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A Study on the Rational Decision-Making Process of Vessel Organization—Focusing on Cases of Vessel Accidents

Yunjae Kim and Dohyung Lee *

Department of Global Trade, Dongguk University, Pildong-ro 1gil 30 Jung-gu, Seoul 04620, Republic of Korea; kyjae0623@dgu.ac.kr
* Correspondence: dohyunglee@dongguk.edu; Tel.: +82-2-2260-3262

Abstract: Vessel organizations are exposed to the risk of accidents due to the limited experience and intuition of the top decision makers in the organization in the special environment of the sea. This study aims to provide a direction for sustainable and rational decision-making in vessel organization through decision making process theory and case studies of actual vessel accidents. The results obtained from the actual case studies show that all three vessel accidents were caused by the arbitrary decision of the decision maker based on the Garbage Can model. This can be attributed to the closed nature of the vessel's organization, which requires a decision-making process that is a hybrid of the Carnegie Decision model and Management Science model. Implications include the introduction of a 'My Ship' system, the de-subjectivization of top decision makers, situational awareness, and the need to provide top decision makers with the context and information relevant to their decisions. Limitations of this study include the fact that the case study was conducted only on Korean-flagged vessels and the study was limited to vessel accidents that occurred in the waters off Korea, China, and Japan, which limits the generalizability of the findings. In order to overcome these limitations, it would be interesting to conduct a follow-up study to include vessel accidents of different nationalities or to further investigate the characteristics of the decision-making process in vessel accidents by country.

Keywords: vessel accident; decision-making; garbage can model; vessel organization; Carnegie Decision model

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1. Introduction

As business environments change rapidly, organizational decisions are made quickly and there is a strong tendency to deal with complex, emotional, and important issues. Since organizational decisions are made in situations where the outcomes are unclear in an uncertain environment, it can be judged that a lot of cooperation and participation is required to reduce the risk of outcomes in implementing decisions.

In addition, decision making tends to be driven by the power of an organization that can move as a team, and solutions are found incrementally as decisions are made.

This is not very different for shipping companies. The organization of a shipping company is divided into a shore-based organization and a marine organization, and the marine organization is called the vessel organization. Despite the increasing reduction in crew due to the automation and smartization of vessels, the vessel organization (crew) is one of the key factors that can influence the growth of a vessel's revenues [1].

Seafarers are an integral part of these shipping companies, and their decision-making processes have a significant impact on the safety of vessels and the operational efficiency of shipping companies. This is due to the diverse and unpredictable conditions under which vessels operate, and the importance of rational decision making within a vessel organization is critical. In general, vessel organizations that do not experience accidents make decisions in a consistent and efficient way by analyzing risk factors and information [2].

Rothblum, Catherine and Rhona [3,4] demonstrated that more than 90% of the causes of vessel collisions are based on human factors and errors. These errors are a subcategory of "unsafe behavior" and include human error, technology-based error, and decision and perception error [5]. Vessel accidents often cause severe damage, such as loss of property, loss of life, and environmental damage [6,7]. Therefore, reducing vessel accidents and improving vessel safety is a very important issue [8]. Moreira, Fossen, and Guedes [9] also argued that it is necessary to have a decision-making system on board vessels to avoid collision situations. In light of this, a more in-depth study of the decision-making process of vessel organization members is required for the rapidly changing maritime environment and maritime safety, and based on this study, it is considered that reducing the vessel accident rate is of utmost importance. It has been well documented in numerous reports and studies that a significant proportion of vessel accidents are due to human factors and human error [3,4,10]. From 2014 to 2022, the proportion of vessel accidents caused by human error was 80.7% [10]. In addition, the International Maritime Organization (IMO) reports that more than 80% of vessel accidents are caused by organizational factors and human error [11,12]. The IMO has made it mandatory for seafarers to complete leadership and teamwork training to address these issues, such as imperfect subjective judgment, decision making, and poor communication account for a significant portion of vessel accidents. In addition, the IMO has mandated that pre-operational or pre-voyage risk assessments be conducted to assist in the decision-making process [13]. Thus, it can be seen that a significant proportion of vessel accidents are closely related to human factors based on subjective judgment. In the shipping industry, responsibility for vessel accidents has traditionally been attributed to the individual responsibility of the crew, but it is simplistic to blame vessel accidents solely on the crew [14]. Accidents at sea are not caused by individual factors alone, but rather by a combination of structural factors, including inefficient decision-making. This suggests that the decision-making process is more important in vessel organizations than in other organizations.

However, most of the existing studies on decision-making processes have been conducted in land-based organizations [15,16] and there are very few studies on decision-making processes in vessel organizations. Despite the fact that this issue has been raised in the past [8,9], there is a lack of research on decision-making processes in vessel organizations.

Therefore, this study aims to provide a desirable direction for the sustainable and rational decision-making process of vessel organizations by analyzing actual vessel accidents in the unpredictable maritime environment.

2. Literature Review

2.1. Vessel Organization

A vessel organization, which is a sub-organization of a shipping company organized on a vessel-by-vessel basis, operates a vessel in the process of providing maritime transportation services by communicating the operational situation through decision-making and solving various issues related to the operation of the vessel through vessel operation-related information, company policies, and vessel organization support services [17]. A typical vessel organization is divided into vertical chains of command and functions.

Unlike onshore organizations within a shipping company, members of a vessel organization are isolated for a period of time in a limited space on a vessel at sea. The vessel organization requires closer interaction between members in the formal work process on board the vessel, as the division and scope of work of members are clearly defined, and the performance of each member's work has a great impact on the operation of the vessel [17]. Therefore, in terms of safe operation and increased operational efficiency, it is particularly important to maintain smooth informal interaction between vessel organization members and formal work performance, and an efficient and appropriate decision-making process between organization members.

