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Maritime catastrophes case studies as part of maritime education and training

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Abstract. Even though advanced technology has given seamen better tools for navigation, communication, and in general safety, ships continue to collide, ground, and sink resulting in lives lost, millions of dollars in damage, and tremendous environmental harm. Human factors are found to be a significant contributing cause of ship catastrophes. Key examples of maritime disasters that incorporate error chains, weaknesses in standardized bridge procedures, loss of communication, distraction, lack of situational awareness and presence of elements of ambiguity which hinder the proses of decision making at the ship's bridge can be studied and recreated during practical exercises. Such approach can prove very valuable for building a sound professional backing of the students especially when properly incorporated in the curriculum of some syllabus such as Shipboard Bridge Resource Management, Use of RADAR and ARPA to ensure safe navigation, Ship Handling, etc. This article points out constructive methods of implementing the lessons learned from maritime disasters investigations in the area of training of personnel for the maritime industry.

1. Introduction

Over the last decade there was a steady decrease in the number of maritime transportation accidents. Even so, marine casualties and incidents are still widely reported and present a source of concern for maritime safety. They have complex nature and usually are a product of combination of events or processes that might eventually result in the loss of human and marine life and irreversible ecological, environmental and economic damage.

The safety analysis of European Marine Casualty Information Platform (EMCIP) [1] based on dataset of the occurrences reported in EMCIP by the EU-EEA Member States between 2011 and 2021 envisages five accident events types: "human action" (addressing human performance, action or omission), "system or equipment failure", "other agent or vessel", "hazardous material" and "unknown". The results show that "human error" scores around 78% of the overall reported navigation accidents. At the same time the main takeout of the analysis stresses the complexity of the human element and that human error itself cannot be considered an acceptable "root-cause" explaining the marine casualty. It is a consequence of the socio-technical complex interactions, involving humans on board, organizations ashore, procedures and machines. For this reason, EMSA safety recommendations [2] address companies, ship owners, maritime administrations, local authorities and last but not least the improvement of maritime education and training (MET) system.

There is a ground to be assumed that competency of an individual can be improved by learning through mistakes and the lessons from it and this could unlock the door towards the goal of success by gaining proper knowledge and skill in the study of casualties and its lessons. Taking into account that a marine casualty has a great influence on the attitude and behavior of an individual, the article will deal only on this from a general point of view and won’t go deeper because of its complexity and broadness.

The aim of this article is examination of the areas within academic curriculum highlighting on hypothetic four-year full time degree program for Bachelor ‘s Degree in Navigation and Waterborne transport (with special emphasis on Bridge Resource Management training) wherein a possible inclusion of maritime casualty case studies could be possible and reasonable. In order to support and justify the proposed approach, the article examines the following three principal issues:

1. Highlighting key conclusions drawn from significant maritime casualties, based on recent safety analyses of navigation accidents and their relationship to maritime education and training.
2. Assessing the most effective teaching methods for incorporating lessons learned from maritime disaster investigations into the training of maritime industry personnel.
3. Presenting a feasible alternative for integrating simulation scenarios based on maritime casualties into bridge resource management (BRM) training.

2. Maritime Casualties

In different maritime materials, books and publications there are numerous definitions of marine casualty. More or less they all have the same thoughts. A maritime casualty can be defined as an unwanted occurrence that have happened in the ocean or in the sea, resulting to misfortunate environmental/property damage or injuries/loss of lives [3]. The most essential factors containing a maritime casualty are that:

1. It is an unplanned, unexpected event and it happens by chance without any human intention or deliberation.
2. It is related to ship operations.
3. It resulted in damages such as death or injury to persons, property-financial, material or natural resource, as well as damages to environment.

The statistical database accumulated on maritime incidents may prove to be a valuable source of information regarding the percentage of the most common causes of maritime disasters, as well as for identifying the weakest points in the operation of complex systems, such as the ship's bridge along with it’s equipment and crew, procedures, and organization [4]. A database can undoubtedly be valuable for safety education because it provides a repository of evidence that highlights the most frequent and severe accidents, along with their causes and contributing factors. Instead of drawing lessons from each individual accident, broader and more systemic insights can be obtained by examining various incidents collectively. This approach allows for more impactful safety improvements that can be derived from the lessons learned. Furthermore, the necessity for change might not be apparent from a single incident until it becomes clear that numerous similar events are occurring. Hence, databases can serve as a catalyst for action and a tool for prioritizing safety measures. While each accident may seem distinct and occur under unique conditions, and every ship and crew might be different, certain issues may consistently emerge across various cases.

