Limiting Ship Accidents by Identifying Their Causes and Determining Barriers to Application of Preventive Measures

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Abstract: When analyzing ship accidents, there may be doubts whether appropriate countermeasures had been taken to prevent known types of accidents. This study aimed to suggest possible solutions by investigating the status and issues associated with the implementation of countermeasures using importance–performance analysis (IPA), Borich’s needs assessment, and locus for focus models based on previously identified causes of the ship accidents. As a result, firstly, we confirmed that there is a need to enhance education and training on specific knowledge, understanding, and proficiency (KUP) regarding ship stability, emergency response, and type specific training. Secondly, we confirmed that there is a need for a system of monitoring a seafarer’s KUP even while onboard a vessel—that is, after completion of identified training. Additionally, it is necessary to improve the seafarers’ working environment, which is subject to regulations. Thirdly, difficulties in solving wrong practice parts of safety and efficiency, such as the costs associated with implementation of safety regulations, were identified as the main reasons for the causes of the “not amended yet” sector after accidents. Lastly, the tools that were employed in this analysis can be used to confirm the implementation status of the actions to be taken after a ship accident.

Keywords: maritime accidents analysis; maritime accidents; Borich’s need assessment model; importance-performance analysis model; locus for focus model; Costa Concordia; Sewol ferry

1. Introduction

There is significant interest in understanding the technical causes of ship accidents, as well as understanding the human factors that can cause them. In addition, the approach to studying these causes was recently expanded to address the issues related to seafarers’ fatigue and hours of rest, and efforts have been made to solve these underlying causes [1,2]. Although a variety of methods to determine the causality of accidents have been developed and discussed, ship accidents with previously identified causes have continued to occur. Such incidents lead us to question whether the identified known causes of ship accidents are properly reflected and addressed by the maritime industry. In addition, the amendment of International Maritime Organization (IMO) conventions and practical application of relevant laws in their respective countries need to be considered based on the identified ship accident causes. More than 100 years after the Titanic disaster, the accident involving Costa Concordia, a ship with state-of-art navigation and safety equipment that satisfied all requirements of various IMO conventions, has further intensified this question [3]. Therefore, investigating how the countermeasures to address the identified causes of ship accidents have been implemented is as crucial as analyzing the causes of ship accidents themselves [3].

In the past, certain ship accidents have indeed led to the development of new IMO conventions. The Titanic and the Herald of Free Enterprise accidents both resulted in several casualties, which led to the introduction of new IMO conventions, including Safety of Life at Sea (SOLAS) 1978 and the International Safety Management (ISM) Code,
respectively [1]. There are studies that argue that these IMO conventions have played a role in preventing accidents to a certain degree [4–6]. Nevertheless, there have been limited efforts by researchers on the reasons why similar ship accidents continue to occur.

In this study, we suggest possible solutions to this problem by investigating the status and problems related to the implementation of countermeasures using importance-performance analysis (IPA), Borich’s needs assessment, and locus for focus models based on identified causes of ship accidents. This study considered the Costa Concordia and Sewol ferry ship accident cases as these represent accidents from the last 10 years that are similar in terms of their operational perspective to the Titanic and the Herald of Free Enterprise accidents. Although the size of the ships and technical aspects are different, Costa Concordia was a state-of-art passenger ship similar to the Titanic at its time, and the Sewol ferry was a RO-RO passenger ship with an operation type similar to that of the Herald of Free Enterprise. Moreover, these two accident cases received significant public attention and various studies have been conducted to identify the cause of the accidents.

The paper comprises of six sections. Following the introduction, in Section 2, we discuss the reasons why some of countermeasures are not properly implemented by conducting a literature review. In Section 3, we present and summarize the identified causes from the previous studies on the Costa Concordia and Sewol ferry accidents. Additionally, we explain the questionnaire developed for a survey of experts. In Section 4, IPA, Borich’s needs assessment, and locus for focus models are applied to the Costa Concordia and Sewol ferry accidents based on the questionnaire survey data, and the causes of ship accidents with high importance and low performance are identified. In Section 5, the meaning of the analysis’ results in Section 4 and limitations of this study are discussed. Finally, conclusions are drawn in Section 6.

2. Literature Review

In the past, the causes of ship accidents were mainly investigated and addressed from a technical perspective. Accordingly, the related IMO conventions focused on the improvement of the technical side. The SOLAS 1978 Convention, enacted in response to the Titanic accident, is the most typical example of such an improvement on the technical side [7]. In addition, the Torrey Canyon accident in 1967 led to the birth of important international conventions, such as the International Convention on Civil Liability for Oil Pollution Damage (1969), the International Convention for the Prevention of Pollution from Ships (MARPOL, 1969), and the International Convention on Standards of Training, Certification, and Watchkeeping for Seafarers (STCW, 1978) [8]. In particular, a significant technical improvement from the MARPOL 1978 Convention was the application of double hulls for tanker ships, which was introduced after the Exxon Valdez accident (1989). The introduction of double hulls proved crucial in reducing oil spills from tanker ships, which reduced by 20–62% on average [5,9]. After the technical amendments made to the IMO conventions, the focus shifted to identifying and addressing human factors-based causes of ship accidents [10]. For example, the ISM code was applied to reduce ship accidents that arose from human factors, and a few studies have been conducted to prove its effectiveness [4,11]. Simultaneously, electronic chart display and information systems (ECDIS) were installed according to SOLAS 1978, Chapter 5 to analyze the technical and human factors. Further, a study revealed that the officers’ awareness toward improving a given situation is instrumental in reducing ship accidents [12].

However, despite the above measures, there have been cases where the amendments and application of IMO conventions were not implemented or there were certain difficulties in their implementation. In certain cases, even though they were applied, they did not function according to their intended purpose. In relation to this, Knudsen and Hassler (2011) argued that the IMO had a weak connection with the administrations of the member states [13]. This resulted in differences in implementation of the IMO conventions between states. On the other hand, new regulations negatively influenced the existing regulations, which were also influenced by the mutual interests of various parties, including the ship
owners, seafarers, shippers, and governments. Viertola and Storgård (2013), Karahalios et al. (2011), and Dewan et al. (2018) referred to the cost burden of implementation as one of the obstacles to the amendment of IMO conventions or national laws [14–16]. In particular, Setyohadi et al. (2018) identified that changes in the IMO regulations for tanker owners put a significant economic burden on the operation of their tanker fleets [17]. Bhattacharya (2012) argued that the birth of the ISM code itself helped in terms of the safe operation of ships [18]. However, because the crew did not participate directly in the management system for the application of the ISM code as a result of the vulnerable employment form and a lack of trust in the managers, it was applied differently from the original intention. In order to overcome these issues, Akyuz and Celik (2014) presented a study that can help apply the ISM code more effectively by improving the conventional system and developing a tool to effectively measure the application of the ship safety management system (SMS) [19]. Tunidau and Thai (2010) also pointed out that the negative safety culture on ships, the absence of seafarers’ participation in the safety system development, and a lack of competence of flag states had a negative influence on the implementation of the IMO conventions [20]. In particular, research on the safety culture and safety management of tankers confirmed that there were significant differences in safety culture and SMS depending on the ship owner, the seafarers’ nationality, and the flag states. Knudsen and Hassler [13] maintained that the new IMO regulations acted negatively on the existing regulations. Because ship accidents put political pressure on member states, the IMO regulations were applied separately in each of the countries, resulting in differences in implementing them [13]. In addition, Eliopoulou et al. (2016) confirmed that despite the implementation of the various new IMO regulations, accidents for certain types of ships did not decrease significantly [21]. Psarras et al. (2010) argued that there were cases where it was not possible to develop appropriate regulations because the analysis of the ship accidents was not properly performed [22]. Eliopoulou et al. (2016) maintained that based on their analysis of the results of recent ship accidents, there is need to intensify training for seafarers, familiarize them with new technologies, and train them on emergency management skills [21]. However, it is difficult to verify the implementation of these findings.

There have been many studies that have analyzed the causes of the Costa Concordia (2012) and the Sewol ferry (2014) accident cases. Schröder-Hinrichs et al. (2012), Di Lieto (2012), Giustiniano et al. (2016), Vidan et al. (2013), Broussole et al. (2014), Brazier (2012), Dickerson (2013), Hasegawa and Awal (2013), and Alexander (2012) analyzed and presented the causes of the Costa Concordia accident by using various ship accident analysis tools [3,23–30]. An accident investigation report published by the Ministry of Infrastructures and Transports of Italy (MIT) (2012), along with the various causes of the Costa Concordia accident, confirmed that the ship manager’s unusual behavior and improper emergency response were considered to be critical factors that led to the accident [31]. As for the Sewol ferry case, Lee et al. (2017) analyzed the accident from multiple perspectives, including the government, relevant laws, shipping inspection agencies, shipping companies, technology, and operational management. This analysis was achieved by applying the Accimap methodology [32]. In addition, by performing the systems-theoretic accident model and processes-based causal analysis, Kim et al. (2016) suggested improvements to the safety system, the traffic safety information system to support decision-making, improvements to ship safety design, instructions that put the safety of ships and passengers first, and the provision of appropriate training [33]. Upon identifying a total of 23 accident causes related to the Sewol ferry by applying several accident analysis techniques, Kim et al. suggested several measures, such as identification of organizational barriers, improving the information flow, establishing independent watchdogs, and encouraging accident mindfulness in the organizations [34]. In summary, the causes of the Costa Concordia and Sewol ferry accidents have been analyzed in a variety of ways, and various countermeasures have been suggested, including amendments to the IMO conventions and to the relevant laws.
of the respective countries. However, the implementation status of these findings in actual practice has not been verified.

3. Materials and Methods

3.1. Procedure and Methods Overview

This study collected identified accident causes of the Costa Concordia and Sewol ferry accidents by examining previous accident studies, reports, and IMO documents. Then, we analyzed whether the countermeasures against identified ship accident causes were taken or not taken through analysis of amendments made to IMO conventions and the relevant national laws. A questionnaire was developed based on collected ship accident causes, and experts were surveyed to confirm the importance and performance of the identified causes. These were analyzed by using the IPA [35], Borich’s needs assessment [36], and the locus for focus models [37], which have been mainly applied in the field of education to identify changes in the education system and perform education demand analyses [38,39]. Through these data, the importance level of each identified cause was confirmed, and the causes for why the countermeasures had not been taken were analyzed. Based on this, possible solutions based on expert suggestions were proposed. The procedure and method of the study are shown in Figure 1.

