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Proactive Steps Towards Sustainable Shipping: Assessing Maritime Accidents of the Past to Prevent Similar Incidents in the Future

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ABSTRACT

Environmental disasters can maliciously affect the property, human lives and entire ecosystems. The magnitude and extent of such a disaster can lead to uncertainty about the measurement and the extent of liability, and how the restoration of the environmental damage will be achieved. Oil spills from tanker vessels constitute the most severe threat to the local and global ecosystem in the shipping industry. when an oil spill incident emerges, it usually spreads rapidly, leading to massive disasters in the local aquatic ecosystem and human property without prompt treatment. This paper assesses the famous accident of Exxon Valdez: (i) to identify and measure the effect of each contributing factor to the accident, (ii) to determine the best solutions to minimise such risks in the future with the implementation of failure mode effect analysis in conjunction with the doctrinal method and at the same time (iii) to propose a new method of accident assessment by combining the doctrinal method with a variation of a well-known risk assessment method.

1. INTRODUCTION

In 1989, Exxon was the dominating company in the oil market, and the tanker Exxon Valdez was the "pride" of its fleet. On his third year at sea, it was one of its newest and most wellequipped ships, and although it was not fitted with a double hull or double bottom, it was considered a Marpol-qualified tanker, fitted with SBT, COW and IGS. But sadly, on March 24, 1989, when this tanker departed from the port of Valdez, it caused the largest oil spill in American history.

The main issues that led to the accident were, among others: (i) the failure of the master to perform his duties properly due to alcohol addiction, (ii) the inability of the active third mate to control the ship due to fatigue and lack of training, (iii) the failure of Exxon Shipping Co. to manage its ship in the aspect of safety and security and (iv) the lack of preparedness and organisation by the competent stakeholders to contain the oil spill [1].

This paper will assess the accident based on the utilisation of risk assessment methods modified by the author to assess and evaluate the chosen accident effectively. Therefore, the first section will identify the most crucial factors that led to the accident. The second section will determine the most prominent factors that led to the accident, utilising the root cause analysis. The failure mode effect critical analysis will be implemented in the third section to evaluate the impact of each factor based on the separate modifiers and the best solutions to minimise and impact such risks regionally. Finally, the fourth section will assess the environmental impact of the accident and the actions to be taken to eliminate such incidents in the future [2].

2. MATERIALS AND METHODS

This paper starts as an exploratory research study on the famous accident of Exon Valdez. Initially, the background information is assessed, and the most prominent reasons are distinguished based on the relevant sources and case law analysis [1]. It is concluded that many factors led to this accident, and further study must be conducted [3]. Then, the research focuses on analysing each aspect based on legal doctrine to implement a root cause analysis [4].

The root cause analysis, based on the doctrinal method, is the dominant form in legal research, aiming to provide a systematic exposition of the legal and regulatory principles upon the concluding factors that led to the oil spill of Exxon Valdez. Also, this method analyses the relationship between those principles to provide clarifications and valuable insights during the execution of the failure mode effect analysis (FMEA) [5, 6].

The relevant bibliography and legislation are the primary data sources; root cause analysis is used to distinguish and hierarchise the factors that led to the accident, and FMEA is used to evaluate and assess those factors to prevent similar accidents in the future [7]. More information on the root cause analysis and FMEA will be provided in the sections below [8].

The research methodology of this paper can be shown in Figure 1.

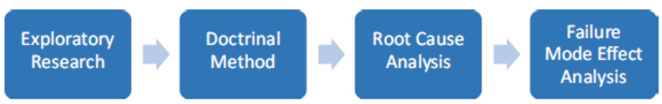

Figure 1. Research methodology

3. THE MOST PROMINENT FACTORS THAT LED TO THE ACCIDENT

The stranding of the "Exxon Valdez", which resulted in the leak of 10.8 million gallons of oil at Prince William Sound, resulted from multiple serious incidents, some of which were caused even by the company's mismanagement.