The development in maritime technologies provides increasingly advanced methods for investigating maritime incidents and processing the accumulated statistical information. On 23 of April 2009 the European Parliament and The Council of the European Union have adopted Directive 2009/18/EC which establishes the intrinsic principles governing the investigation of accidents in the maritime transport sector and amended Council Directive 1999/35/EC and Directive 2002/59/EC of the European Parliament and of the Council. Based on that European Marine Casualty Information Platform (EMCIP) now uses slightly different classification [2] of that formulated by the IMO Casualty Investigation Code [3] for its taxonomy: capsizing/listing (this category comprises two subcategories: capsizing and listing), collision, contact, damage to equipment, grounding/stranding, fire/explosion (this category comprises two subcategories: fire and explosion), flooding/foundering (this category comprises two subcategories: foundering and flooding and the last can be: progressive and massive), hull failure, loss of control (this category is divided to: loss of electrical power, loss of propulsion power, loss of steering control, loss of containment and an accidental spill or loss of cargo or other substances carried on board a ship), missing and non-accidental events (The last are not considered as marine casualties or incidents and are not covered by the scope of the Accident Investigation Directive (2009/18/EC) and cover: acts of war, criminal acts, illegal discharge, other intentional act that incurs loss of or damage to a ship or environmental damage or harm to people on board).

According to the figures presented by EMSA [4], navigational events (collisions, groundings and contacts) represented the biggest part of casualties with a ship (43%). In the following table (table 1) is presented the percentage of casualty occurrences with ship, organized by type of casualty with ship.

Table 1. **-** The percentage of casualty occurrences with ship, organized by type of casualty with ship.

Type of casualty with ship	Repartition 2014/2020
Capsizing / Listing	0.7%
Collision	12.8%
Contact	17.2%
Damage / Loss of equipment	14.7%
Fire / Explosion	6.3%
Flooding / Foundering	2.7%
Grounding / Stranding	13%
Hull failure	0.4%
Loss of control	32.1%
Missing	0%

Despite the many measures taken to improve maritime safety over the last few years, the table below (table 2) shows that from 573 accident events for the period from 2014 to 2020 that have been directly associated to navigation accidents, “Human action” is still, by far, the most reported category (447 events) or 78.0% [1].

Table 2. – Accident event directly associated to navigation accidents.

Navigation accident (collision, contact, grounding/stranding)	Repartition 2014/2020
Human action	78.0 %
Other agent or vessel	13.6 %
System/ equipment failure	7.7%
Unknown	0.7%

Logically, from the data presented, the question arises: What is the manifestation of human action? The reasoned answer is: Error modes refer to the ways the manifestation of errors occurred. The most prominent manifestations of error are related to the wrong timing of a given action, either omissions or actions executed too late. Examples relevant to the analysis of navigation accidents [1] include the lack of change of course, or its delayed execution, in a crossing situation involving two ships evolving is a collision (table 3).

Table 3. - Action modes.

Error Modes	%
Action at a wrong time - Timing - Omission	30.4%
Action at a wrong time - Timing - Late	30.0%
Action at a wrong type - Direction	9.2%
Action out of sequence - Sequence	7.3%
Action at a wrong time - Timing - Other	5.8%
Action at a wrong time - Timing - Early	4.2%
Action at a wrong type – Distance / magnitude	3.8%
Action at a wrong type - Speed	3.5%
Action at a wrong time - Duration	2.7%
Action at a wrong object	1.9%
Action at a wrong type - Force	1.2%
Total	100.0%

The basic conditions of "human actions" could also be divided in categories according to the status of the person.

A first distinction concerns "analysis" and "synthesis".

- "Analysis", refers to the functions that are invoked when a person tries to determine what the situation is, typically including observation, identification, recognition, diagnosis, etc.
- "Synthesis" refers to the functions applied when a person decides what to do and how to do it; this typically includes choice, planning, scheduling, etc. Regarding planning, the most frequent error triggers are wrong plans, in the sense that they do not achieve their purpose, and incomplete plans, i.e., they do not contain all the details needed when they are carried out.

As a second EMCIP distinguishes the personal factors affecting the performance variability – i.e. the continual adjustments necessary to cope with variability in demands and conditions - in two categories, depending on their persistence on the affected person:

- Temporary (e.g. stress, fatigue etc.) are transitional conditions impacting the individual performances for a limited timeframe;
- Permanent (e.g. cognitive style, bad eyesight etc.) are persistent conditions affecting the individual.

Such a view on the basic conditions in individual performance can have its contribution to the identification of the most productive training methods. It deserves to be mentioned that the development of educational simulation scenarios requires a clear understanding of the desired outcome that needs to be achieved. The goal of each scenario must be aligned with both the limitations in the scope of the elements of the situation that can be recreated, as well as the limitations in the number of elements on which a positive relatively permanent transition can be achieved (for example: knowledge, skills, sequence of work, prioritization and distribution of tasks, attitude, new understanding and revision of emphasis during the execution of tasks on the ship's bridge and others).