The outcomes of this study included identification of the implementation status of countermeasures for identified causes of chosen ship accident cases and determination of insufficient countermeasures along with their prioritization.

![Figure 1. Procedure and methods performed in this study. IPA, importance-performance analysis.](image)

3.2. Analysis of Causes of Costa Concordia and Sewol Ferry Accidents

3.2.1. Analysis of Causes of Costa Concordia Accident

To identify the causes of the Costa Concordia accident, we collected and analyzed articles, the official accident report (MIT), and the IMO documents that were produced after the accident [3,23–31,40]. Table 1 includes a summary of identified causes other than the long-term action plan issued by the IMO. In total, 30 causes were classified after excluding duplicates. Of these, 22 causes of the accident already had countermeasures prescribed in international conventions, which were subsequently amended or recommended after the accidents, as shown in Table 1. In addition, two countermeasures (i.e., causes 23–24) were added to the relevant conventions after the accident; six have been identified as causes for which amendments of IMO regulations were not made (i.e., causes 1–6 from the
“not yet amended” section in Table 1). Most of the identified causes that were related to the SOLAS 1978 convention already existed or have been amended and added after the accident. However, the four causes that have not been amended yet are 1 [23], 2 [23], 3 [31], and 4 [31] of the “not yet amended” section in Table 1.

### Table 1. Causes of the Costa Concordia accident and their implementation status.

| Implementation Status of Identified Causes | Identified Causes of Costa Concordia Accident | Related International Convention and Code |
|-------------------------------------------|----------------------------------------------|------------------------------------------|
| Already existed and then amended or recommended | 1. Persons on board who were assigned to safety duties lacked skills and procedures. | International Convention for the Safety of Life at Sea (SOLAS 1978) |
|  | 2. The consequent loss of production and distribution of electric system. | International Convention for the Safety of Life at Sea (SOLAS 1978) |
|  | 3. Once production of electrical power was lost, the inability to have the pumps exhaust large quantities of water, and it takes up the free water surfaces. | International Convention for the Safety of Life at Sea (SOLAS 1978) |
|  | 4. Using inappropriate cartography, including electronic chart display and information systems (ECDIS), radar, and paper chart. | International Convention on Standards of Training, Certification, and Watchkeeping for Seafarers, 1978 (STCW 1978) |
|  | 5. The distraction of the Master by people in the hotel business department. | |
|  | 6. The orders of the Master to the helmsman given by assigning the bow to follow, rather than ordering the rudder angle. | |
|  | 7. Shifting from a perpendicular to a parallel course extremely close to the coast. | |
|  | 8. Instead of choosing the most extreme landmark as reference point for turning, the ship proceeded toward the inner coastline. | International Convention on Standards of Training, Certification, and Watchkeeping for Seafarers, 1978 (STCW 1978) |
|  | 9. Keeping a high speed (16kts) in night conditions too close to the shoreline. | |
|  | 10. Bridge Team, although more than suitable in terms of number of crewmembers, did not pay required attention. | |
|  | 11. Handover between the Master and the Chief Mate did not occur properly. | |
|  | 12. Overall passive attitude of the bridge staff. | |
|  | 13. The captain probably relied more on his visual perception than on integrated navigation system (INS) information, and initially altered course with a too small rudder angle. | |
|  | 14. The alteration of course was not officially approved by the operating company. | |
|  | 15. Cancelling automated alarms. | International Convention for the Safety of Life at Sea (SOLAS 1978) |
| Implementation Status of Identified Causes | Identified Causes of Costa Concordia Accident | Related International Convention and Code |
|-----------------------------------------|---------------------------------------------|------------------------------------------|
| 16. Tendency to underestimate the effect of navigational risk-taking by the Captain and senior officers. |  |  |
| 17. Captain’s failure to command operations, and premature abandonment of the ship. |  |  |
| 18. Cognitive hysteresis or psychological fixation. |  |  |
| 19. Trust in technology may have affected the attitude of the navigators of such ships. | International Convention on Standards of Training, Certification, and Watchkeeping for Seafarers, 1978 (STCW 1978) |  |
| 20. Demonstration of outstanding skills in manual ship handling might have been the cultural driver shaping a chronic, risk taking performance style. |  |  |
| 21. Not promptly declaring the general emergency, despite its occurrence. | International Convention for the Safety of Life at Sea (SOLAS 1978) |  |
| 22. Inadequate risk management, company policies, monitoring, and enforcement about “salutes” (navigation close to island). | International Safety Management Code (ISM code) |  |
| Added after accident |  |  |
| 23. The SOLAS 1978 rules referable to Concordia do not establish that the ship was equipped with an automated system of water detection in the free compartments, and, consequently, a computerized failure control system by direct information was necessary to calculate the residual dynamic stability. | International Convention for the Safety of Life at Sea (SOLAS 1978) |  |
| 24. Failure to conduct a drill with passengers before departure. |  |  |
| Not yet amended |  |  |
| 1. Once defined, the guard sector was not displayed on the screen (making it difficult for operators to remember its parameters). | International Convention for the Safety of Life at Sea (SOLAS 1978) |  |
| 2. The clarity of electronic vector charts on navigational display. In the worst cases, important features became unreadable. |  |  |
| 3. Bridge (fully enclosed by glass windows) did not allow physical verification of outside environment or a clear look during nighttime. |  |  |
| 4. Limited availability of emergency lines in case of failure for flooding and direct consequences on management of residual dynamic stability (absolute absence of redundancy in the production of emergency power; lack of lines available in emergency). |  |  |
| 5. Lack of type specific training. | International Convention on Standards of Training, Certification, and Watchkeeping for Seafarers, 1978 (STCW 1978) |  |
| 6. Efficiency–thoroughness trade-off: Making these efficiency and thoroughness trade-offs is essential for the efficacy of overall performance but can also lead to accidents. | International Safety Management Code (ISM code) |  |

There is a possibility that the international conventions were not amended for these causes because they might either be considered not to be the root causes of the accident or to lead to an additional financial burden for their implementation [14–16,22]. In particular,
cause 4 in the “not yet amended” section in Table 1 is a crucial factor increasing the scale of an accident. It was confirmed that a detailed amendment of the related IMO regulations was not made, although this cause might be relatively significant [31].

Preventive regulations for most of the causes of the accidents that are related to the STCW 1978 convention already existed. In particular, a number of causes related to bridge resource management (BRM) were identified [3,23,30,31]. It was confirmed in the accident analysis that not all of the bridge crew for the Costa Concordia had completed BRM training at that time, which may be one of the causes for the accident [31]. Apart from this, the tendency to neglect situation awareness and management of risks in the bridge was revealed as another reason [3,23,30,31]. The presence of people working in the hotel business department of the ship rather than the bridge members might have also had an influence on the accident [31]. In addition, incorrect plans and guidelines as well as a lack of response from the crew during the emergency were cited as causes of the accident [30,31].

In relation to this, the Cruise Lines International Association (CLIA) had established operational safety guidelines related to bridge access. This helps the bridge crew respond appropriately in case of an emergency without any external influence [41]. Although these regulations already existed, additional supplementary and amendment procedures were put in place at CLIA and IMO as a result of the Costa Concordia accident [42–46]. Failure to fully utilize navigational devices, such as the integrated navigation system (INS), was also cited as one of the causes of the accident. It was indicated that the deck officer had not been trained for the use of certain navigation devices [23]. Currently, companies are responsible for this function in accordance with STCW 1978, as amended (Regulation 1/14). However, we were not able to confirm whether or not it has been properly implemented for each navigation device.

In relation to the ISM code, the “salute” was found to be one of the direct causes for the grounding of Costa Concordia. The cruise operator tacitly condoned it because it helped publicize their activities; they used it in advertisements. This caused the deck officer to ignore the primary importance of safety [3,30]. The intent to prevent this was clearly stated in the ISM code; however, it is highly likely to have been ignored because of the emphasis on economic benefits. Therefore, the fundamental issue still remains that the efficiency–thoroughness trade-off of the ship operation for the six items in the “not yet amended” section shown in Table 1 should be discussed in further detail at the organizational level [3]. Unaddressed, this issue increases the likelihood that seafarers will behave in a way that poses a threat to safety when under pressure, in which they must choose efficiency.

