21 August 2017	USS John S Mccain (DDG 56)*	Collision M/V ALNIC MC, 10 Deaths
17	17 June 2017	USS Fitzgerald (DDG 62)*	Collision M/V ACX CRYSTAL, 7 Deaths
18	09 May 2017	USS Lake Champlain (CG-57)	Collision, M/V Nam Yang 502
19	21 January 2017	USS Antietam (CG-54)	Grounding, Tokyo Bay
20	17 January 2013	USS Guardian (MCM-5)	Grounding, Tubbataha Reef, Philippines
21	12 August 2012	USS. Porter (DDG 78)	Collision, M/V Mitsui OSK, in the Strait of Hormuz

Note: (1) Accident Reports were collected from the USCG, National Transportation Safety Board, the Accident Investigation Board Norway, Philippine Coast Guard, and Supreme Court. (2)* Highlighted in this paper.

- The Military Vessel Incident

Due to the historical difference between the country's navies, three of the most current U.S. military accidents were selected involving the USS McCain and the USS Fitzgerald, and the Norwegian military vessel HNoMS Helge Ingstad because of the similarities and problems related to each of the incidents.

- The Small Passenger Vessel (SPV) Incident

The SPV M/V Conception was selected because the vessel is from the Southern California area. All indications are that the incident and loss of life were related to technological changes and management oversite.

- Merchant Ship Vessel Incident

The Cosco Pusan was selected due to the similarities related to other accidents and some of the problems that existed because of cultural differences between the crew and the Pilot. Moreover, two of the newer cases were selected, namely M/V Leda Maersk and M/V Key Bora.

3. ANALYSIS OF SELECTED MARITIME INCIDENTS

Seven of the 21 selected incident reports were analysed in this study to illustrate the research findings. These Eight accident report analyses were classified into three groups by vessel type and were discussed as follows:

3.1 MILITARY VESSEL INCIDENTS

3.1 (a) HNoMS Helge Ingstad

According to the Frigate Helge Ingstad Collision Report (AIBN, 2018), the collision happened in the early hours of 8 November 2018 between the HNoMS Helge Ingstad and the Sola TS in the Hjeltefjord fjord as the Solas T.S. departed the Sture Terminal and the Frigate was southbound at a speed of 17 to 18 knots. Both vessels exhibited the required navigation lights, but Solas T.S. had additional deck lighting for the crew working on the deck securing the ship for sea. The collision caused extensive damage to the HNoMS Helge Ingstad, causing the Frigate to take on water and partially sink in shallow water. The Solas T.S. suffered minor damage. Seven of the HNoMS Helge Ingstad's crew sustained minor injuries in the incident. There were no injuries to Solas T.S. The Frigate had 137 persons on board. Seven watchstanding personnel were on the bridge, including two trainees. The tanker Sola TS was operating with 24 persons on board. The bridge was crewed by three watchstanding personnel and a Pilot.

The main findings for the Frigate were as follows (AIBN, 2018):

1. the certification of officers of the watch was granted earlier due to the needs of the service and had less training and experience than previous requirements;
2. responsibility for the training of officers of the watch was assigned to inexperienced personnel; and
3. bridge team did not utilise the available and technical resources (RADAR, ARPA, or AIS) to detect (COLREGS, Rule5) what was thought to be a stationary object as a vessel on a collision course.

In contrast, the principal findings for the merchant's vessel were: (1) the forward-pointing deck lights were turned on, obscuring its navigation lights, and the flashing of the signal lamp (signal lamp) in violation of the COLREGS, Rule 20 (d), (Ref 9); (2) there were no Standard Operating Procedures (SOP) establishing safety measures regarding the visibility of the navigation lights due to obstruction by the deck lighting; and (3) bridge Resource Management on the bridge did not sufficiently ensure teamwork to build a collective situational awareness. Moreover, findings related to the VTS indicated that: (1) situational awareness of the VTS area was inadequate; (2) the VTS did not provide appropriate or prompt information to the vessels; and (3) it did not regulate the area's traffic to guarantee the safe passage of vessels from the Sture Terminal.