After the investigation, these issues were, firstly, the irresponsibility of Captain Joseph Hazelwood to perform his duties properly during the critical navigation in the sea area of Prince William Sound. Before the ship departed from the port, he was found to consume alcohol against the regulations of STCW 95 (Section B-VIII/2 Part 5, paragraphs 34-36) and MLC 2006 (Guideline B4.3.1 & B4.3.10). When the ship departed and while under the control of the navigator, the captain had gone to his cabin and returned to the bridge shortly before the navigator left. After the navigator disembarked on the radar screen, ice was shown on the ship's path. Usually, when frost occurs within marine traffic systems, the master can lower the ship's speed to pass the ice or change sea lanes by first receiving approval from the land. In the case of Exxon Valdez, the captain requested permission from the USCG and, after it was approved, instructed the helmsman to change course and enter the opposite sea lane. He then ordered the Lieutenant to turn the ship back to its original course and left the bridge again in violation of STCW 95 rules, leaving an uncertified, as mentioned in the next paragraph, officer alone at a critical navigation point [9].

The captain's decision to leave the ship's bridge was the beginning of the "disaster". The Lieutenant who took control of the vessel turned out to be tired of the consecutive hours of work with just 5-6 h of rest within 24 h. According to the MLC 2006 Convention, rest hours in 24 h must not be less than 10 h. He was also not certified by STCW requirements as an officer on the watch to perform safe navigation duties on the ship's bridge. Therefore, he could not judge when such a large tanker returned to its original course, and its erroneous movements finally led to the ship's stranding on Bligh Reef [10].

It also appeared that the company's manning policy significantly affected crew fatigue. The U.S. Coast Guard had certified a minimum crew number of 15 people, while if a radio operator was not required, 14 people. In addition, the company had manned the Exxon Valdez with 14 crew instead of 24, which was needed based on the vessel's size, to save money, so the ship lacked the necessary amount of trained crew to respond to emergencies appropriately [1].

Finally, it is worth noting that the accident was caused by the ship's crew's wrong response. Still, the magnitude of the spread of the oil spill was not only due to the unskilled and untrained crew but also to the lack of organisation on the part of Alyeska Co, the company responsible for providing clean-up crews and equipment, for the immediate response actions required in case of pollution [9].

4. UTILISATION OF "ROOT CAUSE ANALYSIS"

The root cause analysis method is a way to respond to problems. This method provides guidance to identify possible causes, then collect and analyse the data and ultimately determine the natural causes of the accident. As far as safety is concerned, it is used for accident investigations. The purpose to be used in this report is primarily based on expert analyses, relevant bibliography and ultimately on the outcomes of litigation processes that usually follow the accident.

The previous section mentioned the problems that led to the accident based on Exxon Shipping Co. v. Baker, 2008 Case Law and relevant bibliography. However, to find the natural causes, consideration must be given to how these problems were created, the issue with the company's ship management and the coast guard's response to emergencies [11].

The first problem mentioned above is the captain's consumption of alcohol a few hours before the ship's departure. Hazelwood did not reflect on his actions' impact on his duties' performance because of his alcoholism problem. Exxon was aware of this weakness after also mediating his rehab treatment. Although incidents had been reported before, from testimonies from his associates that he was still drinking quantities of alcohol, the company continued to utilise him on its ships. Therefore, the cause of this problem is the company's wrong decision to re-hire Captain Hazelwood without adequately assessing the implications of that decision [12].

The next thing to consider is crew fatigue. The Lieutenant on the ship's bridge at the time of the accident was tired as he had worked more hours than the law stipulates. The reason is that the company was trying to save money, so it decided to reduce the crew to the minimum. As a result, the 14 people who remained on board worked longer hours and additional responsibilities [1].

Regarding the incidents of violation of the regulations by both the seafarers and the company, namely the absence of the master from the bridge, the extended working hours, and the uncertified and trained crew, are all the results of poor management by the company. Furthermore, the company had not hired a certified crew to ensure that all respect international rules and to undertake the crew's training to respond to emergencies [13].