Since the Costa Concordia accident, the IMO has established a long-term action plan based on the analysis of the causes of the accident. Table 2 shows the classification of improvement requirements in the long-term action plan, which was discussed by the 90th–96th sessions of the IMO Maritime Safety Committee (MSC) [40].
| Implementation Status of Analyzed causes | Description of IMO’s Long-Term Action Plan Outputs | Related International Convention and Code |
|-----------------------------------------|-----------------------------------------------|------------------------------------------|
| Already existed and then amended or recommended | 1. Review and update arrangements for discontinuity between compartments containing ship’s essential systems (such as propulsion sets or main generators sets) in order to preserve their functional integrity for new ships. | |
| | 2. Review of the criteria for the distribution and capacity of bilge pumps, along the length passenger ships, for new ship. | |
| | 3. Amendment to SOLAS 1978 regulation II-1/21 and associated technical guidelines on watertight doors maintenance. | International Convention for the Safety of Life at Sea (SOLAS 1978) |
| | 4. Development of guidelines for comprehensive risk assessment, passage planning, and position monitoring; effective bridge resource management; and removal of distractions. | |
| | 5. Review of conditions under which passenger ship watertight doors may be opened during navigation and prepare amendments to SOLAS 1978 regulation II-1/22 and MSC.1/Circ.1380. | |
| | 6. Revision of SOLAS 1978 Chapter II-1 subdivision and related damage stability regulations:  
  • Limit the down flooding points (the lower edge of any opening through which progressive flooding may take place) on the bulkhead deck for new passenger ships.  
  • Double hull in way of main engine-rooms. | |
| | 7. Revision of Section 3 on damage control plans of the guidelines for damage control plans and information to the master (MSC.1/Circ.1245) to include enhancements to the damage control plan for passenger ships. | |
| | 8. Review of evacuation analysis of SOLAS 1978 Chapter II-1/regulation 13, subparagraphs 3.2, 7.1, 7.2 and 7.4. | |
| Added after accident | 9. Development of onboard damage stability system. | International Convention for the Safety of Life at Sea (SOLAS 1978) |
| | 10. Consideration of the inclusion of inclinometer measurements within all Voyage Data Recorders (VDRs). | |
| | 11. Amendments to SOLAS 1978 Chapter II-1, part B-4, Stability Management, to include requirements on damage control drills for passenger ships. | |
| | 12. Onboard stability computer or shore-based support for existing passenger ships. | |
| Implementation Status of Analyzed causes | Description of IMO's Long-Term Action Plan Outputs | Related International Convention and Code |
|----------------------------------------|-----------------------------------------------|------------------------------------------|
| Already existed and then amended or recommended | 13. Review of the adequacy of passenger ship specific safety training in the STCW 1978, as amended. | International Convention on Standards of Training, Certification, and Watchkeeping for Seafarers, 1978 (STCW 1978) |
| | 14. Development of more detailed assessment criteria for recognizing Manning Agencies. | |
| | 15. Development of guidelines on the appropriate assignment of trained crew to emergency duties. | |
| | 16. Review the adequacy of shipboard safety signs and markings. | International Convention for the Safety of Life at Sea (SOLAS 1978) |
| | 17. Review of the effectiveness of plans for cooperation of passenger ships with appropriate search and rescue services required by SOLAS 1978 Chapter V regulation 7.3 (MSC/Circ.1079). | |
| Not yet amended | 1. Review of emergency power redundancy for existing ships. | International Convention for the Safety of Life at Sea (SOLAS 1978) |
| | 2. Development of guidance on the use of fire doors to prevent flooding. | |
| | 3. Revision of Chapter 13 of the Fire Safety System code (arrangement of means of escape) to indicate the maximum capacity of public spaces. | |
| | 4. Develop guidelines of administrations regarding substitution of lifeboats by life rafts (SOLAS 1978 regulation III/21.1.1—administrations “may permit the substitution of boats by rafts of equivalent total capacity provided that there shall never be less than sufficient boats on each side of the ship to accommodate 37.5% of the total number of persons on board”). | |
| | 5. Review of SOLAS 1978 regulation III/27 to add the nationality of all persons on board. | |
| | 6. Guidance for flag administrations in considering alternative arrangements under SOLAS 1978 regulation III/11.7 (with the ship listed at an angle exceeding 20°; it was demonstrated that traditional embarkation ladders were more useful. Therefore, in light of this it may be necessary to consider whether the minimum number of embarkation ladders (one) on each side should be increased) (MSC 92/6/3). | |

While considering the IMO long-term action plan in Table 2, most of the items related to the SOLAS 1978 convention were amended for the existing regulations. The descriptions of items 9–12 in the “added after accident” section in Table 2 lists the newly enacted SOLAS 1978 regulations after the Costa Concordia accident. Most of the long-term action plan items focused on the seafarers’ emergency response, the stability of the vessel, and evacuation after contact with a reef, instead of addressing the root cause of the accident. Presently, these items have been partially amended. However, there are items that were identified after the accident but were not reflected in the amendment of the regulations, such as items 1–6 in the “not yet amended” section in Table 2 [40]. These included items that were not amended were the ones that were proposed to prevent rapid deterioration after flooding and to help the passengers escape efficiently. They are related to the situation after the contact. Item 5 in the “not yet amended” section in Table 2 was included in the
interim recommendations immediately after the accident [47]; however, we were not able to confirm any changes in the IMO regulations made thenceforth.

The items that are related to the STCW 1978 convention are related to the emergency response of the passenger ship crew members. These items were supplemented and amended such that the companies could guarantee an improvement in the seafarers’ emergency response ability and emergency response familiarity training, etc. [45]. In addition, when comparing these items with the documents of the IMO circular or resolution, it was confirmed that the contents for the shipboard safety signs and markings related to emergency escape and improvement in the efficiency of cooperation between passenger ships and search and rescue services were amended [48,49].

3.2.2. Analysis of Causes of Sewol Ferry Accident

This study analyzed several reports on the Sewol ferry accident, including the maritime safety investigation report that was published by the Korean Maritime Safety Tribunal (KMST), a comprehensive report that was submitted to the Korean government by the Hull Investigation Committee (HIC) for the Sewol ferry accident, articles that analyzed the causes of the accident, and a report compiled by the Korea Maritime Institute [50–53].

The investigative work of the HIC started in July 2017 and ended in August 2018. However, the report failed to present a consensus on the causes of the accident. Therefore, separate reports were prepared for two possibilities: a Hypothesis for Internal Factors (HIF) and a Hypothesis including External Factors (HEF) [52,53]. The commonalities of the two reports are poor cargo securing and a lack of stability at the time of the departure [52,53]. However, the HIF report excludes the possibility of an external force, while the HEF report includes it. All seven articles that analyzed the causes of the accident were based on research prior to the submission of the comprehensive report of the 2018 HIC. In this study, we excluded the presence of the external force which may have affected the Sewol ferry accident and required an additional verification for the causes of the Sewol ferry case. In addition, regarding the rescuing of the passengers of the Sewol ferry, because there were many elements other than international conventions and national laws, we focused on the causes that were related to the Sewol ferry accident only.

Table 3 shows the identified causes of the accident from the above collected data. For classification, we identified the national laws in Korea that existed and were related to the identified causes of the accident at the time. If they existed, we analyzed and identified whether they were amended after the accident. If they did not exist, we analyzed and identified whether there were any new provisions after the accident. It was found that Korea has many relevant laws, such as the Ship Safety Act (SSA), the Seafarers’ Act (SA), the Maritime Safety Act (MSA), the Marine Transportation Act (MTA), and the Ship Personnel Act (SPA).

Table 3. Causes of the Sewol ferry accident and their application status.

| Implementation Status of Analyzed Cause | Identified Cause of Accident of Sewol Ferry | Related International Convention and Code |
|----------------------------------------|--------------------------------------------|------------------------------------------|
| Already existed and then amended       | 1. The maximum allowable age for a passenger ship went from 20 years to 30 years. This enabled the shipping company to purchase the 18-year-old Japanese passenger ship. | International Convention for the Safety of Life at Sea, 1974 (SOLAS 1978) |
|                                       | 2. Modification did not need any approval from the government since it did not violate the domestic law; the company only had to get approval when the usage of the ship changed after the modification. | Ship Safety Act (Republic of Korea (RoK))                                           |
|                                       |                                            | Maritime Safety Act (RoK)                                                             |
|                                       |                                            | Marine Transportation Act (RoK)                                                     |
### Table 3. Cont.

| Implementation Status of Analyzed Cause | Identified Cause of Accident of Sewol Ferry | Related International Convention and Code |
|----------------------------------------|--------------------------------------------|------------------------------------------|
| 3. Limitation of the physical system design is that ships of this type (RO-RO passenger) have an un-subdivided deck and a very large superstructure compared with other types. | | International Convention on Standards of Training, Certification, and Watchkeeping for Seafarers, 1978 (STCW 1978) |
| 4. Use of large angle of rudder—the sudden turn of the ferry made by an unexperienced navigating officer significantly contributed to the capsizing. | | Ship Personnel Act (RoK) |
| 5. Improper decisions of captain in emergency situations. | | Seafarers' Act (RoK) |
| 6. Failure of proper crew response. | | |
| 7. Inexperienced third mate and helmsman conning vessel at the time of accident. | | |
| 8. Lack of emergency response training of shipping company. | | |
| 9. Cursory inspection by ship inspector before ship sailing and being allowed to sail; structural problem in the independence of the marine operation inspection, South Korea's lax RO-RO ferry regulation system—negligent in safety checks due to the special treatment from shipping companies. | | International Safety Management Code (ISM code) |
| 10. Improper management and violation of regulations by ship-owning company—problem of feedback, compliance of regulation, management of crew, etc. | | Ship Safety Act (RoK) |
| 11. Improper activation of life rafts. | | Marine Transportation Act (RoK) |
| 12. Insufficient ballast water on board, large free surfaces in the ballast tank. | | |
| 13. Improper lashing of cargo—movement of cargo. | | |
| 14. Overloaded cargo. | | |
| 15. Insufficient upright metacentric height (GM) force. | | |
| 16. Fail to conduct adequate inspection of cargo movement by ship’s crew. | | |
| 1. Lack of investment in safety. | | International Safety Management Code (ISM code) |
| 2. Lack of experts in disaster management in Central Disaster and Safety Countermeasures Headquarters (CDSCH) led to poor communication and coordination. | | Ship Safety Act (RoK) |
| 3. Shipping company’s culture: priority of short-term profit, employment of low-paid contract workers, and prevalence of operational and safety oversights. | | Marine Transportation Act (RoK) |
| 4. Shipping companies prefer irregular workers—issue of employment structure. | | |
| 5. Although one regulator of Republic of Korea had the knowledge that the ship had exceeded its capacity regularly, this information was not useful because it was not shared with other cognizant agencies with oversight responsibility for the Sewol, possibly because the law did not require it. | | |
| 6. Improper maintenance and inspection of life rafts by external inspection agency. | | |

As each law was enacted for the ratification of the SOLAS 1978 convention, STCW 1978 convention, and ISM code, this study classified them in relation to these relevant
international conventions. The contents related to the procedures and systems were classified under the ISM code, those related to general safety and structure were classified under the SOLAS 1978 convention, and those related to seafarer training and qualifications were classified with the STCW 1978 convention.

For the identified causes of the accident, this study excluded similar and duplicate causes and finally classified 22 causes of the accident as presented in Table 3. Of these, 16 causes in the “already existed and then amended” section were either addressed in existing laws or laws that were amended after the accident. In addition, six causes in the “not yet amended (or not existed)” section were identified as causes of the accident that had no relevant national laws or regulations for them.