3.1 (b) USS John S McCain and USS Fitzgerald Collisions

The two U.S. Navy destroyers were involved in fatal collisions while operating in Asia. First, the USS Fitzgerald collided with the containership ACX Crystal off the coast of Japan on 17 June 2017, resulting in the deaths of 7 Navy sailors (NTSB, 2020). Then on 21 August 2017, in a second incident, the USS John S. McCain collided with the tanker Alnic MC soon after entering the Singapore Strait Traffic Separation Scheme resulting in the deaths of 10 Navy sailors. In both cases, the collisions were avoidable, and the bridge watch team did not adhere to sound navigational practices established by mariners and regulations.

With respect to the USS John S McCain incident, three major causes of the collision had been identified by the U.S. Navy (USN, 2017), Transport Safety Investigation Bureau (TSIB, 2018), and NTSB (NTSB, 2019b), namely: (1) situational awareness was lost due to the mistakes in operating the ship's automated manoeuvring and engineering systems while operating in a high-density traffic area; (2) The vessel failed to follow the COLREGS, a system of rules governing vessels' manoeuvring at sea in all conditions; and (3) Watchstander's operating the steering and propulsion systems had insufficient training, competence, and experience using the automated manoeuvring and engineering systems. Conversely, the USS Fitzgerald incident resulted from the numerous failures that occurred on the part of leadership and watchstanders (USN, 2017). Safety planning is thus viewed as a crucial enabler in improving maritime safety. These safety planning practices include the use of sound navigation practices of target tracing, use of basic watch standing practices, effectively using available navigation tools such as Radar, ARPA, or AIS, and responding effectively when in extremis.

3.2 SMALL PASSENGER VESSELS INCIDENTS

According to the NTSB Preliminary Marine Report (NTSB, 2019c), at approximately 3:14 a.m., the U.S. Coast Guard station in Los Angeles/Long Beach, the U.S.

Coast Guard station received a marine emergency distress call from M/V Conception, a 75-foot commercial sports diving vessel with 39 people aboard. The USCG classifies the Conception as an inspected small passenger vessel (SPV) certified to take passengers on dive excursions off the coast of Santa Barbara in the Pacific Ocean. The voyage was a three-day diving excursion to the Channel Islands. The vessel anchored in Platts Harbour off Santa Cruz Island when it caught fire. Weather reports indicated light winds with sporadic fog, 2 to 3-foot seas, and the air and water temperatures were about 65°F. The vessel had 39 persons embarked, 33 passengers, and six crew members.

The incident is currently being investigated, but it is known that while the passengers were asleep below decks, the captain of the Conception did not have a designated member of the vessel's crew as a roving patrolman in accordance with the Code of Federal Regulations. Preliminary indications from the surviving crew members are that a charging station for cell phones may have caused the fire. In addition, loss of situational awareness of the new technology advances in underwater cameras and electronics that require a greater capacity of onboard charging stations may create the problem. The NTSB has not officially determined the cause of the fire. However, the Coast Guard issued a precautionary Marine Safety Information Bulletin (MSB) warning all vessels about charging station safety.

3.3 LARGE MERCHANT SHIP (LMS) INCIDENT

3.3 (a) M/V Cosco Busan Collision

The M/V Cosco Busan collided with the Delta (D) pylon protection system of the San Francisco–Oakland Bay Bridge on 7 November 2007 (NTSB, 2009a). Allision with the bridge's pylon caused a 212-foot-long, by 10-foot-high, by 8-foot-deep gash on the vessel's side forward and breached the port fuel tanks 3 and 4 and the port ballast tank 2. Resulting in a breach of fuel tanks discharging about 3,500 gallons of fuel oil into San Francisco Bay. There were no injuries, but the resultant fuel spill contaminated about 26 miles of shoreline, causing extensive damage to the local environment. The allision also highlighted the U.S. Coast Guard's lack of medical surveillance of Seafarers, training, and oversight of the vessel's crew.

As a result of its investigation of this accident, the Safety Board made the following finding (NTSB, 2009a):

1. The vessel departed in a severe fog; the vessel's bow was not visible from the bridge;
2. the Pilot asserted that both radars were non-functional and did not report to the Mater the problem; the coastguard later found them fully operational;
3. the Pilot failed to consult an official printed navigation chart at any time;
4. the Pilot was perplexed and disorientated in the operation of the ECIS;
5. the Pilot did not disclose his medical conditions and prescription medications on annual medical forms submitted to the coast guard; and
6. there was no restricted visibility SOP prepared in accordance with the Safety Management System before sailing.