3. Causes of Casualties

Investigators looked for the factors contributing to marine casualties and incidents in the analysis phase. Such causes were made up of accident events (underlying factors) and contributing factors. EMCIP follow an approach where each marine casualty and incident reported in can have one or more accident events [1]. More than one accident events can be associated to a casualty event. EMCIP differentiate five accident event types:

- Human action,
- System or equipment failure,
- Other agent or vessel,

- Hazardous material,
- Unknown.

For example, the percentage of all accident events for the period from 2014 to 2021 was obtained from the count of every single accident event reported in EMCIP [3] of each type (table 4).

Table 4. - Accident events obtained from the count of every single accident event reported.

Accident event type	% of the accident events
Human action	59.6
System or equipment failure	24.5
Other agent or vessel	8.6
Hazardous material	5.3
Unknown	2.0

Further EMCIP adopted a schematic model where each accident event can have one or several contributing factors. Contributing factors have the following three types:

- External environment;
- Shore management;
- Shipboard operation.

When the distribution of contributing factors for the period from 2014 to 2021 that determines the percentage of contributing factors is organized by contributing factor types and accident event types it shows that "Shipboard operation" was the most important contributing factor type, with 70% of all the contributing factors [3].

At the same time the data collected reveals that when the percentage of contributing factors is organized by contributing factor categories and contributing factor types it turns out that "Human behavior" was the most important contributing factor category, with 50.3% of the contributing factors. It was followed by "Environment" with 29.2% of the contributing factors [3].

Further in the article, only navigational incidents will be discussed. The analysis of 1,637 contributing factors reported in 351 safety investigation reports for the period from 2014 to 2021 [1] both directly and indirectly linked to navigation accidents are grouped into nine "safety issues", as presented in the table below (table 5).

Table 5. - Safety issues (Directly and indirectly linked to navigation accidents).

Safety Issues (SI)	CF Nr.	%
Work / Operation Methods	594	36.3%
Organizational Factors	310	18.9%
Risk Assessment	171	10.4%
Environment	139	8.5%
Individual Factors	119	7.3%
Tools & Hardware	117	7.1%
Competence & Skills	69	4.2%
Emergency response	61	3.7%
Operation planning	57	3.5%
Total	1,637	100.0%

The analysis reveals that the majority of the reported problems relate to "work operational methods," "organizational factors," and "risk assessment," which together account for nearly 66% of the contributing factors. Every safety issue has been further analyzed into areas of concern to gain a comprehensive understanding of the consistent factors that explain its occurrence.

Working methods in the multiple operation areas onboard are structured and supported by the Safety Management System (SMS). The analysis showed that this is the most reported safety issues, with 242 investigations addressing 594 contributing factors concerning work/operation methods [1]. The are defined in the following “areas of concern” (table 6).

Table 6. – Work/ operation methods areas of concern.

Area of Concern	CF Nr.
Bridge Resource Management (BRM) Coordination	94
Use electronic equipment (navigation devices)	94
Work methods and supervision	63
BRM Resource availability	63
Communications (External)	53
Coordination with 3-rd parties	48
Maintenance implementation on board	41
Alarm setup	41
Communications (Internal)	31
Use of equipment	26
Multitasking	26
SMS implementation on board	14
Total	594

The stance of organizational and management practices is crucial for the safety of ships, irrespective of the vessel type. In 155 investigations, three hundred and ten contributing factors related to company policies and oversight from shore-based authorities have been identified [1]. Organizational factors are divided in the following “areas of concern” (table 7)

Table 7. – Organizational factors areas of concern.

Area of Concern	CF Nr.
Resource Availability (Plans and Procedures)	73
Culture Climate	65
Resource Availability (Operational information)	44
Resource Availability (Tools)	42
Compliance with regulations and standards	23
Review Critical Tasks	20
Resource Availability (Manning)	17
Maintenance policy (SMS)	17
Resource Availability (Standing Orders)	9
Total	310

Safety and risk assessment, and reviews of tasks and procedures based on such assessment, are essential components of the safety culture and contribute to an effective decision-making process. According to EMCIP data [1], problems associated with "Risk Assessment" have been identified in 133 safety investigations, involving a total of 171 contributing factors (table 8).

Table 8. – Risk assessment areas of concern.

Area of Concern	CF Nr.
Safety Awareness	125
Environment Impact	39
Risk assessment for specific operation	7
Total	171

Despite that data analysis [1] highlights that 78% of collisions, groundings and contacts are associated with human action, this shouldn't be understood as blaming the bridge team for this enormous contribution to navigation accidents. The additional analysis of the data encoded in EMCIP show that human actions or decisions are not the cause of the adverse outcome, but mere events at the end of the accident event chain. Moreover, detecting what is often referred to as "human error" is normally the starting point of safety investigators to understand why the "error" occurred.