The regulations related to SOLAS 1978 include the SSA, MSA, and MTA. In terms of the causes of the accident, the issue of the ship’s age [32] and the obligation to report a modification made to the ship [32] are specified in the MTA and SSA, respectively. In the relevant regulations after the accident, the maximum age of the ship was reduced from 30 to 25 years [50,54], and any modification that caused deterioration of the stability was banned. In addition, ship owners were now required to seek a permit for modifications made to the ship’s facilities as well, apart from the permits already needed for changes in the length, width, height, and use of the ship [50,55]. Considering the items that were identified as causes after the accident, this study confirmed that the causes related to the SOLAS 1978 convention already existed in relevant laws or were amended after the accident in the Republic of Korea (RoK).

STCW 1978 is related to the SPA and SA Korean laws. Rapid movement of the ship using the rudder at big angles [32,33,56,57], the lack of swift decision-making ability of the captain [33], an inappropriate response by the ship’s crew during an emergency [32,56,58], and a lack of understanding of the structural constraints of the car carrier were identified as the causes of the accident [33]. These causes are related to the seafarers’ ability and education. For these, the appropriate laws already existed or have been amended since the accident. More specifically, the required qualifications for captains of large passenger ships were to obtain a second-class license and pass the ability test for the captain on the passenger ship (ATCPS) in the first attempt. However, this requirement was strengthened after March 2015 such that candidates were now required to obtain a first-class deck officer license; the ATCPS schedule was also modified to enable it to be held regularly from July 2015 [59]. In addition, officers were obliged to wear uniforms, the existing exemption from safety retraining was abolished, the training was reorganized based on practice, and the advanced course for the passenger ship (ACPS) was established [59,60]. Since 2019, a full-scale reorganization of seafarer-related training through practice- or discussion-based learning has been enforced in the Republic of Korea. Through this, an effort was made to strengthen the seafarers’ ability. Additionally, the KMST, which published the Emergency Response Manual for the Captain (ERMC) in 2018, has made efforts to strengthen the captain’s emergency response ability [61].

The ISM code is related to the MSA and MTA. It requires coastal passenger ships to operate with an SMS in place according to Article 46 of the MSA, in which the ISM code is accepted by the national laws of Korea. However, ships that are engaged in coastal passenger transportation services, such as the Sewol ferry, are required to satisfy the operation management regulation (OMR) under Articles 21 and 22 of the MTA in the Republic of Korea. In addition, they are subject to inspection in accordance with the passenger ship safety management guidelines, which is notified under the MTA. This means that a similar ship type has to follow different laws depending on its operation type. The details included in the OMR are specified in Article 15-2 of the enforcement ordinance of the MTA. In addition, a ship operates with the SMS in place if it complies with the OMR in accordance with Article 46 of the MSA [54,62].

The previous studies recognized the following as the causes of the accident: an inexperienced third officer’s conning the vessel and helmsman’s poor steering [32], cargo overloading [32–34,57], a lack of ballast water loading [32,34,56,57], poor cargo secur-
ing [32,33,56,57], an improper management system in the shipping company that violated regulations [32–34,56], structural problems in the vessel operation manager (VOM) resulting in superficial pre-departure checks [32–34,56], and lax SMS [32,56]. In other words, the accident was due to the negligence of safety management by the passenger transportation services provider (PTSP) and inherent problems in the overall coastal passenger ship SMS. In order to prevent similar accidents, the authority and responsibility of the PTSP were clarified. In addition, the safety regulations and license systems were completely revised [50,54]. In the event of a maritime accident that could pose a serious risk to several lives due to the intentional or serious negligence of the PTSP or negligence in the duty of care related to the supervision of the captain, a permanent disqualification system for the coastal PTSP’s (CPTSP) license was introduced such that they cannot be licensed again [50,54]. The provisions for the violations were also defined in detail [50,54].

First, the appointment of a safety manager for the CPTSP became mandatory. Second, in order to secure the independence of the VOM, their institution changed from the Korea Shipping Association, which is an interest group of shipping companies, to the Korean Maritime Transportation Safety Authority, which is a public institution, thus clarifying the duties of the VOM. Third, a maritime safety supervisor was appointed to strengthen the safety inspection of coastal passenger ships [50,54,55]. In addition, the identification process for all the passengers was strengthened by mandating ID card and boarding pass checks. Ticketing systems for vehicle cargo have since been fully computerized to prevent overloading of passengers and cargo [50,54]. However, no special actions were taken on the issue of non-regular crew members [32,34,56] or information sharing related to the Sewol ferry remodeling information [32,33].

3.3. Questionnaire Development for IPA, Borich’s Needs Assessment, and Locus for Focus Models

After identifying the causes of the Costa Concordia and Sewol ferry accidents, this study identified whether or not the countermeasures related to the IMO conventions and relevant laws were implemented. Therefore, we conducted an expert survey on the importance and performance of the amendments related to IMO conventions and national laws that were amended after ship accidents by using IPA, Borich’s needs assessment model, and the locus for focus model. IPA analysis can achieve clear results in a simple based on “importance” and “performance”; therefore, it has the advantage of deciding which areas to focus on first. However, problems arise when researchers determine that the center value separating priorities is used as a mean or median because analysis errors in the results may occur depending on the center value set by the researcher [63]. To compensate for this shortcoming, priority through Borich’s needs assessment may be further considered. Unlike the simple difference comparison of the t-test, Borich’s needs assessment gives weight to the level of importance, allowing the results to be listed in order [64]. However, even if the priority is listed, there are limitations as to how far they should be considered first. Thus, the locus for focus model allows us to consider differences in importance and performance while also visually identifying the priorities [64]. However, there may be problems, such as presenting the results of the priorities or in prioritizing the next quadrant after the first quadrant [64]. Therefore, the model can additionally be supplemented through Borich’s needs assessment. Furthermore, AHP analysis allows us to compare the relative priorities of each factor, but the purpose of this study was to explore the priorities for insufficient response; therefore, IPA, Borich’s needs assessment, and locus for focus models were used. In addition, we confirmed the importance and performance of the items in which the causes of the accident were identified but for which the appropriate countermeasures were not taken.

This study conducted a survey on the importance and performance using a Likert 5-point scale for the 24 identified causes of the accident for which the items were amended or recently added to the IMO conventions, as shown in Table 1. A survey on the importance and performance of the 17 amended or newly added items in the IMO long-term action plan using the Likert scale was also conducted. Similarly, this study conducted a survey on
the importance and performance of each item using the Likert 5-point scale by identifying 16 items from the “already existed and then amended items” section in Table 3. The higher the value of the Likert scale used in the survey analysis, the higher was the importance of the cause of the accident and higher was the response to the current level (1 = not at all, 2 = not like that, 3 = common, 4 = yes, 5 = it really is). We identified six “not yet amended” causes in Tables 1–3 each that were included in the questionnaire.

The experts who participated in the survey consisted of a variety of interested parties. These included seafarers, members of the seafarers’ union, shipping company personnel, professors from the seafarers’ educational institutions, officials of the Korean government, and other stakeholders. For the survey questionnaire that was sent out, replies were received from 42 participants, including 12 seafarers, 4 representatives from shipping companies, 18 professors from the seafarers’ educational institutions, 2 government officials, and 6 members from the seafarers’ union, along with public institutions, a maritime equipment research institute, and a quasi-government agency. After a primary analysis of the completed questionnaires, two were excluded because the survey response was incomplete. Fourteen people had 6–10 years of maritime experience, the highest number of participants; 11 had 11–15 years; 8 people had more than 15 years; and 7 people had 0–5 years of experience. IPA was performed using R [65]. Furthermore, by performing Borich’s needs assessment to assess the differences in importance and performance, the results were represented using the locus for focus model. Equation (1) presents the formula for Borich’s coefficient [36]:

\[
\text{Borich’s needs coefficient} = \frac{\sum (RCL - PCL) \times \overline{RCL}}{N}
\]

where \(N\) denotes the total number of cases, \(RCL\) denotes the required competence level (importance level), \(PCL\) denotes the present competence level (performance level), and \(\overline{RCL}\) denotes the average of the required competence level (importance level).

According to Equation (1), by increasing the RCL value and decreasing the PCL value, the Borich’s needs coefficient become higher. The calculated Borich’s needs coefficient provides a basis for judging the priority using relative values instead of absolute values. Accordingly, it should be emphasized that the items with a higher priority have a high Borich’s needs coefficient, which should be corrected, if possible [36]. Figure 2a shows the importance and performance grid of the IPA model, which represents relationships between the importance (vertical axis) and performance (horizontal axis) [35]. Figure 2b shows a schematic representation of Mink’s locus for focus model, which represents the relationships between importance (horizontal axis) and discrepancy (vertical axis) based on the current level of importance and performance [37]. This study focused on the second quadrant in the IPA model and the first quadrant (HH) in the locus for focus model, which represents high importance and low performance, and high discrepancy between the importance and performance, respectively. This is an area where a problem is recognized to be of high importance while its current level (i.e., performance) is low. Therefore, there is a need for the development of a continuous response ability.