3.3 (b) M/V Leda Maersk and M/V Key Bora Collisions

Two recent incidents related to automation were identified. One was the Leda Maersk that ran aground on 10 June 2018. The Transportation Accident Investigation Commission (TAIC, 2018) of New Zealand determined the crew's failure to use electronic navigation aids fully to determine that the vessel was deviating from the planned course. In addition, the bridge team's standard of bridge resource management fell short of industry best practices. Another incident was on 28 March 2020, the chemical tanker Key Bora ran aground on approach to Mowi's facility in Kyleakin, Isle of Skye, Scotland, due to the bridge crew's inability to work effectively together or make full use of the ship's ECDIS during the transit. Instead, the navigation team relied on local data and disregarded ECDIS data, which did indicate the obstruction.

Although these additional recent cases are relatively insignificant compared to the other selected cases, they illustrate an ongoing problem with the interface between human factors and automated systems. Modern, technologically advanced automated systems such as radar, ECDIS, and other automated navigation systems were involved in these accidents.

4. RESEARCH FINDINGS AND RECOMMENDATIONS

After analysing the selected maritime incidents, the research finding, and recommendations are presented in this section according to different types of vessel incidents. Firstly, analysing the information from the investigating authorities related to the three Navy accidents, the findings show a common trend in training new generations of officers advancing to command and operational level bullets lacking the skills and experience needed to operate effectively and safely at sea. The world's growing dependence on automation and technology has diminished the basic seamanship skills at all command and operational levels. This erosion due to technology is also apparent in the training of ship's officers in 2003 when the U.S. Navy reduced its Surface Warfare Officer (SWO) course hours. Instead*, t*hey issued each new officer a box of 21 CD-ROMs called "SWO in a Box". Additionally, the U.S. Navy has removed the requirement for the use of manoeuvring boards and celestial navigation. As a result, the current Celestial Navigation course is only three hours of the Surface Warfare Officers Training school curriculum. In 2023, following the dismal performance of its cadets on the U.S. Guard Third Mate certification examinations, attorneys for the Consortium of State Maritime Academies of the six U.S. academies requested that the Terrestrial Navigation examination module be modified. Requesting that the examination no longer has linked questions and that they be modified to assess a single navigation task using standardized maritime terminology (USCG, 2020; USCG, 2022; Konrad, 2023).

In contrast to the military, Merchant Mariners are required by STCW to take many required courses and certification examinations administered by a third-party agency. Therefore, creating a standardised training regime based on USCG and IMO standards will positively impact the Navy (Schwartzstein, 2019).

With respect to the passenger's vessels, the findings from the M/V Conception case indicated that the M/V Conception incident is still under investigation. However, it is known that while the passengers and crew members were asleep below decks, the captain of the Conception did not have a designated member of the vessel's crew as a roving patrolman in accordance with the Code of Federal Regulations. In M/V Conception's case, the lack of following the regulations and not having a roving patrolman may have contributed to the loss of life. However, it is discouraging that mariners still do not follow the regulations after 32 years, many deaths, and safety incidents (NTSB, 2019c).

Finally, regarding the large merchant ship incident, the Cosco Pusan was concluded for discussion, not because of the captain, crew, and Pilot's poor Seamanship. Instead, because of the following recommendation by the NTSB, it is worthy of discussing the ramifications as it relates to vessels travelling from different foreign ports having different cultures: (1) the NTSB recommended that the IMO includes a lesson on cultural and language differences and their possible influence on mariner performance in its bridge resource management curricula of the STCW, emphasising Pilot and crew interaction; (2) maritime schools must alter their training of all officers to be more independent and assertive because of the cultural differences; (3) additionally, concurring with the Board Member Deborah A. P. Hersman, who took the unusual step of voting against the findings. Since the investigating teams' findings neglected to evaluate the Master's and VTS's role in the accident's proximate cause, therefore, the Master and VTS should have been referred to as a contributing cause rather than as one of the probable reasons; (4) the Master of a vessel retains all responsibility for safe navigation at all times. There are only two exceptions when operating within the Panama Canal System (Rules and Regulations of the Panama Canal, sec. 4.6) and entering a drydock. The ship's responsibility is transferred to the Panama Canal Pilot and the Drydocking Officer.

The aforementioned reviewed incidents have given us a lesson learned from maritime incidents. Particularly identifying errors and specific training deficiencies contributing to accidents must be addressed. However, many of these errors can be remedied via better training—competency training in the proper use of technology; adequate basic navigation training to recognise and solve human-interaction technology failures.