The analysis indeed demonstrates that "behind the scenes" of "human errors" there are many contributing factors from various domains deriving from complex interactions between people and systems. On the one hand there are challenges with the coordination of the bridge team, ergonomic issues, lack of resources, completeness and realistic implementation of the SMS, use of technology, etc. On the other hand, the pressure to "get the job done", thus to cope with the actual situation on board, pushes the crew to optimize the processes. Therefore, blaming the key actors on the bridge, usually the Master or the OOW, for poor professional performance is just an oversimplification of the real world. The complexity of the human element and that "human error" itself cannot be considered an acceptable "root-cause" explaining the marine casualty. Conversely, "human error" is a consequence of the sociotechnical complex interactions, involving humans on board, organizations ashore, procedures and machines [5].

The main takeout of the analysis [1] points out some safety issues and safety recommendations considered by the accident investigative authorities, as well as safety actions implemented by the relevant parties, that might have a potential horizontal impact on ship safety. They are divided into the following four main areas":

1. Coordination of the bridge team, workload and resource availability:

The biggest precent of accident events in this area occurred as a result of poor bridge team coordination. Data indicates that it was fairly common to leave the Officer on Watch (OOW) alone on the bridge, especially during night hours. EMCIP data revealed that approximately 42% of all open sea collisions occurred between 00:00 hrs. and 06:00 hrs. [1]. It seems that the decision to navigate without a lookout was deliberately made as a compromise to balance the work demands on the ship with the available resources.

Another aspect to consider is multitasking, which involves handling two or more tasks at the same time, each demanding attention and various complex cognitive processes. Any human action necessitates a set of corresponding brain functions for efficient execution. Switching between tasks also entails phases of goal shifting and rule activation. When multiple tasks are performed concurrently, the interconnected cognitive processes prioritize tasks as they vie for attention, and the brain allocates its resources accordingly. Safety investigations have also highlighted issues stemming from assigning seafarers to duties other than lookout or burdening the OOW with additional tasks, thereby shifting their focus from the primary task of navigation monitoring to other activities, often involving paperwork.

2. Conflicts of shipborne technology:

Navigational tools such as ARPA, GPS, RADAR, and particularly ECDIS still introduce new complexities. In certain situations, technology can overwhelm the bridge team, and in an attempt to manage their tasks, they may disable specific safety features designed to prevent navigational accidents. This represents a fundamental dilemma: technology can simultaneously create and resolve safety issues. Issues associated with electronic navigation tools were identified in 83 safety investigation reports, accounting for 23.6% of the total. Areas of concern related to conflicts arising from shipborne technology included the use of electronic equipment (93 instances), and problems with alarm setups (41 instances), totaling 134 instances. Examples documented in EMCIP include alarms that were frequently triggered near port areas, leading crew members to either deactivate or ignore them, especially during crucial operations. Additionally, it was observed that while ECDIS was the primary tool for navigation monitoring and planning, its numerous features, such as safety contours, were not fully utilized, even though officers were trained on the tool. Parallel indexing, a technique used to monitor a vessel's progress along a track to minimize cross-track distance and maintain a safe distance from charted dangers like shorelines or rocks, was also found to be underutilized in regular ship monitoring activities. Furthermore, issues related to RADAR usage were noted. One report highlighted that despite all duty officers being aware of the RADAR's utility and familiar with the "guard zones" function, they did not use it to receive alerts when targets entered designated areas or when their vessel approached a hazardous area. Notably, the practice of deactivating the alarms of the BNWAS, reported in 16 safety investigations (4.6% of the total), suggests that this might be a more widespread practice on board.

3. Bridge ergonomics and equipment design:

Fifty-six contributing factors involving bridge ergonomics or equipment design were identified in 46 safety investigations, accounting for over 13% of all safety investigations recorded in EMCIP. These factors are broken down as follows: 33 occasions related to equipment design and 23 occasions to bridge ergonomics. The data indicated that the improper placement of equipment (such as VHF stations, screens, and indicators) relative to the position of the Master's chair, as well as inadequate bridge lighting, negatively impacted the crew's awareness and ability to swiftly respond to unexpected situations. Additionally, issues with the design of audible and visual alarms were reported. As a result, these systems were ineffective in quickly alerting the bridge team about anomalies and emergencies during navigation.