The late response of Alyeska Co., the company responsible for providing clean-up crews and equipment, contributed to the uncontrolled spread of the oil spill. According to the centre's response plan, the response team, cleaning equipment and boats that would take them to the pollution site should be on standby within 5 h of the call for help. However, there had been a reduction in staff in recent years, and there was no 24-h readiness on the day of the accident. In addition, the aircraft transporting the necessary equipment to limit the spread of pollution was unavailable due to unscheduled repair [10].

Lastly, the confusion over the responsible party for undertaking the pollution clean-up also dramatically delayed the issue's response. By the time the clean-up vessel was finally arriving at Exxon Valdez, it had been 13 critical hours. These delays were due to the lack of organisation to deal with marine pollution from coastal states and the lack of cooperation and communication between ships and land [14].

5. RISK MINIMISATION MEASURES-FMEA (FAILURE MODE EFFECT ANALYSIS)

Failure mode and effect analysis (FMEA) is a qualitative, systematic and very structured technique used to investigate how a system or parts of the system can lead to performance problems [11]. The FMEA identifies possible failure functions, i.e., what is not working correctly, the results of these failures, how to avoid them and even measures to minimise the impact of these failures on the system [15, 16].

In theory, FMEA is a technique that systematically identifies and evaluates the consequences of an individual fault mode. It is usually used as an inductive technique that uses a hypothesis of event development after postulating the failure of a component, part or subsystem. It is usual for the components, parts, or subsystems to be analysed one at a time, thus generally looking at a single-fault condition. Additionally, FMEA is usually enriched with other risk evaluation techniques to incorporate the analysis of the probability of occurrence and detectability of failures and the degree of severity of the consequences [17, 18].

In the Exxon Valdez accident, there was severe mismanagement from the company regarding their crews in terms of ship safety, cargo handling and the response to environmental threats and finally, the lack of an organised response to reduce pollution from the Alyeska Company, charged for clean-up operation in the area [14].

These failures resulted in 10.8 million gallons of oil at sea, which contaminated 2,100 km of coastline, killing thousands of birds and marine beings and causing substantial economic disasters in the broader region [19].

Therefore, considering all the above measures that should have been taken to minimise the risk are:

1. Compliance with STCW regulations on the prohibition of alcohol consumption by the crew during safety tasks.
2. Compliance with STCW regulations on the certification and training of safety officers for the safe navigation of the ship and their duties in an emergency.
3. Compliance with MLC 2006 regulations on the crew working and rest hours.
4. Creation of emergency response plans, both by the shipping companies and the coastal states, so that they are ready to respond in a timely and organised manner to combat and minimise the risk.

The analysis below will include a risk assessment matrix for each separate factor, distinguishing each contributing factor of the accident and assessing them based on their severity (S), probability of occurrence (O) and the possibility of detection (D). The evaluation of each factor will be numerical, and a risk priority number (RPN) will signify the magnitude of each separate factor. This study aims to minimise the risks assessed; thus, recommended actions will be proposed, stating the obligatory party and the review requirements, thus providing new results of Risk Priority Numbers with the execution of the said corrective actions [8]. The calculation method is based on the rating each separate factor will receive and then multiplied by each other to provide an outcome. All ratings are calculated on a scale of one up to five, whereas the higher the rating, the higher the severity or the chance of an event occurrence. For detection rating, the higher the score, the lower the probability of detection. After calculating the rating, pursuant to root cause analysis and all relevant information from primary sources (such as the ruling of the appropriate case), each score is multiplied. From the outcome, a risk category number (RPN) is provided. Should the result of S × O × D range from 91 up to the maximum of 125, the assessed factor poses a significant threat or should be considered the primal reason for a hypothetical accident; the responsible stakeholder should immediately plan a response or should have located the danger sooner. If the outcome of multiplying the above rating scales is from 90 to 61, the responsible parties should schedule a response within a year of the emerging factor. Subsequently, if the RPN is on a scale of 60 to 20, the competent party should only monitor the event-in-assessment and impose proactive measures for the RPN to decrease progressively. Lastly, if the RPN is below 20, there is no reason for the responsible party to take any effort or further action. The most essential and evidently difficult part of the method mentioned above is the calculation of the rating of each factor. The root cause analysis, which also relies on previous cases assessed by experts, is a reliable method mainly when applied realistically and the provided data are valid. For more information regarding the ratings of each factor, see Table 1 [20].