**Figure 2.** Schematic representation of the analysis: (a) importance—performance grid (IPA model); (b) locus for focus model.
4. Results
4.1. IPA, Borich’s Needs Assessment, and Locus for Focus Models
4.1.1. Costa Concordia Case 1 from Accident Investigation Report and Articles

Table 4 summarizes the analysis results of the IPA [65], Borich’s needs assessment, and the locus for focus model for the 24 identified causes (excluding the 6 causes in the “not yet amended” in Table 1). Figure 3a provides an illustration of the IPA results. The causes located in the second quadrant (high importance/low performance) of the IPA model in Figure 3a include causes number 1 and 12 in the “already existed and then amended” section in Table 1. Both causes involved seafarers. In response to these causes, an amendment was made after the accident with a focus on strengthening the overall emergency response ability of the crew working on the passenger ships, such as the addition of emergency familiarization training for passenger ships [44,45,65]. Currently, causes regarding suggestion and information sharing within the bridge team through seafarer education/training are provided in the leadership and teamwork courses and the leadership and managerial skills courses. At the time of the Costa Concordia accident, training was not mandatory, and although BRM training was being conducted, nobody in the bridge team had received the training [31]. A total of 10 causes were included in the first quadrant (high importance/high discrepancy) of the locus for focus model in Figure 3b—namely, 2, 3, 10, 11, 16, 17, 21, and 24, including number 1 and 12 as mentioned in the IPA. The lowest and highest Borich’s needs coefficients were for cause numbers 3 and 12, respectively. Numbers 15 and 18 had higher Borich’s needs coefficients than that for number 3 in the first quadrant of the locus for focus model. However, these values are of less than the importance of the mean; thus, they belong to the second quadrant (low importance/high discrepancy) of the locus for focus model. Number 15 represents “cancelling automated alarms” and 18 represents “cognitive hysteresis or psychological fixation”. Both the items do not belong to the first quadrant, in which the items that belong to the same set of human factors are from the IPA. Numbers 2, 3, 10, 11, 16, 17, 21, and 24, which were added in the locus for focus model, were present in the first quadrant (high importance/high performance) of the IPA, along with the items of high importance and performance. However, because the locus for focus model determined that the performance was relatively low in comparison to the importance, they belonged to the first quadrant. When examining the contents of the causes, they were not the root causes of the contact; however, the causes that were identified in the electric power system, such as the inability to use the bilge pump and production facilities (items 2 and 3), were seen as key elements that extended the flooding area and eventually grounded the ship after the contact. However, the importance and performance related to them was low. In addition, the Borich’s needs assessment model of the ship’s uncontrollable issues that were related to electricity production exhibited a high priority level of five. Problems other than the ship’s electric power system involved the crew members along with the problems that were previously analyzed—problems related to situational awareness, takeover, risk response, and the decision-making abilities of the bridge team. Therefore, it was a problem concerning the seafarers’ behavior and the ability to respond in real situations, rather than their practical knowledge itself. In fact, at the time of the accident, most of the human-related causes were addressed through amendments in the form of requirements for seafarer education/training. Nonetheless, most of the causes showed high Borich’s needs coefficients. This indicates that the amendments were not executed.
Table 4. IPA, Borich’s needs assessment, and locus for focus models for Costa Concordia Case 1 (from an accident investigation report and the provided articles).

| Questionnaire | IPA Importance | IPA Performance | Borich’s Needs Assessment Model | Borich’s Needs | Priority | Locus for Focus Model |
|---------------|----------------|-----------------|--------------------------------|----------------|----------|-----------------------|
| 1             | 4.53           | 3.28            | 5.66                           | 2              |          | HH                    |
| 2             | 4.48           | 3.53            | 4.25                           | 5              |          | HH                    |
| 3             | 4.25           | 3.43            | 2.54                           | 12             |          | HH                    |
| 4             | 4.23           | 3.63            | 2.01                           | 16             |          | HH                    |
| 5             | 3.83           | 3.30            | 0                              | 19             |          | LL                    |
| 6             | 3.55           | 3.55            | 1.80                           | 24             |          | LL                    |
| 7             | 4.00           | 3.55            | 0.45                           | 22             |          | LL                    |
| 8             | 3.63           | 3.50            | 2.50                           | 10             |          | HH                    |
| 9             | 4.00           | 3.38            | 3.96                           | 6              |          | LL                    |
| 10            | 4.33           | 3.65            | 3.78                           | 8              |          | HH                    |
| 11            | 4.33           | 3.45            | 1.80                           | 10             |          | HH                    |
| 12            | 4.50           | 2.93            | 7.09                           | 1              |          | HH                    |
| 13            | 4.08           | 3.30            | 1.52                           | 21             |          | LL                    |
| 14            | 3.58           | 3.15            | 3.62                           | 11             |          | LL                    |
| 15            | 4.03           | 3.13            | 3.90                           | 9              |          | HH                    |
| 16            | 4.33           | 3.41            | 5.34                           | 4              |          | HH                    |
| 17            | 4.75           | 3.63            | 4.13                           | 6              |          | HH                    |
| 18            | 4.13           | 3.13            | 3.38                           | 13             |          | HH                    |
| 19            | 4.10           | 3.28            | 0.17                           | 23             |          | HH                    |
| 20            | 3.36           | 3.31            | 5.46                           | 3              |          | LL                    |
| 21            | 4.65           | 3.48            | 2.77                           | 15             |          | LL                    |
| 22            | 4.10           | 3.43            | 2.26                           | 18             |          | LL                    |
| 23            | 4.10           | 3.55            | 4.01                           | 7              |          | HH                    |
| 24            | 4.45           | 3.55            |                                |                |          | HH                    |

Figure 3. Analysis of the causes of the Costa Concordia accident from the provided articles using: (a) IPA model; (b) locus for focus model.

4.1.2. Costa Concordia Case 2 from IMO Long-Term Action Plan

Table 5 shows a summary of the analysis results of the IPA [65], Borich’s needs assessment, and the locus for focus model for items 1–17, which have been included in the long-term action plan demonstrated in Table 2. Figure 4a shows the IPA that is based on Table 2. In the IPA, items number 8, 11, and 13 in Table 2 had a low performance relative to the importance [65]. These three items are related to the response issues after the contact with the reef. Although they were not the root causes of the accident, the seafarers’ response to the accident and the ship stability management after the contact were considered to have an insufficient performance relative to the importance. Figure 3b provides the locus for focus model for Table 5. Considering items 1, 2, and 15, in addition to items 8, 11, and 13 that were identified in the IPA, a total of six items were included in the first quadrant.
(high importance/high discrepancy). The item with highest Borich’s needs coefficient was item 15, while that with the lowest Borich’s needs coefficient was 11. Item 14 had higher Borich’s needs than item 11, but it did not reach the importance mean; thus, it belonged to the second quadrant (low importance/high discrepancy). Items 1, 2, and 15 were added to the locus for focus model and belonged to the first quadrant in the IPA, in which they were considered to be of high importance and performance. However, it was determined that the performance was relatively insufficient for the locus for focus model. Among the items that were identified in the long-term action plan, item 15 had the highest Borich’s needs coefficient. As this result depended on the seafarers’ response ability, the seafarers’ ability to respond was still indicated to be relatively insufficient.

Table 5. IPA, Borich’s needs assessment, and the locus for focus model for Costa Concordia Case 2 (from the IMO long-term action plan).

| Questionnaire | IPA Importance | IPA Performance | Borich’s Needs Assessment Model | Borich’s Needs | Priority | Locus for Focus Model |
|---------------|----------------|-----------------|---------------------------------|----------------|----------|----------------------|
| 1             | 4.25           | 3.58            | 2.87                            | 2              | HH       |                      |
| 2             | 4.10           | 3.53            | 2.36                            | 6              | HH       |                      |
| 3             | 3.78           | 3.43            | 1.32                            | 15             | LL       |                      |
| 4             | 3.83           | 3.33            | 1.91                            | 9              | LH       |                      |
| 5             | 3.90           | 3.45            | 1.76                            | 12             | LL       |                      |
| 6             | 3.93           | 3.50            | 1.67                            | 13             | LL       |                      |
| 7             | 3.88           | 3.53            | 1.36                            | 14             | LL       |                      |
| 8             | 4.08           | 3.45            | 2.55                            | 5              | HH       |                      |
| 9             | 3.93           | 3.45            | 1.86                            | 11             | LL       |                      |
| 10            | 3.28           | 3.40            | −0.41                           | 17             | LL       |                      |
| 11            | 3.98           | 3.44            | 2.09                            | 7              | HH       |                      |
| 12            | 3.95           | 3.48            | 1.88                            | 10             | HL       |                      |
| 13            | 4.05           | 3.35            | 2.84                            | 3              | HH       |                      |
| 14            | 3.93           | 3.28            | 2.55                            | 4              | LH       |                      |
| 15            | 4.25           | 3.53            | 3.08                            | 1              | HH       |                      |
| 16            | 4.13           | 3.65            | 1.96                            | 8              | HL       |                      |
| 17            | 3.83           | 3.50            | 1.24                            | 16             | LL       |                      |

Figure 4. Analysis of the causes of the Costa Concordia accident from the IMO long-term action plan using: (a) IPA model; (b) locus for focus model.

4.1.3. Sewol Ferry Case

Table 6 summarizes the analysis results for the IPA, Borich’s needs assessment, and the locus for focus model based on the 16 causes from the “already existed and then amended” section in Table 3. Figure 5a shows the results for IPA [65]. Upon examining the causes that showed a significant discrepancy between importance and performance (i.e., the high
importance and low performance items in Table 3), causes number 5 and 6 were located in the second quadrant (high importance/low performance). These causes depended on the captain’s and seafarers’ decision-making abilities and the response on board. In response to these two causes, the Republic of Korea strengthened the ATCPS after the accident. Moreover, through the publication of the ERMC and its distribution to shipping companies, as well as establishing the ACPS, efforts have been made to strengthen the ability of the captains and seafarers on passenger ships [50,61,66].

Table 6. IPA, Borich’s need assessment, and the locus for focus model for the Sewol ferry accident.

| Questionnaire | IPA          | Borich’s Needs Assessment Model | Locus for Focus Model |
|---------------|--------------|--------------------------------|-----------------------|
|               | Importance   | Performance                     | Priority              |                      |
| 1             | 3.80         | 3.65                           | 0.51                  | 16                   |
| 2             | 4.28         | 3.60                           | 2.89                  | 11                   |
| 3             | 4.20         | 3.43                           | 3.26                  | 10                   |
| 4             | 3.93         | 3.50                           | 1.67                  | 14                   |
| 5             | 4.68         | 3.40                           | 5.96                  | 1                    |
| 6             | 4.53         | 3.43                           | 4.98                  | 4                    |
| 7             | 3.77         | 3.56                           | 0.75                  | 15                   |
| 8             | 4.28         | 3.48                           | 3.42                  | 8                    |
| 9             | 4.10         | 3.45                           | 2.67                  | 12                   |
| 10            | 4.05         | 3.50                           | 2.23                  | 13                   |
| 11            | 4.53         | 3.80                           | 3.28                  | 9                    |
| 12            | 4.55         | 3.73                           | 3.75                  | 7                    |
| 13            | 4.78         | 3.58                           | 5.73                  | 2                    |
| 14            | 4.78         | 3.58                           | 5.73                  | 3                    |
| 15            | 4.73         | 3.73                           | 4.73                  | 5                    |
| 16            | 4.53         | 3.58                           | 4.30                  | 6                    |

Figure 5. Analysis of the Sewol ferry accident from the provided articles using: (a) IPA model; (b) locus for focus model.