4. Complexity of "procedures" in safety:

Deviations from established procedures, inadequately detailed protocols, or even the absence of necessary procedures have been extensively reported in EMCIP as contributing factors to accidents. These issues are particularly prevalent in critical areas such as coordination in Bridge Resource Management, work methods, supervision, usage of navigation equipment, passage planning, and maintenance implementation. The procedures, while generally static tools, could be problematic under certain conditions. The voluntary deactivation of alarms on equipment such as BNWAS, ECDIS, and ARPA highlighted safety concerns. It was evident that crew members occasionally bypassed the procedures outlined in the Safety Management System (SMS) to undertake other crucial tasks, such as coordinating port approach maneuvers with the pilot. Sometimes, bypassing procedures for specific activities was essential for effectively executing other critical procedures. The impact of procedures as noted in EMCIP was twofold. On one side, they were viewed as a safety barrier, and their deactivation could contribute to accidents. On the other side, procedures were sometimes written in a manner that made them difficult or even impossible for frontline operators to implement under dynamic and challenging conditions. This latter observation suggested that instead of attributing fault to seafarers' abilities or willingness to follow procedures, a critical examination of how procedures performed during the events leading up to an accident could help uncover underlying safety issues.

4. Safety recommendations

These are recommendations derived from the analysis and conclusions of the investigation and are related to particular subject areas, such as legislation, training, maintenance, etc. They are addressed to those best placed to implement them, such as ship owners, maritime authorities, etc. Safety recommendations made by EMCIP [1] are organized by the focus areas (table 9).

Table 9. - Evolution of safety recommendations, organized by focus area.

Focus area	% of recommendations
Ship related procedures	45.5
Human factors	21.6
Ship structure and equipment	15.0
Other procedures	13.9
Shore and water equipment	3.0
Other	1.0

“Ship related procedures” is the main focus area of the safety recommendations reported since 2014. The trend clearly outlines the areas where additional actions should be taken and improvements has to be made.

Further each focus area is divided in sub-categories, and they are analyzed for each focus area excepting other. It should be noted that for focus area “Ship related procedures” 42.9% of the safety recommendations are in the subcategory “Operation” [1].

Regarding the focus area “Human factors”, 45.1% of the safety recommendations are in the subcategory “training, skills and experience” [1] (table 10).

Table 10. - Evolution of safety recommendations for human factors focus area, organized by focus area subcategories.

Focus area subcategories in area “Human factors”	% of recommendations
Training, skills, experience	45.1
Management	14.9
Company and organization	12.4
Equipment	8.2
Crew factors	5.2
Study/review	5.0
Medical, physical	2.8
Other	2.8
Working environment	1.8
External bodies liaison	1.0
Individual	0.8

5. Education and Training

"Typically, the creation of any training program involves several steps [6]:

1. Identifying the training needs,
2. Specifying the training goals,
3. Designing the training content, structure, and methods, and
4. Assessing the training's effectiveness.

While it is often presumed that training should rely mainly on lectures supplemented by simulator exercises, numerous alternative methods exist, and using a simulator is not always necessary. Therefore, there is a broad review of training methods employed in the broader Human Factor training area.

When developing and implementing maritime casualty case studies teaching program or BRM training program with special emphasis on simulation of real maritime accidents, two critical questions must be addressed.

First, what level of expertise or learning do we aim for our participants to achieve? A commonly employed framework in the field of education is Bloom's taxonomy. This framework categorizes and differentiates various stages of cognitive abilities, learning, and comprehension. Bloom's taxonomy includes six levels: Knowledge, Comprehension, Application, Analysis, Synthesis, and Evaluation [7], [8].

The second question pertains to the various levels of psychological functions that training should encompass. These levels include:

1. The level of explicit, verbal knowledge, such as understanding human performance and limitations, human error, coping mechanisms, and theoretical concepts related to chain of errors and maritime accidents general contributing factors and areas of concern.

2. The level of pattern recognition, for instance, accurately detecting signs of fatigue, boredom, complacency, or diminished situational awareness.
3. The level of plans, rules, or action patterns, such as frameworks for decision-making, conducting risk assessments, or managing priorities in maritime emergencies.
4. The level of generic personal and interpersonal skills and competencies that are applicable in various situations, including effective communication, leadership and followership behaviors in different contexts, teamwork dynamics, maintaining situational awareness, and cross-cultural communication.
5. The level of attitudes, including cultural stereotypes and perceptions about leadership.