Table 1. FM EA ratings

S=Severity rating	O=Occurrence rating (frequency)	D=Detection rating (adequacy of present controls)	RPN=Risk category number
5. High severity	5. Very high chance of occurrence	5. Very low chance the control will detect a potential cause/mechanism and subsequent failure mode	125-91: High-Planned response within one month 90-61: Medium-Planned response within twelve months 60-20: Low-Monitor only 20 >: Very low-No action required
4. Moderate severity	4. Moderate chance of occurrence	4. Low chance the control will detect a potential cause/mechanism and subsequent failure mode	
3. Low severity	3. Low chance of occurrence	3. Moderately high chance the control will detect a potential cause/mechanism and subsequent failure mode	
2. Severity is almost non-existent	2. Very remote chance of occurrence	2. High chance the control will detect a potential cause/mechanism and subsequent failure mode	
1. No severity exists	1. No chance of occurrence	1. Control will almost certainly detect the chance the control will detect a potential cause/mechanism and subsequent failure mode	

From the court proceedings and the overall assessment of the case, the alcoholism of the captain was considered the most critical reason that effectively caused the accident. Due to his condition, the captain was practically absent during the event, leaving an exhausted and inexperienced third mate in his stead. The absence of the captain when a vessel has to execute dangerous manoeuvres significantly increases the likelihood of an accident [21]. In practice, the role of the captain is to perform or coordinate the execution of the most challenging operations, where the more inexperienced shipmates are not able. Also, alcoholism is prohibited from the STCW regulations, especially when the responsible crew is executing his role. In the assessed case, the alcohol rendered the captain unfit for service and made him be away during the event [11, 22].

The most worrying fact of this incident is that it became evident that the company was aware of the captain's issues with alcoholism; nevertheless, they re-hired him in violation of international regulations, thus conducting gross negligence and setting the ground for one of the most notorious disasters in maritime history. Should the company have been more diligent and made the necessary controls at the start of the accident, this catastrophe probably should not have occurred [23]. As for the calculation for each rating, all scores are set to the highest rating, as this factor has been considered the primary source of the accident. Therefore, the outcome for multiplying each rating is 125, meaning that the company should have substituted the captain even before the start of the voyage. In this case, should the captain have been replaced, the new RPN would be 4, meaning that no action is required [12]. For more information, see Table 2.

Table 2. 1st factor: Captain's alcoholism

Incident	The captain has suffered from alcoholism	New result*
Potential failure mode	Loss of life, property and environmental pollution	
The possible effect of ailure	Likelihood of accident. The captain was not present during the accident.	
Severity rating	5	1
Potential causes of failure	with STCW regulations on the prohibition of alcohol consumption by the crew during safety tasks.	
Occurrence rating	5	2
Current process controls	Captain unfit for service, away during the occurrence of the event	
Detection rating	5	2
RPN=Risk category percentage	125-High risk	4-Risk Acceptable
Recommended actions	The company was aware of the captain's problem. Thus, the relevant STCW processes should have been implemented, and the captain should have been unfit for service and substituted with other personnel.	No further Action
Responsibility and completion date	General manager, safety officer, crew manager	
Reviewed by and date	At the start and during each voyage	

Undoubtedly the captain's issue with alcoholism is the most critical factor for the occurrence of this accident. Nevertheless, the ship, absent the captain, was operated by the third mate during the event. The assessment of the case proved that the third mate was affected by three aggravating factors during the event. Firstly, the third mate was inexperienced in operating those demanding man oeuvres, and the captain himself should have guided him; thus, the vessel's operation under those challenging circumstances was solely due to the above assessed factor, namely the absence of the captain due to alcoholism. Secondly, the third mate was found to lack proper training, absent relevant certificates and training processes to be charged to lead such a vessel. For the training of the crew, the sole responsible is of the shipping company managing the ship, with all the relevant international legislation considering the training to be of paramount importance [24].