The ratio of personnel in a vessel's organization varies depending on the size of the vessel and the situation of the vessel, but it usually consists of 18 to 20 people, divided into officers and crew, with officers comprising 9 and crew comprising 11 individuals. To break it down, the deck department is usually composed of three navigation officers, three quarter master, and two sailors, and the engine department is composed of chief engineer, three engineers, two or three oilers, and one wiper. The galley department is composed of a chief steward and messman and, depending on the vessel's situation or the vessel's command, there may be additional personnel such as electricians, welders, and multi-officers in each department.

As shown in Figures 1 and 2 it is divided into the deck (navigation) department and engine department according to function, and is divided into management, operation, and assistant grades according to position. Management ranks are the master, chief officer, chief engineer, and first engineer, who are responsible for ensuring that all functions are properly performed within their assigned scope of responsibility. Operational ranks are officers performing navigational and engine room duties on a vessel under the direct supervision of management-level vessel personnel. Auxiliary ranks perform duties under the direct control and supervision of management and operational level shipboard personnel. Because they work under the control and supervision of a higher rank, their duties are limited in scope and their responsibilities are not as broad.

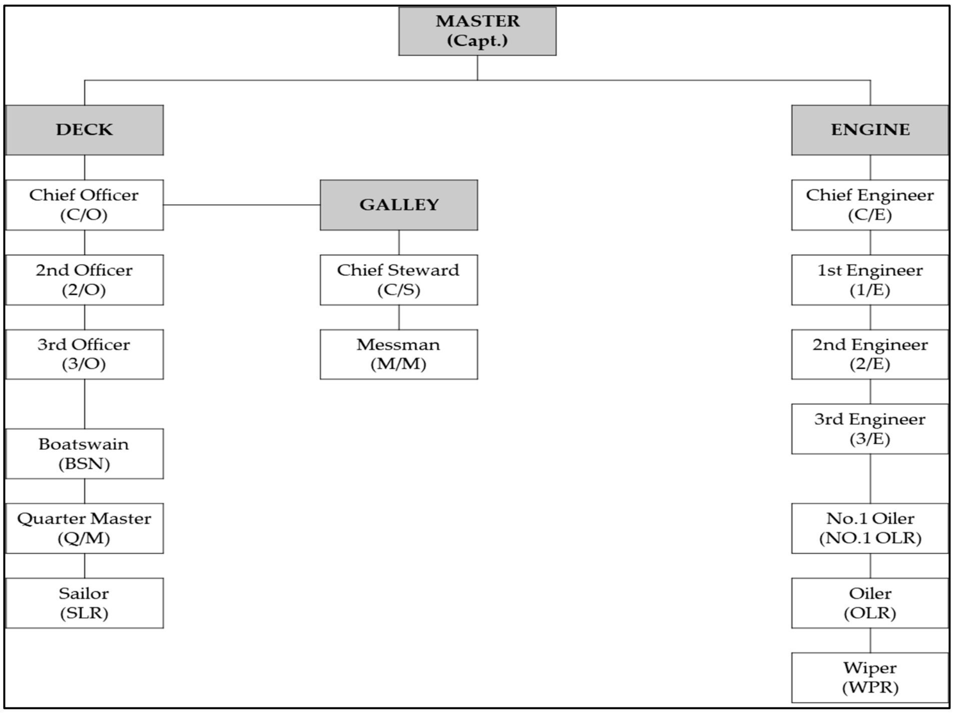

Figure 1. Vessel organization structure (created by the author).

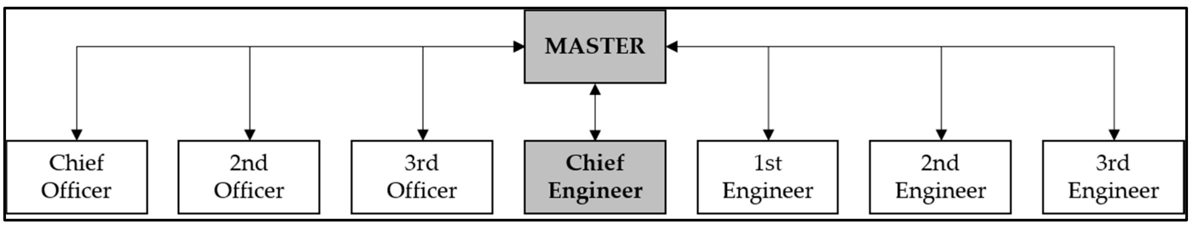

Figure 2. Principle of participation in decision-making in vessel organization (created by the author).

Relying on a clearly defined division of labor or procedures among the vessel organization members, there is a vague expectation that efficient decision making will take place as a matter of course. Problems arise due to inadequate interaction among vessel organization members, or conflicts between senior officers (Master, C/O, C/E, 1/E) and junior officers (2/O, 2/E, 3/O, 3/E), between Korean and foreign seafarers, between deck and engine departments, etc. In terms of employment, there are many cases where vessel organization members work for the same company for a long period of time under a long-term employment system such as regular employees, but in terms of vessel organization units, the members (seafarers) who board a particular vessel usually stay on board for 4 to 9 months and then rotate with their successors [17]. However, the rotation of vessel organization members is not carried out as an organizational unit, and vessel organization members board and disembark individually, depending on the length of their contract. Assuming an average of two months per voyage, 30% of the crew is typically replaced at the end of a voyage, resulting in a very short-term nature of organization formation and dissolution, with the average length of service between crew members being 3 to 4 months [17]. In the case of a large shipping company with a fleet of about 100 vessels, even long-term employees have very limited experience working with other seafarers in the same company, with only about a 1% chance of re-boarding after disembarking, and very limited staff rotation [17]. These unique circumstances have led to the formation of vessel organizations that closely resemble the nature of transient task groups. This is likely to reduce trust and cooperation among members of vessel organizations and may have a negative impact on organizational and work attitudes, motivation, and morale. The unique environment of vessels is also believed to be a significant contributor to poor decision making in vessel organizations.