It's evident that different levels necessitate different training approaches, or conversely, no single method can address all aspects. However, it is feasible to tentatively associate certain levels with specific methods [9]:

1. Explicit verbal knowledge is best taught through instructional methods that facilitate the integration of new information with personal experiences.
2. Pattern recognition requires some instructional input but should be supplemented with other techniques such as relevant case studies or experiential learning. Challenges arise because phenomena like fatigue or complacency develop over extended periods, making them tough to simulate effectively in a short training program.
3. Plans, rules, or action patterns often utilize checklists. Knowing about a checklist isn't usually the issue; the challenge lies in using or ignoring it appropriately. Checklists detailing specific actions or operations benefit from training in high-fidelity environments, whereas those that are more abstract or generic (such as emergency decision-making models or shared mental model development) can initially be taught through experiential methods without requiring high fidelity.
4. Generic personal and interpersonal skills and competencies are central to BRM training. Starting with case studies and group discussions is beneficial, but these should be enhanced with experiential learning. Techniques like communication games, indoor and outdoor problem-solving activities, and simulations are particularly suitable for training interpersonal behavior and team resource management. Given that trainees usually have extensive histories of social learning, acquiring new behaviors can be challenging. When time allows, progressing through a sequence of exercises from simpler activities focused on a single aspect to more complex simulations integrating various skills is recommended.
5. Attitudes represent the most challenging level to impact through the training. Traditional verbal instruction is typically ineffective at altering dysfunctional attitudes. Instead, addressing attitudinal issues through experiential methods during relevant moments when they emerge tends to be more effective.

5.1 Maritime casualty case studies included as a separate syllabus

If a maritime casualty case studies are included as a separate syllabus in the curriculum probably should be used a mixture of instructional and case studies methods.

Teaching methods frequently focus on cognitive learning. These methods are employed to impart theoretical knowledge and scientific terminology essential for grasping the principles of technology, human behavior (at individual, team, and organizational levels), and their interplay. The goal of instruction is to provide a framework of language that enables learners to achieve a deeper understanding of specific phenomena than previously attained.

Case studies consist of real-world material, typically based on significant incidents such as a catastrophe, accident, or a minor event (such as a near miss) that previously occurred involving a ship. These studies draw from official accident investigation reports and various sources to present the "case," detailing the ship, its environment, the people involved, and a mix of critical and sometimes extraneous preliminary events for context. This narrative is followed by an account of the incident itself and its consequences. Visual aids like films may also be used to enrich the case study.

Case studies usually conclude with a set of "discussion questions" designed to promote independent thinking among participants. These questions are intended to spark a reflective process fueled by curiosity to delve into the root causes of the incident. Participants are often encouraged to propose measures to prevent the recurrence of such events. Instructors may also use these studies to highlight the relevance of key theoretical concepts such as "situational awareness," "passage planning," "leadership," or "closed-loop communication."

Case studies can be explored individually or in small groups. When working in groups, it is recommended to ensure active participation from all members in both the analysis and discussion phases. The essence in connection with the marine casualties is the spreading of important and vital lessons from these casualties.

If a subject concerned with casualty lessons is taught and included during formative years of the students, safety awareness and consciousness would gradually build up, making a stronger foundation once the students have reached their professional career. Additional positive effect would be that the subject enhances the knowledge and skills gained from previous academic years intensified by extensive use of group activities, case studies, and role playing in order to augment investigative and analytical skills.

There are two issues concerning such an approach.

The first issue is that currently, in the curricula for the training of watchkeeping officers, chief mates, and masters, it is rare and almost unheard of to include a separate specialized discipline that addresses the investigation of maritime disasters, the conclusions that can be drawn from them, and the analysis of accumulated statistical data related to maritime disasters. Usually such a curriculars are based on IMO model course 7.03 for Officer in charge of a navigational watch and 7.01 for Master and Chief mate. There is IMO model course 7.11[10], but it is designed to introduce potential flag State investigators with an introduction to accident investigations and accident investigation methodology. This means that there exists only a limited possibility to build the students safety awareness. Of course, incorporating a separate discipline focused on the investigation of maritime disasters and incidents would additionally burden the students' curriculum. That is why it is preferable that a separate maritime casualty learning course to be one of the selectable courses that form the professional qualification of graduates.

The second issue is that, before carrying out casualty lessons, prerequisite subjects must be taken and sufficient practical experience on board a ship should be gained in order to appreciate the subject. Therefore, the maritime casualty subject should be given in the later part of the study program for Bachler's degree. In such a way the students have already acquired the necessary knowledge and skill to fully understand the lessons and be able to analyze the probabilities and key factors which have caused the casualty.

5.2 Maritime casualty case scenarios included as a part or as additional BRM training

There are teaching syllabus which are part of curriculums based on IMO model course 7.03 and 7.01 and gives to a certain extend the opportunity for emphasis on maritime casualties and its vital lessons. Bridge resource management training proves to be most beneficial in this regard [11], [12]. One of the reasons for this situation is that there is no validated standard format for BRM training [13].

As outlined in the International Convention of STCW (Standards of Training, Certification, and Watchkeeping for Seafarers), 2018, and the Manila amendments of 2010 [14], [15], [16], Bridge Resource Management (BRM) training is now a compulsory requirement for the Master and deck department. According to Table A-l/ll (IMO STCW) [14], [15], BRM training enhances skills in:

1. Resource allocation, assignment, and prioritization.
2. Effective communication.
3. Leadership and assertiveness.
4. Situational awareness.
5. Leveraging team experience.