Last but not least, the third mate was found fatigued during the event because the vessel was under the minimum required number of crew to be operated safely. The lesser the crew is from the set as the minimum number, the more hours they work and the fewer hours they have for rest. This was the exact case with Exxon Valdez, where the third mate was alone and fatigued during the crucial moments from extensive shifts and mounting tiredness [1, 25].

When calculating each rate of this factor, the severity and occurrence are set to the highest. In contrast, the detection is set to 4 since each ship member possesses certificates of competence. While this factor is essential, the captain's presence during this event should have been enough to avoid the accident. For example, should the captain have been present and in proper condition, he would have noticed the tiredness of the third mate, and he would have asked for a substitute or discharged the fatigued shipmate and executed the ship's operation himself [26]. Likewise, should the crew have been experienced and in a good state, the accident would not have likely occurred. Still, the presence of experienced personnel is the crucial factor that practically eliminates the chances of such an accident and any possible inexperience and fatigue of the crew, while in some cases not evident enough, should be easily noticed by the master of a ship [9, 27]. For more information, see Table 3.

Table 3. 2nd factor: Defective crew management

Incident	Crew Service-The third mate in service lacked proper training and was unfit for service (fatigued)	New result*
Potential failure mode	Loss of life, property and environmental pollution	
The possible effect of failure	Likelihood of accident	
Severity rating	5	2
Potential causes of failure	Improper crew management and awareness of responsibilities by the company and the shipmaster.	
Occurrence rating	5	2
Current process controls	Crew unfit for service and unaware of action in case of force majeure	
Detection rating	4	2
RPN=Risk category percentage	100-High risk	8-Risk acceptable
Recommended actions	Better training and awareness of crew responsibilities, safety processes and company actions to avoid similar cases in the future. Stricter company policies in case of master/officers/crew noncompliance with company QMS.	No further action
Responsibility and completion date	General Manager, Safety Officer, Crew Manager	
Reviewed by and date	Daily	

Table 4. 3rd factor: Defective crew training

Incident	Crew training and experience	New result*
Potential failure mode	Loss of life, property and environmental pollution	
The possible effect of failure	Decreased crew productivity, leading to near-miss accidents to ecological hazards.	
Severity rating	5	2
Potential causes of failure	Lack of experience and proper training	
Occurrence rating	4	3
Current process controls	Crew members are unaware of their responsibilities and basic safety processes.	
Detection rating	4	2
RPN=Risk category percentage	80-High risk	12-Risk acceptable
Recommended actions	1. Proper and adequate crew training from certified training centres and experienced staff. 2. Regular training through seminars and information programs. 3. Constant on-board training and crew awareness under QMS Company Manual.	No further action
Responsibility and completion date	1. Crew training from certified training centres. 2. Constant training of the company's fleet and company executives while on board or even before embarking.	
Reviewed by and date	Weekly	

The third mate's state during the accident is only a sample of the state of all crew during the event. It has been proved that the human element is the principal reason behind almost all disasters [28]. Thus, all international organisations have recognised the importance of training to avoid or minimise the impact of accidents. The constant training of the crew, especially when the cargo poses such a threat to the environment, should be strict and continuous, abiding by all international legislation [29]. The cost increase for the constant and qualitative training of the crew is minimal, considering the costs of such a catastrophe. In the assessed case, it was proved that not only the third mate, but all crew was inexperienced and untrained, lacking a master's firm discipline. While this factor is not the primary source of an accident, it always indirectly affects the occurrence of an event and the aftermath when the crew tries to counter the threat, minimise the damage or even save itself. In most accidents, the crew lacks proper training and practical experience to respond efficiently to such cases [30].