Furthermore, reviewing official accident reports taught us a lesson from maritime incidents to identify the incidents caused by human factors and automation. In particular, various errors and specific training deficiencies contributing to accidents were identified, and these should be addressed. As shown in Table 2, these deficiencies could basically be summarised into three categories.

Competency-based errors refer to the errors made due to the lack of knowledge or training, error of action, or unintentional actions during routine activities; basic skills are understood, but the individuals lack competency. Regulatory-based errors refer to people showing far more indifference to particular incidents and differences in attitudes towards compliance within any given population. Lack of leadership, compliance is not aligned with organisational goals, and the business has no accountability. Finally, perception-based errors are caused when the individuals do not understand a stimulus as a primary perceptual process or the operator's integration of information and understanding of situational awareness.

5. CONCLUSIONS AND SUGGESTIONS

This study evaluated several recent maritime incidents to identify relevant academic MET methodologies for enhancing the quality of present maritime education and training in this digital age.

The main findings pertaining to the research questions were as follows:

From a historical and country perspective, results found that maritime accident rates have decreased significantly, according to recent studies. Accident rates are at their lowest in the past 19 years, reduced by 70%, and shipping losses have declined by over 50% over the last 100 years (Allianz, 2019). This same trend has been replicated in the fatality rate among professional seafarers. Seafaring continues to be one of the hazardous professions (Pavlakis & Pavlakis, 2014). In case studies, the research validates that these accidents have changed the nature relating to the implementation of innovative navigation equipment such as radar (ECDIS), AIS, and other systems, but also shows a lack of basic navigation skills because

Table 2. A summary of deficiencies in maritime training

Incidents Caused by Human Factors and Automation			
Vessels Name	**Competency-Based Errors**	**Regulatory-Based Errors**	**Perception-Based Errors**
HNoMS Helge Ingstad	1. Lack of sound navigation practices 2. Failure to use available navigation tools 3. Inadequate training experience 4. Absence of basic watch standing practices	1. Ineffective use of technology AIS, ARPA, ECDIS, 2. Rule violation - COLREGS	1. Inadequate training/experience before advancement at command levels 2. Loss of situational awareness – poor Bridge Resource Management
Solas T.S		1. Rule violation - COLREGS 2. Rule violation - no SOP	1. Loss of situational awareness
USS McCain	1. Lack of sound navigation practices 2. Failure to use available navigation tools Inadequate training and experience in steering and propulsion systems 3. Lack of onboard training programs	1. Rule violation - COLREGS 2. Captain's indecision to operate the ship's propulsion system independently in a high-traffic area	1. Inadequate training/experience before advancement at command levels 2. Loss of situational awareness - ship's steering and propulsion system
Alnic MC		1. Rule violation - COLREGS actions in extremis	1. Loss of situational awareness
USS Fitzgerald	1. Lack of sound navigation practices Failure to use available navigation tools 2. Lack of onboard training programs	1. Ineffective use of technology, AIS, ARPA, ECDIS, 2. Rule violation - COLREGS 3. Rule violation - no safety plan	1. Inadequate training/experience before advancement at command levels 2. Loss of situational awareness
ACX Crystal			1. Loss of situational awareness
M/V Conception		1. Rule violation CFR - no roving patrol	1. Loss of situational awareness, charging station safety
M/V Cosco Busan	1. Lack of Leadership Training	1. Ineffective use of technology, AIS, ARPA, ECDIS, RADAR 2. Communication problem between master/pilot 3. No passage plan or SOP for restricted visibility 4. Rule violation - the Pilot failed to disclose his medical conditions	1. Loss of situational awareness
M/V Leda Maersk		1. Ineffective use of technology, ARPA	1. Loss of situational awareness
M/V Key Bora		1. Ineffective use of technology, ARPA	1. Loss of situational awareness
M/V Chem Alya		1. Ineffective use of technology, ARPA	1. Loss of situational awareness

of the emphasis on these systems. This trend can be reversed by monitoring these critical variables and establishing a productive and efficient interface between MET institutions, universities, and industry (Fonseca et al., 2019).