Figure 5b is a visualization of the locus for focus model results shown in Table 6. The five added causes from 12 to 16, including causes number 5 and 6 mentioned in the IPA, are in the first quadrant (high importance/high discrepancy). The five added causes were in the first quadrant (high importance/high performance) of the IPA, which were answered in the expert survey with a high importance and performance. However, the Borich’s needs assessment determined that they had low performance relative to the importance; therefore,
they are in the first quadrant. These causes are mainly human-related. Amendments regarding causes from 12 to 16 were confirmed by existing laws. These were added after the accident, such as the SSA, the guidelines for managing passenger ship safety, the ship stability criteria, and the standard for cargo loading and securing [50,54,55,59]. However, they revealed high Borich’s needs coefficients, which indicates that they were not recognized as being improved.

4.2. Importance Rank and Causes of Accidents That Were Not Addressed

4.2.1. Costa Concordia

This study confirmed the importance by listing the six causes from the “not yet amended” section in Table 1 and the six causes from the “not yet amended” section in Table 2 for the questionnaire in sequence. Table 7 shows the contents of the 12 causes that are listed in the questionnaire by analyzing their importance after the survey. Cause 6, which indicated that the benefit (efficiency) to the shipping company was placed over safety, was perceived as the highest importance. In relation to this cause, a comprehensive system of improvements, such as the ISM code, was already present; however, there were no additional amendments made to the specific details related to this cause after the accident. Subsequently, the issues related to numbers 4 and 7 were perceived to be important. Apart from them, numbers 1, 3, 8, 10, 11, and 12 were perceived to be lower than the importance mean. These causes were mostly cases where the improvement effect could be insignificant due to the low effectiveness of the amendment. Furthermore, the respondents to the survey had the view that, if necessary, through additional tests, the verification of the actual effectiveness of the improvements related to these causes should take priority over the amendments of the regulations. As for the causes that were answered with low importance, the participants had the view that there was a lack of efficiency due to the amendment itself. In addition, the question of the seafarers’ qualities was first raised for the parameter marking problem of the guard sector and the structural problem of the bridge. These were identified as a problem in the bridge that occurred before the contact with the reef.

Table 7. Causes of the accident from the accident report, articles, and the IMO long-term action plan that were not addressed after the Costa Concordia accident.

| Questionnaire Number | Rank by Importance | Importance | Cause |
|-----------------------|--------------------|------------|-------|
| 1                     | 9                  | 3.49       | Once defined, the guard sector is not displayed on the screen (making it difficult for operators to remember its parameters). |
| 2                     | 6                  | 3.60       | The clarity of electronic vector charts on navigational display. In the worst cases important features become unreadable. |
| 3                     | 11                 | 3.43       | Bridge (full enclosed by glass windows) did not allow physical verification of outside environment or a clear look at nighttime. |
| 4                     | 2                  | 3.90       | Limited availability of emergency lines in case of failure for flooding and direct consequences on management of residual dynamic stability (absolute absence of redundancy in the production of emergency power, lack of lines available in emergency). |
| 5                     | 5                  | 3.65       | The lack of type specific training. |
| 6                     | 1                  | 4.03       | Efficiency–thoroughness trade-off: Making these efficiency–thoroughness trade-offs is essential for the efficacy of overall performance but can also lead to accidents. |
| 7                     | 3                  | 3.78       | Review of emergency power redundancy for existing ships. |
| 8                     | 8                  | 3.50       | Development of guidance on the use of fire doors to prevent flooding. |
Table 7. Cont.

| Questionnaire Number | Rank by Importance | Importance | Cause |
|----------------------|--------------------|------------|-------|
| 9                    | 4                  | 3.70       | Revision of Chapter 13 of the FSS code (arrangement of means of escape) to indicate the maximum capacity of public spaces. Develop guidelines of administrations regarding substitution of lifeboats by life rafts (SOLAS 1978 regulation III/21.1.1—administrations “may permit the substitution of boats by rafts of equivalent total capacity provided that there shall never be less than sufficient boats on each side of the ship to accommodate 37.5% of the total number of persons on board”). |
| 10                   | 10                 | 3.45       | Review of SOLAS 1978 regulation III/27 to add the nationality of all persons on board. |
| 11                   | 12                 | 3.30       | Guidance for flag administrations in considering alternative arrangements under SOLAS 1978 regulation III/11.7 (with the ship listed at an angle exceeding 20°, it was demonstrated that traditional embarkation ladders were more useful. Therefore, in the light of this it may be necessary to consider whether the minimum number of embarkation ladders (one) on each side should be increased) (MSC 92/6/3). |
| 12                   | 7                  | 3.58       | |

4.2.2. Sewol Ferry

By listing six causes from the “not yet amended (not existed)” section of Table 3 in the questionnaire, this study confirmed their importance. Table 8 shows the details of the six causes that were listed in the questionnaire by analyzing their importance after the survey. The analysis results of the responses to the survey show that cause number 1 (lack of investment in safety) in Table 8 was perceived to be of highest importance. Following this, the importance of the remaining causes was confirmed in the decreasing order of numbers 3, 6, 2, 5, and 4.

Table 8. Causes of the accident that were not addressed after the Sewol ferry accident.

| Questionnaire Number | Rank by Importance | Importance | Cause |
|----------------------|--------------------|------------|-------|
| 1                    | 1                  | 4.60       | Lack of investment in safety. Lack of experts in disaster management in Central Disaster and Safety Countermeasures Headquarters (CDSCH) led to poor communication and coordination. |
| 2                    | 4                  | 4.28       | Shipping company’s culture: priority of short-term profit, employment of low-paid contract workers, and prevalence of operational and safety oversights. |
| 3                    | 2                  | 4.45       | |
| 4                    | 6                  | 4.10       | Shipping companies prefer irregular workers—issue of employment structure. Although one regulator of South Korea had knowledge that the ship had exceeded its capacity regularly, this information was not useful because it was not shared with other cognizant agencies with oversight responsibility for the Sewol, possibly because the law did not require it. |
| 5                    | 5                  | 4.25       | Improper maintenance and inspection of life rafts by external inspection agency. |
| 6                    | 3                  | 4.38       | |
In terms of the reasons for the lack of improvements related to the importance rank of causes number 1, 2, and 6, the respondents to the survey regarded the structural problems related to the small sizes of shipping companies that are engaged as the CPTSP and market uncertainty as the biggest causes. A lack of awareness of safety measures was the most important, and it was also perceived as an important cause. The poor SMS and insufficient regulations of the CPTSP, along with the incompetence and lack of responsibility of external professional organizations, were perceived as the causes of cause 6. As for rank 4, a lack of ground placement in experienced personnel, the absence of strong and centralized accident response organizations based in the field, an inefficient reporting system, and the absence of institutions and training courses to train experts for a domestic ship emergency response were regarded as the causes. With regard to the fifth ranked importance in Table 8, the respondents mostly declared that they did not even recognize the need for information sharing in ship remodeling before the accident. In addition, there was a lack of networking for information sharing among the related organizations.

5. Discussion

After collecting the causes for the two ship accident cases, this study conducted a quantitative and qualitative analysis to determine how the countermeasures related to the identified causes were implemented internationally and nationally.

From the two specific ship accident cases, this study confirmed that there were certain limitations to the implementation of clearly identified causes of ship accidents. This has been discussed in previous studies [14–16]. Furthermore, it was confirmed that it is more effective and practical to enhance education and training for seafarers rather than to improve ship structure or equipment [67,68]. Table 9 provides a summary of the identified problems of addressing identified causes and describes the possible solutions to address the identified causes listed in Section 4.

According to the analysis results in Section 4.1.1 of the 24 causes in which actions were taken after the Costa Concordia accident, 10 causes that had a low performance relative to the importance were human-related except for two. The IMO enhanced the education and training in accordance with the STCW 1978, as amended to address these identified causes. For example, leadership and teamwork as well as leadership and managerial skills became mandatory in accordance with the current STCW 1978. However, most of the survey respondents recognized that it is difficult to share information in a bridge working environment in practice even though training was being conducted [69]. In addition, it was confirmed that the effect of education and training on the causes of maritime accidents was considered to be insignificant [70]. In particular, hierarchical culture has been widely seen as prevailing in Asian countries and far different from European cultural characteristics [71]. However, the respondents to the survey had the general view that the dominant and vertical culture of ships prevailed because of the unique hierarchical cultural elements of ships rather than the cultural differences of countries. In a ship’s working environment, it is relatively more difficult and crucial to address human-related issues than to respond to ship technology-related ones [72]. In order to address this issue, there is a strong need to enhance the current education and training courses and improve the seafarers’ awareness of the tasks [65]. In particular, a lack of response, an insufficient situation awareness, and a lack of decision-making from experienced and knowledgeable senior seafarers in emergency situations can have a negative impact on the entire team, which can have severe consequences [73]. To address this issue, it is necessary to develop and apply tools to verify the abilities of the seafarers rather than providing mandatory education and training in accordance with STCW 1978 [70,74]. As a future study, research on the development of this tool is needed.

The analysis results in Section 4.1.2 of the long-term action plan conducted by the IMO after the Costa Concordia accident confirmed that the performance of the seafarers’ response and the ship stability management was inadequate after the accident, rather than highlighting the matters that triggered the causes of the accident. In addition, the results
exhibited that seafarers must be familiar with stability information and knowledge [75]. By analyzing the causes of the Costa Concordia accident and the response process after the accident, we confirmed that the current response method for human-factor issues are inadequate. Most of the technology-based causes were because of issues such as loss of stability after flooding due to contact, problems with the machinery, and problems with the escape facilities, rather than issues that were related to situation awareness and the detection and prevention of the accident. This indicates that most of the technical improvements that addressed these causes before the accident were considered to have been well established. Therefore, there is an increasing need to develop relevant technology to respond to a loss of stability, mechanical issues, and evacuation after an accident [76–78]. Because ship accidents occur due to the complex action of various factors, they must be considered together with the cause of these problems; however, this study is limited to analysis using a questionnaire survey. Therefore, studies on appropriate escape procedures and response to a loss of ship stability should be carried out in future.