By calculating each rating, the severity rating is at the highest because the crew's inexperience and lack of training are considered the primary source of accidents in most cases. The other rating is set to 4 due to being less important than the factors mentioned above, providing an RPN of 80. The crew training should be constant, with strict operational controls and firm actions by the master and the company to keep the occurrence of an accident to a minimum. For more information, see Table 4.

The proper manning of the vessel is equally essential, as is the crew training. For example, during the accident of Exxon Valdez, the third mate, while inexperienced and poorly trained, was deemed unfit for service due to fatigue. The MLC and STCW regulations regarding the crew's work/rest ratio are stringent. To protect this balance, they have established minimum manning standards based on each vessel's type, size and operational needs [27, 31].

When these standards are not kept, the crew must work more hours, and the work/rest ratio is violated. In the assessed case, the vessel was understaffed; thus, the third mate was fatigued during the accident due to extended service hours. It has been proved that, as the human element is principally responsible for most shipping accidents, crew fatigue is one of the leading causes of accidents; as the present research has shown, due to COVID-19, the crew on board remained active for extended periods. This extension of service for the active personnel on board resulted in a rise in maritime accidents [32, 33].

It should be stated that rarely is a ship understaffed due to extenuating circumstances, such as COVID-19. Usually, the managing company violates the minimum number of on-board personnel requirements to cut expenses and minimise the operational costs of a voyage [34]. This practice was common until the managing companies realised that the cost of a shipping accident is substantially more than the benefits for crew decreases. To this end, international legislation, along with marine insurance and P&I Clubs, is critical in establishing the concept of due diligence not to be deemed liable and be partially excluded from liability [35]. Thus, the violation of the minimum crewing standards is considered severe, resulting in the managing company abolishing marine insurance and P&I cover and any chance of liability limitation [36].

In our case, by calculating each rating of this factor, the RPN is set to 64. While 64 needs attention, it is nearly as crucial as the crew training. The utilisation of timely and effective crew changes undoubtedly positively impacts crew performance and significantly reduces the chances of maritime accidents [37]. For more information, see Table 5.

From the above analysis, there should be some clarifications. First, while the severity and occurrence ratings are pretty objective, based on similar incidents and common sense, the detectability rating is subjective. It is an outcome of the efficient and effective management executed by the master and the shipping company. In our case, while some factors were practically easy to be spotted, such as the inexistence of adequate documentation proving the training of the crew, the ratings were high, taking into consideration the captain's failure to exercise his role and responsibilities, one of which being the constant evaluation of the state of the crew. In addition, even the captain's incompetence resulted from the company's practice of manning its vessels poorly trained and unfit for service personnel, possibly cutting operating expenses [38].

Also, the factors chosen for assessment were all crucial for avoiding the accident. However, while important, the depreciation of the accident's impact cannot be effectively calculated. To this end, the late response of Alyeska Co. was not evaluated despite its importance to promptly and effectively minimise the damage from the accident. The only safe result is that Alyeska Co. delayed more than it should have, further increasing the overall damage and impact of the accident on the local environment [9].

Table 5. 4th factor: Insufficient vessel manning

Incident	Manning of ship (required number of seafarers on board, fit for action)	New result*
Potential failure mode	Loss of life, property and environmental pollution	
The possible effect of failure	Improper ship operation and untimely execution of required tasks	
Severity rating	4	1
Potential causes of failure	Decrease in company expenses	
Occurrence rating	4	2
Current process controls	1. Lack of crew 2. Failure of the company to comply with the MLC 2006 & STCW rules 3. Failure in risk assessment	
Detection rating	4	2
RPN=Risk category percentage	64-High risk	4-Risk acceptable
Recommended actions	Good crew manning, constant officer and company control if each crew member is fit for service.	No further action
Responsibility and completion date	General manager, crew dept., captain and officers on-board	
Reviewed by and date	At the start and during each voyage	

6. ENVIRONMENTAL IMPACT OF THE ACCIDENT: AIMS THAT SHOULD BE ACHIEVED

An ecosystem consists of plants, animals and other organisms interacting with each other and their environment, such as water. When everything is in balance, ecosystems are self-sufficient. Ecosystems generally change slowly over time, but a disaster can change an ecosystem. That is the case with the Exxon Valdez accident on Prince William Sound [9].