While operating a vessel, members of the vessel's organization make decisions based on information obtained by sensing and perceiving various pieces of information, which are then translated into actions. During this decision-making process, members of the vessel organization may make incorrect decisions that lead to accidents. Hetherington, Flin, and Mearns [3] described the factors that can contribute to marine casualties, listing situational awareness and decision making in addition to human factors. In particular, decisions made in crisis situations such as vessel accidents are fraught with uncertainty [18], and they defined the origin of accidents as unsafe human behavior or decisions [19]. As shown in Table 1, the percentage of accidents caused by human error accounts for the majority of vessel accident causes, regardless of the type of vessel. These human errors can be compensated and corrected through repeated education and training [20,21]. In addition, as shown in Table 2, the main cause of human error is decision-making errors.

Table 1. Percentage of contributing factors related to human element organized by ship type (2014–2022) (adapted from [10]).

Vessel Type	Contributing Factors Related to Human Element (%)
Cargo Vessel	81.4
Passenger Ship	80.1
Fishing Vessel	76.1
Service Ship	82.9
Others	87.7

Table 2. Factors affecting human element in ship accidents (adapted from [22]).

Influencing Factors	Contributing Factors Related to Human Element (%)
Decision-making errors	14.2
Routine violations	13.3
Inadequate supervision	11.7
Crew resource management	7.3
Organizational process	7.3

As a previous study analyzing the communication and decision-making process of vessel organizations, Kim, Shin, and Kim [17] analyzed the factors affecting the formation of attributional trust among the relational and personal characteristics of vessel organization members and conducted an empirical study on the impact of attributional trust on organizational effectiveness. The results suggest that in order to build attributional trust among vessel organization members, it is necessary to inherit masters and officers with relatively high levels of reputation and integrity, strengthen the transformational leadership of top decision makers in the vessel, and further expand the promotion of shared values and communication. In addition, Kim, Nam, and Ahn [23], who conducted a study on culture in vessel organizations, concluded that developmental culture, rational culture, and collective culture have a significant effect on job satisfaction in the relationship between culture and job satisfaction in vessel organizations through multiple regression analysis. They argued that instead of strongly controlling vessel organization members, it is necessary to create an organizational culture that allows vessel organization members to feel that they are growing by performing their work and to inspire cooperation and bonding with other vessel organization members. Shin and Yoon [24] studied the effect of the master's leadership on the vessel and the decision-making process. The results of the study provided response strategies and solutions to reduce human error on vessels through behavioral characteristics that may occur on board during emergency situations. Shin [25] found that conflicts between vessel organizations and shore-based organizations and conflicts of interest among vessel organization members have a negative effect on job satisfaction, organizational commitment, and group cohesion, and group cohesion has a positive effect on job satisfaction and organizational commitment. Yoon, Shin, and Lim [26] conducted a study on the appropriate decision making of the captain of a passenger ship during an emergency situation regarding the evacuation of passengers. The results showed that capsize (lateral inclination), fire, and explosion, in that order, influenced the decision-making process. Soltani, Issa, and Garay [27] combined analytical, practical, and theoretical approaches to identify the most effective decarbonization strategies for container shipping, using multi-criteria decision making (MCDM) analysis to assess decarbonization potentials and barriers, and to investigate the optimal functional and technological choices to meet IMO GHG reduction targets.

In a study of decision making in shipping companies, Han and Jung [28] established a decision process model for investment that reflects the characteristics of customer demand at the business unit level, operational decisions to put vessels into service, purchase and sale of vessels by period, and chartering issues. In addition, he proposed an integrated enterprise-wide model that reflects financial conditions so that investment decisions and business unit operations are considered under the constraints of corporate resources and budgets.

2.2. Decision-Making Process

The decision-making process is the process of identifying and solving problems, which is the process of identifying and solving problems. Compared with the past, organizations in modern society have greatly increased not only in size but also in internal complexity, and the changes in the environment surrounding the organization and the progress of technology are also very fast and rapid [29]. In addition, the decision-making process is divided into programmed decisions and non-programmed decisions according to the degree of complexity. Furthermore, programmed decisions are repetitive and well-defined problems, while non-programmed decisions are unique problems that are not clearly defined.

The nature of organizational decision-making can be characterized by the fact that decisions are made more quickly and tend to be more complex, emotional, and involve high-stakes issues. They are also made under conditions of uncertainty, in situations where neither the means nor the ends are clear and require the cooperation and participation of more people in decision making and execution.

New decision-making processes are necessary because no single entity has the information needed to make important decisions and the time and effort needed to persuade the majority to implement what has been decided. They tend to be driven by organizational actors who can work as a team and accept that decisions will be made through trial and error or, in some cases, incremental improvement.

2.2.1. Management Science Model

Management Science models are models that use scientific methods to help business managers make decisions and are characterized by the use of statistics to identify appropriate variables. This type of Management Science model is similar to the rational decision model among individual decision types and can be considered an appropriate model for problems such as military operations. They are useful when you want to identify and measure variables using mathematical and statistical techniques. Management Science models originated during World War II, when mathematical and statistical techniques were used to solve large-scale, urgent military problems that were beyond the capabilities of individual decision makers. Since then, mathematical models have been applied to the field of business administration, and companies have also used mathematical models to quantify the variables involved and provide solutions and probabilities of success. Techniques such as linear programming, Bayesian statistics, PERT charts, and computer simulations are used for this purpose [30]. Despite these advantages, the problem with Management Science models is that they lack quantitative data and do not reflect tacit knowledge.

Airlines are among the most prominent organizations to use Management Science techniques. United Airlines, for example, uses route navigation software to reduce aircraft fuel and tolls by suggesting optimal fuel usage, flight speeds, and routes to help them take a new approach to reducing costs. United's software collects and tracks all information related to operations, including tolls in each country, weather conditions, unit fuel costs, airport locations, and available runways. This information is then used to evaluate different scenarios and make decisions to maximize the airline's revenue. As Green, Winebrake, and Corbett [31] found, proper operational planning and decision-making can reduce GHG emissions and environmental impact by 2–4%.