The analysis results in Section 4.1.3 of the 16 causes for which actions were taken after the Sewol ferry accident confirmed that far more human casualties were caused by human factors, such as lack of decision-making ability by the captain and an inadequate response by the seafarers. To improve this, the government of the Republic of Korea confirmed that it was making efforts to enhance the seafarers’ ability by amending the related national laws. However, it was confirmed by examining causes with a low performance in the survey results that simply improving the seafarers’ ability to respond to emergencies was not well established [76–78]. In order to address this issue, the improvement of the working environment of the seafarers—who are the main subjects for implementing regulations—and employing highly qualified seafarers were confirmed to be essential [79]. In addition, it was determined that there was a limit to the improvement in abilities of passenger ship crews that could come from only enhancing the education and training of seafarers and amending national laws—their effects were insignificant. In order to reduce marine accidents, it is necessary to improve the working environment of ships by investing in better equipment such that a number of highly qualified seafarers can be employed [80,81]. Because the working environment of a ship varies greatly depending on the country, shipping company, and ship type, it cannot be considered that it is only the working environment that is weak. In addition, this study observed that the working environment of ships navigating in territorial waters and that of international voyage ships are fundamentally different. Therefore, based on these considerations, research on the proposals of rational methods for improving the ship working environment must be carried out.

Through Sections 4.2.1 and 4.2.2, this study confirmed the causes in the “not yet amended” section. As for the Costa Concordia accident, the main reasons for the “not yet amended” causes were determined to be difficulties in terms of solving the specific aspects of safety and efficiency, as well as cost issues and the necessity of primarily enhancing the seafarers’ knowledge, understanding, and proficiency. A lack of funding from the shipping company, which limited the safety and hiring of highly qualified seafarers, was considered to be the main cause behind the Sewol ferry accident. A lack of ground placement for experienced personnel, and a lack of ownership and expertise from the business owner were also exposed as the reasons. In other words, there are several reasons why the identified causes were not addressed after the accident. These include: a lack of a financial support to invest in safety because of the financial difficulty of the shipping company, a lack of thought about the need to proactively invest in the prevention of accidents that have not occurred, and a shipping company structure in which non-regular workers are preferred for cost reduction. As suggestions to address this, a few useful responses from the survey are shown in Table 9.
Table 9. Problems in the effective implementation of identified maritime accident causes and possible suggested solutions [65].

| Analyzed Cases | Identified Problems through IPA and Borich’s Needs Assessment | Suggested Solutions through Articles and Received Answer from Experts |
|---------------|---------------------------------------------------------------|-----------------------------------------------------------------------|
| IPA and Borich’s need assessment Case 1 (articles and accident report) | - It is very difficult to present an objection by sharing information in the bridge working environment.  
- Poor or ineffective education.  
- The problem that the hierarchical cultural elements peculiar to ships dominate.  
- It is relatively more difficult and important to solve human factors.  
- Lack of response ability in emergency situations by experienced and knowledgeable senior crews; wrong situation recognition and decision making.  
- After the accident, causes were identified and international or domestic laws were revised accordingly; however, only paperwork increased and actual problems did not improve. | - Reinforcement of education and training related to human factors internationally and domestically.  
- Development and application of tools for the continuous verification of ability for seafarers’ capacity rather than single mandatory education and training according to STCW 1978, as amended.  
- It is more effective to enhance the crew’s complete understanding and use of the equipment than to improve the equipment.  
- Provide continuous education and training for emergency devices that are rarely used in the ship.  
- Enhancement of Port State Control (PSC); regular internal and external ship inspection to assessment of implementation. |
| Not yet amended cases | - Difficulties in solving customary parts of efficiency–thoroughness trade-off; cost problem. | - The authorization of the seafarers must be the first priority. |
| IPA and Borich’s need assessment Case 2 (IMO Long Term Action Plan) | - Lack of seafarer’s response capability and lack of implementation of ship’s stability management.  
- Current responses to problems caused by human factors are not yet adequate.  
- Loss of stability after flooding, problems with mechanical devices, and problems with escape equipment. | - Need to continuously improve the crew’s ability to respond to emergencies through education and training.  
- Among various ship technologies, loss of stability, mechanical system’s problems, and effective response technology for ship escape are needed.  
- Enhancement of PSC; regular internal and external ship inspection to assessment of implementation. |
| IPA and Borich’s need assessment Sewol ferry | - Lack of ability in emergency situations by experienced and knowledgeable senior crews; wrong situation recognition and decision making.  
- Lack of decision-making capacity of captain and inexperienced response to accidents by crew.  
- Improvements not made yet to develop the crew’s ability to respond to emergencies.  
- Reinforcement of education and training and amendment of relevant national laws and international regulations have limitations in improving the ability of passenger ship seafarers and staffs.  
- Institutionalization of training on safety and regulations for shipping companies and reinforcement of punishment levels. | - A system is needed to continuously conduct and verify the crew’s capabilities.  
- Improving the working environment of the crew for employing highly qualified crew.  
- It is more effective to enhance the crew’s complete understanding and use of the equipment than to improve the equipment.  
- Strengthening government’s support in terms of funds for coastal passenger shipping companies.  
- Enhancement of PSC; regular internal and external ship inspection to assessment of implementation. |
| Not yet amended | - There are limits to ensuring safety and hiring quality seafarers due to financial constraints.  
- Lack of on-site arrangement of field experts, lack of ownership and expertise.  
- Financial constraints and lack of thought about the need to proactively invest in potential accidents.  
- A structure in which irregular seafarers are preferred to cut down on cost. | - Ship owners and managers should provide adequate funds to improve the ship’s system and support seafarers in obtaining systematic education and training.  
- Necessary to improve and introduce the system for consideration of repetitive education and training.  
- Necessary to change the perception of safety by the shipping company; preventing accidents through close communication about safety between the shipping company and seafarers. |
The limitations and concept of this study present some directions for possible future research. First of all, this study does not deny the results of maritime accidents analysis using various tools that have been conducted and used for this study but confirms how the identified causes by such analyses are being addressed. The first limitation is that this study did not confirm the countermeasures that are taken after analyzing the causes of ship accidents in all ship types; a second limitation is that it does not address all the aspects in analyzing the causes or investigating whether countermeasures were taken. This study selected and analyzed two specific ship accident cases only; therefore, this study is limited to selected specific international and domestic passenger ship accident cases and cannot be regarded as representative of all passenger ships or ship accident cases. Therefore, it is necessary to group similar ship cases and analyze each group based on the findings of this study in the future. Another limitation is that this study did not cover other aspects such as technical and socio-technical issues; however, such an analysis has been covered by a previous study that this study used as a base reference. For the Sewol ferry accident, an investigation report that was related to the accident was prepared; however, there are still some controversies over the causes of the accident. Therefore, further investigation is still underway. There may be a possibility of deriving additional causes of the accident after this study; hence, there is a limitation that some of the identified causes might be revised in the future. While knowledge, understanding, and proficiency is a minimum requirement for seafarers, as prescribed by STCW 1978, the economic aspects of shipping companies are challenging for IMO conventions to address. Therefore, it is difficult to provide a solution to such issues through this study. Based on an understanding of these limitations, the studies mentioned above must be carried out to address the identified limitations.

6. Conclusions

This study presents four important outcomes. Firstly, the countermeasures taken after the Costa Concordia accident were mostly related to human factors. This confirmed a need for enhanced education and training in identified areas. Specifically, these areas include improving the emergency response and decision-making abilities of ship’s officers rather than enhancing education and training of seafarers. In the long-term action plan proposed by the IMO after the Costa Concordia accident, it was confirmed that there is a need to enhance the seafarers’ education and training and verify their practical knowledge in areas such as ship stability, emergency response, and decision-making.

Secondly, the analysis of the countermeasures taken after the Sewol ferry accident confirmed that the lack of decision-making of the shore side manager and inexperienced accident response by ship’s officers resulted in serious casualties. Therefore, it was confirmed that there is a need for a system to monitor the seafarers’ decision-making capabilities and emergency response toward solving the identified problems rather than providing mandatory training courses according to STCW 1978, as amended. It was further confirmed that crucial elements are improving the seafarers’ working environment for coastal or small-sized international passenger ships on short voyages, as well as providing financial support to shipping companies that operate small passenger ships and improving the safety awareness of the company managers.

Thirdly, difficulties in addressing specific aspects of safety and efficiency, as well as financial problems, such as the costs associated with implementation of safety measures, were identified as the main reasons for the “not amended yet” items after the Costa Concordia and Sewol ferry accidents. Consequently, this study confirmed that the causes of the accidents and the countermeasures to be taken revolved around human factors. However, similar accidents were repeated because seafarers were neither properly informed about the countermeasures to be taken nor trained in relevant areas such as ship stability, emergency response, and proper decision-making. In addition, despite appropriate countermeasures, this study confirmed that the ongoing conflict over the efficiency–thoroughness trade-off continued to be an issue.
Lastly, through the questionnaire survey, it was confirmed that the IPA, Borich’s needs assessment, and the locus for focus model employed to analyze the countermeasures taken after the ship accidents can be appropriately used to identify their adequacy and investigate the reasons for issues that require proper countermeasures but are not implemented.

As a future study, this analysis could be applied to other ship types, covering a larger number of accident cases. In addition, there is also a need for research on the development and application of tools to evaluate the ability of seafarers while on board vessels. In addition, it is necessary that all IMO conventions apply minimum requirements; however, enhanced education and training should be provided for seafarers rather than simply satisfying the minimum requirements of STCW 1978, as amended. Moreover, research on various rational methods proposed to improve the working environments on ships must be carried out.