Participants are required to validate their skills through assessments based on:

1. Approved training.

2. On-the-job experience.
3. Simulator training.

The Manila amendments also outline some general (and somewhat indistinct) criteria for evaluating these competencies [14], [15]:

1. Resources are allocated and assigned as necessary, prioritizing essential tasks.
2. Communication is clear and precise.
3. Decisions and actions are met with appropriate challenges and responses.
4. Effective leadership is demonstrated.
5. Team members have a precise understanding of the vessel's current and anticipated situation, the navigational route, and external conditions.

Currently, there is no IMO model course tailored to the Manila amendments for guiding trainers and training institutions in designing and assessing BRM training. The 2002 edition of the IMO model course 1.22 combines ship bridge simulator exercises with theoretical classroom lectures [11] The introduction to this model course stresses that its purpose is to aid maritime training centers and their staff in developing and initiating new courses, rather than providing a rigid teaching package for instructors to follow blindly. Consequently, the IMO model course syllabus serves as a guideline or inspiration for designing, planning, and implementing BRM training. With no updated model course available, training centers and instructors must rely on the requirements from Table A-l/ll as their primary guidelines. This situation grants course providers significant creative freedom, but also places the responsibility on them to meet the vaguely defined requirements.

The aim in this paper is to provide an overview of the general design of BRM training and the most beneficial available training methods that can be used to recreate key scenarios from maritime disasters and incidents for training purposes.

BRM allows the use of so-called experiential methods. Experiential methods encompass a broad range of varied exercises, all united by one fundamental aspect - they necessitate active participation from the attendees. Typical examples of these exercises include: tabletop secrecies, communication games, brief problem-solving games and exercises, outdoor team activities and escape-room settings and simulations. Special attention will be given to the latter.

In the context of training methods, the concept of "simulation" lacks a clear definition. There are three distinct types of simulations that can be utilized in BRM training: (command) staff exercises, low- and mid-fidelity simulation games and high-fidelity simulations. We will focus on the last two types of simulations as the most suitable methods for enacting scenarios related to maritime disasters.

Low- and mid-fidelity simulation games comprise a category based on sophisticated computer models that replicate a complex, dynamic, and opaque segment of the real world. These simulation games are employed to train participants on the general demands of rapidly evolving crisis situations, such as strategic thinking, complex decision-making, and team communication and interaction [17]. Referred to as low- or mid-fidelity simulations, these games model the internal structure of the problem but lack visual or other sensory representations. Typically, these simulations require a trained facilitator to guide the process. Such simulation games are considered highly valuable for BRM training as they circumvent a common issue in realistic settings where participants might concentrate more on operational or technical details (e.g., ship handling) rather than on broader Human Factors such as leadership or complacency [18].

High-fidelity simulations represent the cutting edge in BRM training at most maritime training centers, utilizing detailed bridge or engine control room simulators. This approach is based on the principle that team resource management is most effectively learned in an environment that closely mimics real-life conditions. In such high-fidelity simulations, participants face no difficulties transferring learned skills to real situations, allowing them to directly integrate team behaviors with the technical and operational contexts they will later operate in.

In the case with recreation of marine causalities scenarios as a part of BRM training, much like any comprehensive human-factor training, should employ a variety of methods. This diverse approach is crucial not only for achieving training objectives across various psychological levels but also for meeting the different needs and expectations of diverse learner types.

Educational literature identifies several classifications of learner types. A straightforward model by Honey & Mumford [19] categorizes learners as "doers" and "thinkers." "Doers" are divided into "activists," who are excited by immediate action but quickly lose interest in theoretical discussions, and "pragmatists," who are engaged by practical activities that have clear relevance to their professional lives and are not interested in superfluous activities. "Thinkers" include "theorists," who seek explanations and prefer overarching theoretical frameworks, and "reflectionists," who take time to thoroughly consider and reflect on their practical experiences.

Given the likelihood that these four learner types will be present in BRM training sessions, a varied mix of methods is essential to maintain engagement and participation throughout the training.

When it comes to recreation of circumstances around a chosen maritime accident scenario the "experiential learning cycle" developed by Kolb [20], [21] is a practical and empirically supported model that effectively serves this purpose:

1. The cycle typically begins with an simulator exercise that challenges the participants and includes an emotional or surprising element (High-fidelity simulation). For example, bridge watchkeepers must be placed in scenarios that closely mimic the circumstances surrounding the incident, without additional cues for the scenario's development other than the main tasks of executing the transition to the specific moment.
2. Next, after the end of the first session of the simulation, the activity is debriefed, allowing participants to reflect on their actions: correct adherence to company procedures and safety standards, task prioritization, situational awareness, proper use of equipment, detection of hidden malfunctions in device operation, etc. (Mid-fidelity simulation).
3. Then, a theoretical or conceptual explanation of the events that occurred during the simulation and assessment of the appropriateness of actions according to the situation is provided.
4. Finally, participants are given a chance to apply their new insights in a subsequent simulation session – usually same scenario (High-fidelity simulation), thus restarting the cycle.