Shipping has been viewed as a business activity that requires large amounts of capital and involves speculative risks due to the uncertainty and unpredictability of the shipping industry [32,33]. To minimize these risks, Management Science models have been applied to shipping companies and used for decision making. Since the 2000s, the environmental regulations required for vessels by the International Maritime Organization (IMO) and the international community, such as MARPOL (International Convention for the Prevention of Pollution from Ships) and IMO2020, have been strengthened, and the quantification of the degree of environmental pollution, such as IMO DCS and SEEMP (Ship Energy Efficiency Management Plan), have been legislated and required to be reported to each flag state. In response, the shore-based organizations of shipping companies statistically analyze environmental issues and use them for decision making. They also provide decision support to vessel organizations at sea. In order to respond effectively to fleet safety management and vessel inspections, decision making is based on Management Science models. In particular, we have set up a system that analyzes and quantifies the points and peculiarities noted in various inspections (e.g., Port State Control, Classification Survey, etc.) of the entire fleet, and distributes and circulates them to the entire fleet. Vessels can use the inspection data as a reference to determine the areas to be checked and inspected during the inspection. In addition, near misses, accidents, and non-conformities that occurred on vessels each month are identified and compiled to determine the direction of fleet maintenance and management.

In recent years, the number of vessels has increased along with the volume of cargo, resulting in more shipping accidents [34–36]. In response, shipping companies are increasingly using Management Science models. HMM has established a "Fleet Control Center" at its R&D center to monitor the detailed information of HMM's fleet of vessels operating at sea in real time. The establishment of the Fleet Control Center is believed to have strengthened HMM's competitiveness in the shipping industry by enabling safe operation and efficient and systematic management of the vessels it operates. The Fleet Control

Center provides real-time location, arrival and departure information, fuel consumption, weather conditions, cargo loading status, etc., and supports decision-making to improve vessel efficiency and safe operation by identifying and managing risk factors in advance and sharing key information. In addition, information such as the ECDIS (electronic chart display and information system), Doppler log, heading, wind direction, and wind speed installed on the bridge can be shared with the Fleet Control Center for a quick response when passing through densely populated waters and dangerous areas. In particular, the CCTV installed on the vessel enables the vessel's CIC to understand the situation inside and outside the vessel and support important decision-making. In addition to the bridge, major equipment such as the main engine and generator can be checked together on shore and on the vessel and troubleshooting and quick decisions can be made immediately with the service engineer on shore, saving costs in vessel operation. HMM plans to proactively respond to vessel efficiency analysis and future autonomous vessel development/analysis based on big data collected in real time from the Fleet Control Center [37]. Previously, it was not possible to grasp the status values and situations of vessel information in real time. If there was a problem with the equipment, engineers had to be called in to fix the equipment at a high cost, but with the establishment of the situation room, the vessel's equipment can be maintained remotely.

Shipping companies have built software and organizations based on Management Science models, as shown in Table 3, which can reduce and prevent vessel accidents by making decisions based on big data collected through these models. In addition, AI and big data technologies have recently been applied to collision avoidance decisions to prevent accidents, and various studies on intelligent vessel technologies have been conducted in depth [38–45]. Therefore, it is essential for vessel organizations to receive guidance from shore-based organizations and support from various stakeholders [46]. On the vessel organization side, it is believed that such decision support can reduce the burden of voyage planning for new routes by enabling lower fuel consumption and efficient route planning to the next port. In addition, the real-time communication of vessel information with the shore organization is possible, and all vessel status values are immediately available on the server. Existing incidents and responses are recorded so that data can be used to guide future decisions and prevent recurrence.

Table 3. Analytical framework for utilizing a suitable decision-making model (created by the author).

Company Name	Organization	Main Purpose
HMM (Republic of Korea)	Fleet Control Center	Increased safe operation and efficiency based on navigation and equipment data.
ONE (Japan)	Operating Room	Real-time sharing of vessel operations with shippers.
Columbia Shipmanagement (Republic of Cyprus)	Digital Control Room	Sharing the information of the management vessel with the vessel owners.

2.2.2. Carnegie Decision Model

The Carnegie model falls under the bounded rationality perspective of individual decision making and is characterized by a coalition of managers making decisions through factionalism rather than a top decision maker. The Carnegie model is based on research conducted at Carnegie-Mellon University. Prior to their research, it was assumed that all information in an organization was concentrated in the hands of the top decision maker. However, their research showed that managers are involved in decision making and that the final decision is made by a collection of managers. The Carnegie model contradicts the Management Science model by suggesting that it is enough to present a satisfactory solution to find a solution, and the top decision makers will accept the first satisfactory solution presented.

In the decision-making process, a coalition of managers cannot reach a consensus on the priorities related to a problem if the goals of the department's activities are inconsistent or the organization's goals are vague. Therefore, they must bargain over the solution to the problem and form a coalition to solve the problem around that problem. In addition, even when top decision makers try to make a rational decision, various constraints and personal perceptions make it impossible to make a decision. Given resources, time, and skill constraints, it is not possible to obtain all the information and variables relevant to the decision [47].

The Carnegie model is particularly useful in the problem identification phase. It is important to include managers from key departments in the coalition to ensure that very important decisions, such as restructuring, can move forward without being overwhelmed. It is important for the top decision maker to be aware of the problem or to have positive buy-in from managers who will support the decision when it is made. Another characteristic is bounded rather than perfect rationality, which means that decisions are limited by a number of constraints that prevent rational decision-making. These constraints include lack of information, including limited capabilities, complexity of the problem, time pressure, and uncertainty. In particular, Carnegie types emphasize the importance of problem identification steps, such as receiving buy-in from other managers.