The Exxon Valdez oil spill's environmental impact has been devastating. It was estimated that 250,000 seabirds, nearly 4,000 marine otters, 300 sea seals, 250 bald eagles, more than 20 Orca whales, and billions of salmon and herring eggs were killed. The result of these effects was also the economic destruction of the region, as the losses of local fishing reached $286.8 million [19].

To eliminate such accidents, appropriate milestones should be set. Every ship-handling company must harmonise its policy based on the ISM Safe Management Code and the newly developed TMSA, the new ISGOTT principles and vetting inspections. These objectives should provide safe practices for the operation of vessels and a safe working environment. Also, all recognised risks should be assessed regarding the ship, human life and the environment and establish safety measures. Furthermore, it is essential to continuously improve the skills of both land and ship personnel to enhance operational efficiency, effectiveness and safety awareness [10].

Also, based on SOLAS regulations and, by extension, STCW and MARPOL, it is mandatory to conduct training drills on-board ships to prepare the crew in emergencies. Additionally, it is evident that guidebooks, such as the International Safety Guide for Oil Tankers and Terminals (ISGOTT), are crucial for developing safety measures. Their outcomes and suggestions are based on similar risk assessment techniques [39, 40].

7. CONCLUSION

Nowadays, where 11 billion barrels of oil are consumed daily, oil spills have become familiar. Environmentalists worldwide are trying to reduce their dependence on oil, but scientists have identified at least 500,000 different oil uses and derivatives. While the utilisation of new energy sources is rapidly evolving, oil dependency will continue to exist for humanity for many more years.

After the Exxon Valdez disaster, governments and businesses realised how poorly prepared they were to deal with such a tanker disaster. As a result, in 1990, the Oil Pollution Act 1990, passed by Congress, was revised with a more robust set of regulations to prevent and deal with oil spills. Additionally, Conventions such as CLC and Bunker Convention were initiated, guidelines such as the International Safety Guide for Oil Tankers and Terminals (ISGOTT) were drafted, and Associations, such as P&I Clubs, became more aware and involved actively in the prevention and enhancement of safety measures and other pro-active and reactive policies.

Unfortunately, history shows that a severe disaster must establish and implement rules and practices to protect human life, the environment and property. A very efficient method has been developed in the study of previous incidents to find the root of the cause and utilise measures to prevent those incidents from happening in the future through implementing risk assessment methods. In this paper, we used the root cause analysis and FMEA to assess the most prominent factors that led to the accident, evaluate their effectiveness in the outcome and propose measures to avoid similar incidents. The primary outcome was that the accident resulted from the company's mismanagement, establishing firm management on board, properly managing the ship and adequately training the crew on-board. The company's gross negligence is purely economic, namely, to minimise the operating expenses of the journey. It has been proved that such mismanagement usually has adverse outcomes in the long run because the likelihood of an accident is increased, and the more the ship is operated, the more the chances that a severe accident will emerge.

It has been 30 years since that fateful night in Prince William Sound, and its ecosystem has not recovered yet. A recent example is the oil spill caused by the oil extraction platform Deep Horizon explosion in 2010. In this case, the company's mismanagement played a significant role in the cause of the accident again. It is evident that the environmental disaster of "Exxon Valdez" has not become a lesson yet. Still, many steps have been taken to avoid and minimise damage from similar incidents.

DECLARATIONS

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•Conflicts of interest: The authors declare there is no conflict of interest regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and falsification, double publication and submission, and redundancies, have been ultimately observed by the authors.

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