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**References**

1. Awal, Z.I.; Hasegawa, K. A study on accident theories and application to maritime accidents. *Procedia Eng.* **2017**, *194*, 298–306. [CrossRef]
2. Akhtar, M.J.; Bouwer Utne, I. Common patterns in aggregated accident analysis charts from human fatigue-related groundings and collisions at sea. *Marit. Policy Manag.* **2015**, *42*, 186–206. [CrossRef]
3. Schröder-Hinrichs, J.-U.; Hollnagel, E.; Baldauf, M. From Titanic to Costa Concordia—A century of lessons not learned. *WMU J. Marit Aff.* **2012**, *11*, 151–167. [CrossRef]
4. Lee, M.-J. A Study on the Effectiveness of the ISM Code through a Comparative Analysis of ISM and PSC Data. 2016. Available online: [https://commons.wmu.se/cgi/viewcontent.cgi?article=1542&context=all_dissertations](https://commons.wmu.se/cgi/viewcontent.cgi?article=1542&context=all_dissertations) (accessed on 5 November 2020).
5. Yip, T.L.; Talley, W.K.; Jin, D. The effectiveness of double hulls in reducing vessel-accident oil spillage. *Mar. Pollut Bull.* **2011**, *62*, 2427–2432. [CrossRef]
6. Mattson, G. MARPOL 73/78 and Annex I: An assessment of its effectiveness. *J. Int. Wildl. Law Policy* **2006**, *9*, 175–194. [CrossRef]
7. Callis Oliver, L.-M. SOLAS Convention: Safety on Board. Universitat Politècnica de Catalunya. 2018. Available online: [https://upcommons.upc.edu/handle/2117/119127](https://upcommons.upc.edu/handle/2117/119127) (accessed on 5 November 2020).
8. Schröder-Hinrichs, J.-U.; Hollnagel, E.; Baldauf, M.; Hofmann, S.; Kataria, A. Maritime human factors and IMO policy. *Marit. Policy Manag.* **2013**, *40*, 243–260. [CrossRef]
9. DeCola, E. A Review of Double Hull Tanker Oil Spill Prevention Considerations. In *Report to Prince William Sound Regional Citizens’ Advisory Council*; Nuka Research & Planning Group, LLC: Seldovia Village, AK, USA, 2009.
10. Alexopoulos, A.; Katerelos, E.; Fournarakis, N.; Sakkas, K.; Aviyannis, K. A Critical Analysis of the IMO’s Conventions and Codes from the Techno-Economic & Managerial perspectives. In Proceedings of the International Conference on Technology and Environment, Piraeus, Greece, 1 January 2001.
11. Batalden, B.-M.; Sydnes, A.K. Maritime safety and the ISM code: A study of investigated casualties and incidents. *WMU J. Marit. Aff.* **2014**, *13*, 3–25. [CrossRef]
12. Asyali, E. The Role of ECDIS in Improving Situation Awareness. In Proceedings of the 13th Annual General Assembly of the IAMU, St. John’s, NL, Canada, 15–17 October 2012. Available online: [http://iamu-edu.org/wp-content/uploads/2014/07/The-Role-of-ECDIS-in-Improving-Situation-Awareness.pdf](http://iamu-edu.org/wp-content/uploads/2014/07/The-Role-of-ECDIS-in-Improving-Situation-Awareness.pdf) (accessed on 11 September 2020).
13. Knudsen, O.F.; Hassler, B. IMO legislation and its implementation: Accident risk, vessel deficiencies and national administrative practices. *Mar. Policy* **2011**, *35*, 201–207. [CrossRef]
14. Viertola, J.; Storgård, J. Overview on the Cost-Effectiveness of Maritime Safety Policy Instruments. 2013. Available online: http://projects.centralbaltic.eu/images/files/result_pdf/MIMIC_result3_report_ENG.pdf (accessed on 10 September 2020).
15. Karahalios, H.; Yang, Z.; Williams, V.; Wang, J. A proposed System of Hierarchical Scorecards to assess the implementation of maritime regulations. Saf. Sci. 2011, 49, 450–462. [CrossRef]
16. Dewan, M.H.; Yaakob, O.; Suzana, A. Barriers for adoption of energy efficiency operational measures in shipping industry. WMU J. Marit. Aff. 2018, 17, 169–193. [CrossRef]
17. Setyohadi, P.; Artana, K.; Manfaat, D.; Gurning, R. Dynamic response of risk management model to mitigate impact of maritime regulatory changes: Oil tanker owners perspective. Oper. Supply Chain Manag 2018, 11, 118–127. [CrossRef]
18. Bhattacharya, S. The effectiveness of the ISM Code: A qualitative enquiry. Mar. Policy 2012, 36, 528–535. [CrossRef]
19. Akyuz, E.; Celik, M. A hybrid decision-making approach to measure effectiveness of safety management system implementations on-board ships. Saf. Sci. 2014, 68, 169–179. [CrossRef]
20. Tunidau, J.; Thai, V.V. Critical factors for successful implementation of the ISM Code in some Pacific Islands states. WMU J. Marit. Aff. 2010, 9, 63–80. [CrossRef]
21. Eliopoulou, E.; Papanikolaou, A.; Voulgarellis, M. Statistical analysis of ship accidents and review of safety level. Saf. Sci. 2016, 85, 282–292. [CrossRef]
22. Psarros, G.; Skjong, R.; Eide, M.S. Under-reporting of maritime accidents. Accid. Anal. Prev. 2010, 42, 619–625. [CrossRef]
23. Di Lieto, A. Costa Concordia: Anatomy of an Organisational Accident; University of Tasmania: Hobart, Australia, 2012.
24. Giustiniano, L.; Cunha, M.P.; Clegg, S. The dark side of organizational improvisation: Lessons from the sinking of Costa Concordia. Bus. Horiz. 2016, 59, 223–232. [CrossRef]
25. Vidan, P.; Bošnjak, C.R.; Eng, B.; Derado, I.; Eng, B. Analysis of the accident of m/v costa concordia. In Proceedings of the Zbornik Radova Conference Proceedings, Zadar, Croatia, 3 October 2013; p. 80.
26. Broussolle, J.; Kyovtorov, V.; Basso, M.; Castiglione, G.F.D.S.E.; Morgado, J.F.; Giuliani, R.; Oliveri, F.; Sammartino, P.F.; Tarchi, D. MELISSA, a new class of ground based InSAR system. An example of application in support to the Costa Concordia emergency. J. Photogramm. Remote Sens. 2014, 91, 50–58. [CrossRef]
27. Brazier, A. What can we learn from the Costa Concordia? Loss Prev. Bull. 2012, 224, 8–9.
28. Dickerson, T.A. The Cruise Passenger’s Rights and Remedies 2014: The COSTA CONCORDIA Disaster: One Year Later, Many [CrossRef]
29. SETouchTec. Operation Safety. Available online: https://cruising.org/about-the-industry/policy-priorities/clia-oceangoing-cruise-line-policies/operational-safety (accessed on 14 March 2020).
30. Alexander, D.E. The ‘Titanic Syndrome’: Risk and crisis management on the Costa Concordia. Transp. Rev. 2012, 32, 199–214. [CrossRef]
31. MIT. Cruise Ship Costa Concordia Marine casualty on January 13, 2012. Repot on the Safety Technical Investigation. 2012. Available online: http://3kbo302xo3lg2i1rj8450xje.wpengine.netdna-cdn.com/wp-content/uploads/2013/05/Costa_Concordia-_Full_Investigation_Report.pdf (accessed on 6 June 2020).
32. Lee, S.; Moh, Y.B.; Tabibzadeh, M.; Meshkati, N. Applying the AcciMap methodology to investigate the tragic Sewol ferry accident in South Korea. Appl. Ergon. 2017, 59, 517–525. [CrossRef] [PubMed]
33. Kim, T.-E.; Nazir, S.; Øvergård, K.I. A STAMP-based causal analysis of the Korean Sewol ferry accident. Saf. Sci. 2016, 83, 93–101. [CrossRef]
34. Kim, H.; Haugen, S.; Utne, I.B. Assessment of accident theories for major accidents focusing on the MV SEWOL disaster: Similarities, differences and discussion for a combined approach. Saf. Sci. 2016, 82, 410–420. [CrossRef]
35. Martilla, J.A.; James, J.C. Importance-performance analysis. J. Mark. 1977, 41, 77–79. [CrossRef]
36. Borich, G.D. A needs assessment model for conducting follow-up studies. J. Teach. Educ. 1980, 31, 39–42. [CrossRef]
37. Mink, O.G.; Shultz, J.M.; Mink, B.P. Developing and Managing Open Organizations: A Model and Method for Maximizing Organizational Potential, 2nd ed.; Somerset Consulting Group: Austin, TX, USA, 1991.
38. Febriani, S.; Sudomo, J.; Setianingsih, W. Development of Student Worksheet Based on Problem Based Learning Approach to Increase 7th Grade Student’s Creative Thinking Skills. J. Sci. Educ. Res. 2017, 1, 1. [CrossRef]
39. Kim, K.E.; Kim, J.R.; Woo, H. Analysis of differences in perceptions and educational needs of university students, graduates, human resource manager on NCS basic job skill. J. Eng. Educ. Res. 2017, 20, 12–20.
40. IMO. Updated Long-Term Action Plan on Passenger Ship Safety. Available online: http://docs.imo.org/ (accessed on 14 March 2020).
41. CLIA. Operation Safety. Available online: https://cruising.org/about-the-industry/policy-priorities/clia-oceangoing-cruise-line-policies/operational-safety (accessed on 14 March 2020).
42. IMO. Amendments to the International Convention for the Safety of Life at Sea, 1974, as amended. In Resolution MSC.350(92); IMO: London, UK, 2013.
43. IMO. Amendments to the International Convention for the Safety of Life at Sea, 1974, as amended. In Resolution MSC.404(96); IMO: London, UK, 2016.
44. IMO. Amendments to the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW), 1978, as amended. In Resolution MSC.416(97); IMO: London, UK, 2016.
45. IMO. Amendments to Part A of the Seafarers’ Training, Certification and Watchkeeping (STCW) Code. In Resolution MSC.417(97); IMO: London, UK, 2016.