2.2.3. Incremental Decision Process Model

The incremental decision process model focuses on a sequence of structured activities that gradually move from the discovery of a problem to a solution. Important or big decisions are made up of a series of smaller decisions and combinations. Similarly, the decision process in organizations is a series of smaller decisions rather than one big decision. It also consists of the following sequence: identify $\rightarrow$ develop $\rightarrow$ choose. The identify phase recognizes the problem and examines whether it should be raised as a problem by interpreting the circumstances when external environmental factors change or internal performance fails to meet the standard. This is followed by the diagnosis phase, where more information is gathered and analyzed to define the problem situation. The development phase is where a solution to the problem defined in the identification phase is found. This can be achieved by finding a solution among existing methods or by designing one's own solution. In the selection phase, the solution is selected through judgment, analysis, and negotiation. However, this does not mean approval, and there is still a step to take the decision to a higher level that can be held accountable.

As organizations move through the various decision points, they face obstacles at each level. Mintzberg calls these obstacles decision interruptions [48]. A decision interruption means that the decision maker must go back to the previous decision and try again. Cycling through the decision process is one way to find a viable solution. The final solution that emerges may be somewhat different from what was initially expected.

Examples of incremental decisions used in Mintzberg's research include the installation of a new port container terminal, the opening of a new social club, the choice of which type of jet aircraft to purchase for a regional airline, the development of a new market for air fresheners, the firing of an influential radio announcer, and the distribution of a controversial new drug in a hospital [47,48]. Most of these problems require different solutions.

2.2.4. Garbage Can Model

The garbage can model is a model that characterizes the aspects of decision making in a group or organization where there is little cohesion among its members or among its constituent units and in a chaotic situation, focusing on the flow or pattern of multiple decision issues [48]. As the most recent model of organizational decision making, the garbage can model describes the decision-making process under very high uncertainty, such as organized disorder. It also focuses on the course and flow of events and issues rather than defining problems and solutions. It also helps to understand organizational units from a holistic perspective and to understand the process of multiple decisions made by managers in all sectors. The implication of this garbage can model is that solutions can be proposed (e.g., introducing computers to the workplace) even when the problem does not exist, and options can be chosen that do not solve the problem (e.g., creating new departments, downsizing the organization). Problems can persist without being solved, but that does not mean that all problems and issues are solved. It can be said that most decisions are not made in a logical way, and while individuals make decisions, organizational decisions are not made by a single individual. In addition, when there is no agreement on an issue, there is a high probability of conflict. Organizations often make decisions in rapidly changing environments, and if bias is allowed to enter the decision-making process, the potential for negative outcomes is very high.

Michael Cohen, James March, and Johan Olsen, professors of business administration at Cornell University, who first proposed the dumpster model, referred to uncertainty as "organized anarchy" [30]. The decision-making process is driven by three perspectives: the problem of choice criteria, job changes, and the ambiguity and intractability of technology. Furthermore, the dumpster model does not view decision making as a continuous process that begins with problem identification and ends with solution. In fact, problem identification and solution may not be connected. An idea may be a solution without a problem being identified. Or a problem may be identified but no solution found. In this way, decision making can be seen as the result of a series of independent events in an organization. The forms of decision making in organizations are random in nature. In another sense, it is like a big garbage can of mixed streams. When the participants, the problem, and the solution are connected at the same point, a decision is made and the problem is solved [47]. There may also be cases where a problem exists but is not solved, or a solution is implemented but does not have a timely effect. In this dumpster model, organizational decisions are chaotic or random in nature. If they can be connected, a solution to the problem can be achieved, but if not, the likelihood of a solution is not high. Applied to a vessel organization, the behavior of top decision makers and lower-level members in the midst of solutions, problems, and the complexity of decisions during an emergency is similar to the dumpster model. Therefore, we believe that the decision-making process in a vessel organization during an emergency tends to be very similar to the dumpster model.

3. Methodology

In this study, we used the qualitative research method of case study. In general, the main advantage of case study is that it allows for the in-depth investigation and analysis of real-life cases and is considered more robust because it is more deeply grounded in a variety of empirical evidence [49].

Case studies are characterized by the researcher investigating a real case in a specific and complex context. To do this, the researcher collects qualitative or quantitative data using a variety of methods, including studies, interviews and observations. A case is distinguished from other cases by its specific context, situation, and characteristics. Therefore, the case as a research object must have certain limitations [50]. The advantage of case studies is that they can provide an in-depth understanding of a specific situation, and the specific information obtained during the research process can be directly used to solve real-world problems or develop policies. On the other hand, they have limitations that make it difficult to generalize the findings. The cases studied may be specific to a particular situation, and there is always the possibility of subjective interpretation by the researcher. This makes case studies a research method that aims to gain an in-depth understanding of a specific situation rather than drawing generalized conclusions.

In this study, the decision-making process in maritime emergencies experienced by vessel organizations is more important than in any other organization, so it is appropriate to use accident case studies of Korean-flagged vessels with strong hierarchical cultures to identify problems in the decision-making process through a qualitative analysis method. The flow chart of this study is shown in Figure 3.

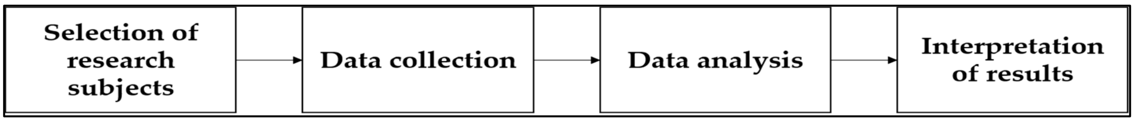

Figure 3. Research flowchart (created by the author).

4. Case Study

4.1. Data Source

The case study data are taken from the decision of the Korean Maritime Safety Tribunal, an organization that is part the Korean government that investigates and adjudicates maritime accidents [51].

Specifically, the number of accidents involving Korean-flagged vessels in the last three years was 121 in 2021, 131 in 2022, and 112 in 2023, totaling 364 cases [52]. First, the accidents selected for this study were limited to those that occurred in East Asian waters between 2021 and 2023 and involved Korean-flagged vessels. Second, we selected one accident case each from Korea, China, and Japan, which are the most common countries involved in accidents in the region, and finally analyzed a total of three accidents. By analyzing the problems in the decision-making process within the Korean-flagged vessel organization, which has a strong hierarchical culture, through actual vessel accident cases, we aim to analyze and observe the decision-making process within the Korean vessel organization in depth.