Reflecting on Bloom’s taxonomy, it is clear that this method is designed not just to enhance knowledge and understanding, but also to facilitate learning at the application and analysis levels.

An expert selection of scenarios is necessary for the purposes of training. The selection can be made after a careful review of maritime disaster and incident investigations. The scenarios should aim to overcome commonly encountered deficits and oversights. Guidance for the selection can be obtained from the analyses of accumulated statistical information in the maritime casualties database. Each scenario must be aligned with both the limitations in the scope of the elements of the situation that can be recreated, as well as the limitations in the number of elements on which a positive relatively permanent transition can be achieved (for example: knowledge, skills, sequence of work, prioritization and distribution of tasks, attitude, new understanding and revision of emphasis during the execution of tasks on the ship's bridge and others).The main goal of the scenario is to put trainees in a situation where they are required to perform the exercise without the impending incident occurring. They should have the opportunity during the exercise to gain a full understanding of their surroundings and, based on the knowledge and skills acquired, succeed in preventing what has happened in reality. Therefore, the situation should be such that, on one hand, there is an opportunity for a response, and on the other, the outcome of the situation is uncertain and in the hands of trainees . The scenarios may include identifying mistakes made at the level of planning the transition, elimination of errors in the actions of watch officers from a previous watch, detection of malfunctions in the operation of navigation equipment or incorrect settings, discovering of deficiencies in the operational procedures on the bridge, situations of disrupted communication, situations of suddenly changing circumstances, and others.

Every training institution should be invested in assessing their training methods to enhance and ensure their effectiveness. One way to evaluate the impact of the incorporation of maritime catastrophes case scenarios into BRM training is by employing Kirkpatrick’s four-level model: (1) Reaction, (2) Learning, (3) Behaviour, and (4) Results [22], [23], [24], [25]:

1. Level 1: Reaction. This level measures how participants perceive the training. Whether they find it enjoyable, engaging, and relevant to their roles.
2. Level 2: Learning. This level assesses the extent to which participants have gained the intended knowledge, skills, attitudes, confidence, and commitment from the training.
3. Level 3: Behaviour. This level gauges how well participants apply the skills and knowledge learned in training to their job settings.
4. Level 4: Results. This level determines the extent to which the training has achieved its targeted outcomes, including the effectiveness of ongoing support and accountability mechanisms.

However, it is debatable whether it is feasible for all participants to attain levels 3 and 4 within the allotted time frame. Realistically, levels 1 and 2 are achievable during a BRM course or a separate maritime catastrophe case study syllabus, and level 3 might be reached during simulator exercises, depending on the quality of feedback from peers.

6. Summary and discussion

IMO and the EU have adopted measures largely as a response to various maritime incidents to enhance safety in all aspects and protect the world's oceans from environmental hazards. It should be noted that 59.6% of accident events from 2014 to 2021, as recorded in EMCIP, are associated with "Human action,". Within the focus area "Human factors," 45.1% of the safety recommendations fall under the subcategory "training, skills, and experience."

To reduce the recurrence of accidents and improve safety, incorporating the study of casualties into the teaching curriculum could be a valuable asset. This would enable every future officer in charge of the watch to detect danger as early as possible and respond appropriately. There is reason to believe that studying casualties and their causes can foster awareness and understanding of the risks involved in vessel operations among future marine officers.

The two main approaches for incorporating maritime catastrophe case studies into maritime training and education programs presented in the article have their advantages and limitations. They have their rationale and deserve further development with the aim of creating several different experimental courses and disciplines and conducting additional research into the feasibility and effectiveness of such training. Within such future research, a comparison can be made between the positive and negative aspects of each approach, while also allowing for a thorough investigation into the most effective methods for planning, executing, and evaluating the different options for implementing this type of training for watch officers, chief mates, and masters.

Furthermore, the ideas presented in the current article can be used as a foundation for the future development of a comprehensive concept, an exhaustive methodology, and detailed documentation for a sample course that integrates various exercises and simulations of maritime accident scenarios on a ship simulator. A source of information related to the subject could be the European Marine Casualty Information Platform, state agencies, and other leading entities in this field. After a thorough review, a proper selection of marine casualty cases could be made, and a simulation developed to realistically recreate scenarios and events during practical exercises on a bridge simulator. This could be implemented as an additional module as part of an extended bridge team and resource management course program.

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