In these and many other cases, it can show that the failure to follow established navigation practices of seamanship and not following the regulation or the vessels SOP has contributed significantly to the accidents. "Familiarity breeds complacency" because you have done it many times and think it is easy. Therefore, mariners must always be vigilant because they cannot relax. The present generation of sailors has been raised to rely on what they see on visual display units. However, they can have a false sense of security and loss of situational awareness without appropriate competency training. Seafarers feel technology makes them safer, but it does not account for human error or the requirement for training to ensure seafarers have a firm foundation in basic navigation methods and situational awareness principles. All officers and seamen should get appropriate vocational training. It should be noted that there is a significant difference between academic courses and training courses – training courses provide knowledge, skills, and competencies. Most of these young officers believe that the ship could just about run itself. This will be the next question that will have to be answered as the companies try to implement autonomous vessels.

This study has several practical and managerial implications for related authorities to propose maritime education and training strategies. First, after the Cosco Busan incident, it is suggested that the training schools update the Bridge Resource Management Program, pilot interaction, and situational awareness components to include additional casualty situations using a bridge/engineering simulator. In addition, the curriculum should be submitted for reapproval by the government or related authorities. Second, most schools in the United States do not have a Standard Maritime Communication Phrases (SMCP) course since English is the primary language. Therefore, using the radiotelephone and communications requirements is essential as part of other classes. In particular, to better serve the influx of foreign-speaking students with English as a second language and promote safety at sea, an approved SMCP course using many different pilot interaction role-plays and scenarios is suggested by training schools.

Second, schools should implement semi-annual (once a semester) Occupational Advisory Committee meetings with their clients (Military, shipping companies, sportfishing and recreational, fishing fleet, offshore marine insurance companies, etc.), with the following minimum standards:

1. ensure that your program incorporates current IMO, STCW, local regulations, and current job market requirements in its instruction through the involvement of the constituencies served;
2. ensure that your advisory committee represents the industry's interests of the communities served; and
3. ensure that the involved members review programs regularly and provide recommendations on a variety of critical program design and implementation elements that include, but are not limited to objectives, length, admissions, evaluation, delivery methods, competency-based instructional content, equipment, and instructional materials, and the knowledge, skills, and work ethics related to the maritime occupations.

Third, the world's militaries need to implement the same strict standards required of the Merchant Marine under STCW (USN, 2017; Schwartzstein, 2019). These standards require documented training and competency assessments with a minimum of one year of sea service (360 days, day for day) via a third party. Fourth, simulator training must be used more efficiently. For example, when visiting other schools and company training sites to evaluate their courses, they often want to show off their simulation equipment. So they take you to the simulation room, turn on the equipment, and run it through some of the basic exercises to show its capabilities for training. It is always amazing how proud they are to have the newest technological training equipment, but 80% of the time, they turn it on to demonstrate the equipment. The question is, why isn't the equipment in use? Training must be conducted on the simulators and use them in conjunction with Integrated Bridge and Navigation Systems (Radar, ARPA, ECDIS, and other bridge equipment) and require demonstrated proficiency in all system functions. Simulation is an excellent way of providing this integrated training and building competencies.

Last but not least, to improve marine safety, shipowners and masters must require onboard training; it saves lives and money. Insurance companies can get involved with their clients to ensure that training and safety practices reduce losses. When paying out losses to your clients and seeing a situation where training can help provide local Merchant Marine Schools feedback. Schools must talk to shipowners, seafarers, insurers, and other schools. STCW is a minimum standard.

However, several limitations were suffered in this study. Firstly, this qualitative study mainly explores official maritime accident reports to examine past lessons' human and automation factors. Although current quantitative research is being conducted to ascertain the critical risk associated with autonomous vessels (Chang et al., 2021), few studies quantitatively examine the challenges and drivers of adopting autonomous ships from the perspective of shipping companies (Tijan et al., 2021). Thus, the drivers influencing the adoption of the autonomous ship can be conducted in future studies. Second, the adoption of new technologies seems to improve the maritime, but the results were qualitatively summarised and identified from prior incident reports. Therefore, future studies can conduct a survey to examine the impact of adopting automated technology on safety performance for shipping companies. Finally, an effective human-technology interaction requires education and training. Given the fact that few quantitative studies examine the competence development or skillsets needed to handle these new technologies (Sharma et al., 2021), future studies thus can conduct quantitative research to evaluate the policy priorities for the implementation of autonomous vessels from the perspective of MET. In particular, it can concentrate on maritime education and training curricula, incorporating current risk management and maritime education students.

6. REFERENCES

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