4.2. Container Carrier Hakata Voyager Weather Buoy Contact Incident

The G/T 7447 M/T container carrier Hakata Voyager departed Kobe Port, Japan, with a crew of 18, including the master, bound for the Busan Port. When the vessel arrived near the Busan Port, there was a shortage of berths, so the vessel decided to wait in nearby sea until the next day. As a result, at approximately 06:06 on 6 June 2021, the Hakata Voyager shut down its engines and began to drift. At approximately 19:45 on 6 June 2021, the vessel's chief officer, while conducting navigational watch according to the on-duty plan, sighted a buoy approximately 3.3 nautical miles to the northeast and reported it to the master. At approximately 19:55 on 6 June 2021, the master was on the bridge. He was not asked to come up by the chief officer, who was on navigational watch, but went to the bridge to check the buoy. When the master went to look at the buoy, it appeared to be a fishing net buoy, but when he checked the chart, it appeared to be a weather buoy. The master asked the chief officer about the CPA (closest point of approach), and the chief officer replied that he had checked the CPA with the buoy on the radar and that it looked like they were going to avoid it. However, the Hakata Voyager continued to approach the weather buoy due to the current. On 6 June 2021, the third officer, who had been on duty since 20:00, reported to the master at about 21:00 on the same day that the radar's latest approach continued to change. Upon receiving the third officer's report, the master realized the danger of contact with the weather buoy and ordered the engineer to start the engines [53]. The Hakata Voyager then continued to approach the weather buoy, as shown in Figure 4, but the engine did not start until just before contact with the weather buoy. The master quickly used the engines to minimum ahead and attempted to steer to port, but before the engines could take effect, at approximately 21:16 on 6 June 2021, the Hakata Voyager struck the weather buoy at Lat. 35°20′43″ N, Long. 129°50′29″ E, approximately 23 nautical miles east of Ganjeol Cape, Ulsan, Korea. The impact bent a portion of the Hakata Voyager's propeller blade and damaged the weather buoy's superstructure.

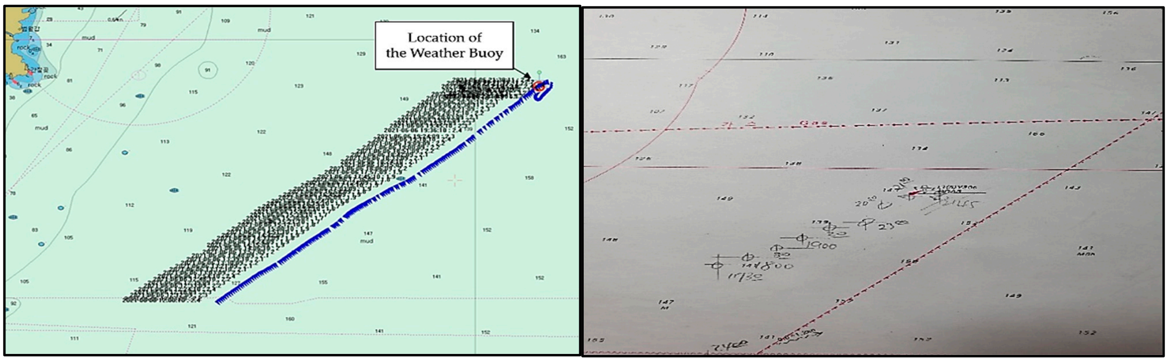

Figure 4. The track at the time of the accident (adapted from [53]).

The master of the Hakata Voyager was aware of the presence of the weather buoy when he reported it, stopped the engine and waited at sea near Busan Port until a berth became available. However, he failed to monitor it continuously and did not realize the possibility of contact with the weather buoy until about 15 min before the accident and ordered the engineer to start the engine, which did not prevent the accident. The master responsible for the safety of a vessel must always make appropriate decisions using all means and information available to him at the time, including sight, sound, and other means to fully understand the situation and the hazards around him. Despite the master's reliance on his past experience and the fact that he was approaching the weather buoy, he was lax in his vigilance, disregarded the reports of the navigators on watch, and made arbitrary decisions without going through the proper decision-making process, resulting in contact with the weather buoy. This is considered a contributing factor to the accident because the top decision maker acted on his own authority when, from a vessel operations perspective, more people should have been involved in decision making and execution. As such, vessel organizations often make decisions under rapidly changing conditions, and when bias is allowed to enter the decision-making process, as in this case, the potential for negative outcomes is very high.

4.3. Container Carrier Hongkong Voyager Collision with Container Carrier Tian Fu He

The G/T 12,645 M/T container carrier Hongkong Voyager departed Haiphong Port at 08:12 on 8 August 2021, with a total of 18 crew members and 919 containers on board, and navigated to its next destination, Incheon Port. The chief officer of the vessel performed the navigational watch twice a day (04:00 to 08:00 and 16:00 to 20:00), but since it was determined that he could perform the watch alone without the on-duty crew, the on-duty crew was asked to take a break from the navigational watch and participate in the day's work. Thus, the chief officer performed the navigational watch without an on-duty crew, but never reported it to the master. On 9 August 2021, at approximately 21:00, the master went to the bridge and wrote in the master's night order "Call me anytime if you have any problems" during the night watch, and the chief officer confirmed this night order at approximately 04:00 on 10 August 2021. At 04:00 on 10 August 2021, the chief officer exchanged navigational watches with the second officer. After signing the master's night order, he checked his surroundings visually and by radar and determined that the weather and visibility were favorable, there were several other vessels underway and a group of fishing boats in the vicinity, but there were no special circumstances, so he decided to conduct the navigational watch alone without the crew on duty. The chief officer spotted the G/T 54,005 M/T China-flagged container carrier Tian Fu He on the radar, sailing at 11 o'clock on the bow of the Hongkong Voyager. As the Hongkong Voyager maintained its course and speed, the chief officer was suddenly restricted by fog so thick that he could not see the bow. Although the chief officer's visibility was extremely limited and there were several vessels in the area, including a passing fishing boat, he did not call the crew on duty or inform the master that his visibility was limited. While the chief officer was taking action to avoid a collision with the fishing boat, the Hongkong Voyager was approaching the Tien Fu He on the portside, which he did not recognize because he was engaged in collision avoidance maneuvers against the fishing boat. However, as shown in Figures 5 and 6, at approximately 05:52 on 10 August 2021, approximately 65 nautical miles southwest of the Xiamen port, China, the port bow of Hongkong Voyager collided with the starboard stern of Tien Fu He at sea [54].

Figure 5. Photos at the time of the collision (adapted from [54]).

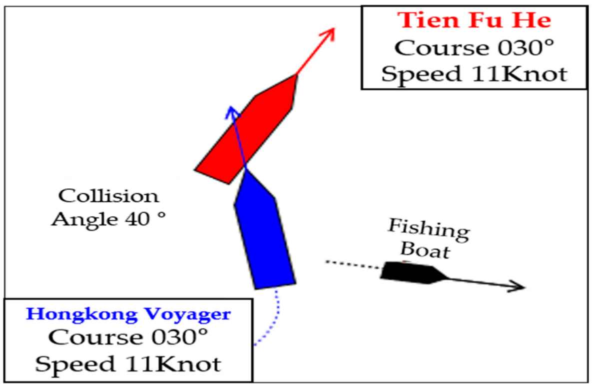

Figure 6. Overview at the time of the collision (adapted from [54]).

According to Article 9 of the Seafarer's Act, the master should be in direct conning of the vessel when the visibility restricted, so the navigation officer must report to the master when the visibility is restricted [55]. This was reflected in the company's procedures. As the officer on watch, the chief officer was required to maintain proper vigilance at all times and to make systematic observations to determine whether there was a risk of collision with another vessel. Despite having sighted the Tien Fu He on radar, he subsequently failed to detect the approach of the Tien Fu He in front of him as he approached a fishing boat in front of him with extremely limited visibility due to the sudden onset of fog and failed to slow down after making a collision avoidance decision for the fishing boat. When you have restricted visibility, you must follow the rules of navigation on restricted visibility, including being underway at a safe speed and navigating with due regard to the conditions at the time. Even though the visibility was restricted, the chief officer should have asked the captain to steer the vessel through the proper decision-making process, but instead he made arbitrary decisions and caused the accident.

This inaccurate decision making by the officer of the watch (OOW) is one of the causes of vessel accidents [56]. Such decision errors have been consistently reported as a major cause of vessel accidents [57–61]. Decision errors are mainly due to the decision maker's lack of experience, lack of information, or incomplete or inappropriate mental state [62,63]. In practice, the officer of the watch often makes subjective decisions based on experience under the constraints of regulations [64]. In addition, the navigational watch of the Hongkong Voyager was supposed to be carried out by a two-people team consisting of the chief officer and the crew on watch, according to the navigational watch instructions and work plan. However, the chief officer made arbitrary decisions and performed vigilance, observations, and evasive maneuvers without reporting to the master at the time of the incident. The company's procedures state that "The navigational watch shall be continuous for 24 h, and the watch shifts shall be 4 h apart, and the watch members shall be designated by the master, one for each watch." and "When navigating in coastal waters with high navigational hazards, when visibility is restricted or expected to be restricted, in waters with heavy vessel traffic, or where fishing boats are expected to be present, the Master should take direct command from the bridge". Despite the existence of guidelines for decision making while on watch, the chief officer did not follow them. This may have contributed to his failure to recognize that the Hongkong Voyager and the Tien Fu He were approaching each other prior to the collision.

4.4. Chemical Tanker Ulsan Pioneer Collision with Pure Car Carrier Byakko

At 07:10 on 25 May 2021, the G/T 2696 M/T chemical tanker Ulsan Pioneer departed Nanjing port, China, loaded with the chemical product acetic acid, and sailed toward Osaka port, Japan, with 13 crew members, including the master, on board. At 21:00 on 27 May 2021, the master of the Ulsan Pioneer confirmed that there were no significant dangers on the route at Seto Naikai, Japan, and instructed the third officer on duty to call for the master near the Kurushima Kaikyo, Kurushima MARTIS (Marine Traffic Information Service), reporting point. The master of the Ulsan Pioneer then ascended to the bridge at 23:48 and assumed the conning of the vessel. The third officer and the crew were on watch on the bridge at that time. The Ulsan Pioneer detected Kurushima Kaikyo's entry vessel, the Byakko, on radar. At 23:49, the Byakko was navigating at about 17.8 knots. The Ulsan Pioneer considered that in a crossing situation, the other vessel is the stand-on vessel and the Ulsan Pioneer is the give-way vessel, and according to the CPA, if the Byakko maintained a course of approximately 264 degrees, there would be no collision and the Ulsan Pioneer could maintain its current course. However, the Byakko's second officer changed the course to 230 degrees to port in order to avoid Kurushima Kaikyo and then started on their intended course, increasing the risk of a collision between the two vessels. The master of the Ulsan Pioneer panicked and urgently instructed the third officer on duty at the time to call the other vessel on the VHF, and the third officer hastily called the Byakko twice. The third officer then arbitrarily insisted on a port to starboard course with the second officer of the other vessel, and the second officer of the Byakko agreed and changed the course from 230 degrees to 240 degrees to starboard. At 23:54 on 27 May 2021, the Ulsan Pioneer and the Byakko collided at 90 degrees, as shown in Figure 7 [65]. The collision caused a large breach on the portside of the Byakko, which allowed seawater to enter and cause the vessel to sink. The accident resulted in the deaths of the Byakko's master, chief engineer, and second engineer. The Ulsan Pioneer sustained damage to her superstructure as shown in Figure 8.

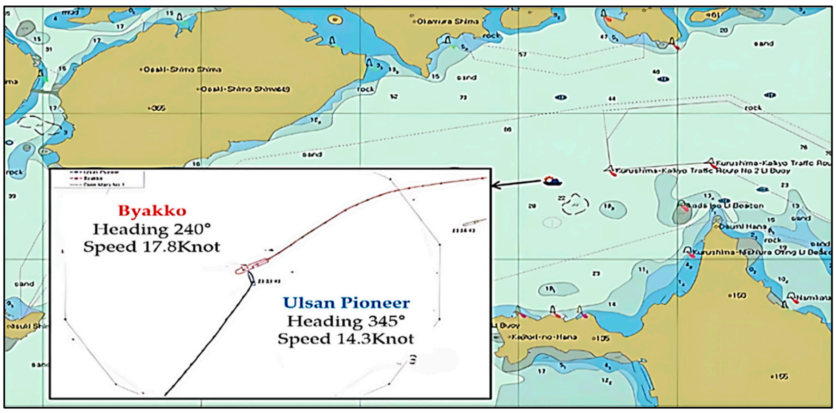

Figure 7. The track at the time of the accident (adapted from [65]).

Figure 8. The bulbous bow of Ulsan Pioneer after collision (adapted from [65]).

The Byakko was a pure car carrier, and the second officer was in conning of the vessel at the time. As in the Hongkong Voyager–Tian Fu He incident, the second officer was the officer on watch and should have maintained proper vigilance at all times and made systematic observations to determine whether there was a risk of collision with other vessels. In addition, Kurushima Kaikyo is classified by regulation as a narrow channel, which requires the master to maneuver the vessel himself. The Kurushima Kaikyo has some of the strongest currents in Japanese waters, making it essential for the master to maneuver the vessel himself. The second officer was supposed to call on the master to maneuver the vessel through a proper decision-making process, but the master made decisions on his own, leading to the accident. The second officer of the Byakko, although it was a give-way vessel with no give-way duty, was alert and turned to port just before the collision, increasing the risk of collision and ultimately causing both vessels to collide. The Ulsan Pioneer was also a give-way vessel and according to Article 16 of the International Regulations for Preventing Collisions at Sea (COLREG), which states that "A vessel in need of give-way, as far as practicable, make a large maneuver in advance and keep a sufficient distance from other vessels", the master and the third officer should have made a decision in advance, but they did not make a decision until just before the collision, which ultimately caused the collision and resulted in loss of life and damage to property. Despite the fact that vessels are equipped with navigational aids (e.g., automatic identification system (AIS), automatic radar plotting aids (ARPA), and integrated navigation systems (INS)), more than 80% of vessel accidents are related to human error [64,66–69]. As shown in Table 4, three of the cases involved decision-making errors.

Table 4. Problems and improvement measures in decision making (created by the author).

Vessel Name	Decision-Making Problems	Decision-Making Improvement Measures
Hakata Voyager	Arbitrary decision-making by top decision-makers based on heuristics using the Garbage Can model	Proposing the Carnegie Decision model through collaboration and participation of many people.
Hongkong Voyager	Arbitrary middle-manager decisions based on the Garbage Can model	Proposing a Management Science model through quantification and manualization.
Byakko	Arbitrary decisions by subordinate staff based on the Garbage Can model	Proposing a Management Science model through quantification and manualization.
Ulsan Pioneer	Failure of the decision-making process based on the Garbage Can model	Proposing the Carnegie Decision model through collaboration and participation of many people.

5. Conclusions

This study examines the decision-making process in vessel organizations based on case studies and aims to help shipping companies improve their decision-making processes in the future. The specific findings of this study are as follows.

First, the Hakata Voyager weather buoy contact incident was caused by the master (the top decision maker) relying on his past experience, ignoring the navigation officer's reports, and making arbitrary decisions without going through the proper decision-making process. This accident was caused by the authority of the top decision maker based on the Garbage Can model, when from the perspective of vessel operation, more people should have been involved in decision-making and execution based on the Carnegie Decision model.

Secondly, in the case of the collision between the Hongkong Voyager and the Tian Fu He, the chief officer did not comply with regulations, despite the existence of guidelines on decision-making during navigational watch, such as having two people on watch and establishing an appropriate decision-making process by calling the master when the watch is limited. It is believed that the accident was caused by arbitrary middle-management decision-making based on a Garbage Can model. A Management Science model with manualization is needed to improve this.

Thirdly, the collision between the Ulsan Pioneer and the Byakko was caused by the Byakko's negligence in keeping watch and failing to call the master when navigating in the narrow channel. The Ulsan Pioneer was also required to give way, but it made decisions when the collision was imminent, thereby increasing the risk of collision. Similar to the collision between the Hongkong Voyager and the Tian Fu He, this accident is believed to have been caused by arbitrary subordinate decision-making. For the Byakko, it seems necessary to apply the Management Science model through quantification and manualization, and for the Ulsan Pioneer, it seems necessary to apply the Carnegie Decision model.

All three of the above accidents can be said to have been caused by arbitrary decisions by decision-makers based on the Garbage Can model. All of them can be said to have been caused by the closed nature of the vessel organization, so a decision-making process that is a mixture of the Carnegie Decision model and the Management Science model seems necessary. The most important factors for rational decision making in a vessel organization are communication between the master and the navigation officer, and adherence to manualized rules in case of emergency. In order to achieve more rational decision-making, it is necessary to provide systematic and continuous training for the members of the vessel organization so that they are fully aware of the importance of the decision-making process and have confidence in it.

Based on these case studies, the policy, theoretical, and practical implications of this study are as follows.

Firstly, the policy implication is that the frequent changes in organizational structure due to personnel rotation at sea necessitate the introduction of the 'My Ship' system. My Ship is a system that allows seafarers to stay on board the same vessel rather than being assigned to the right vessel at the right time due to personnel rotation. The implementation of 'My Ship' is fundamentally dependent on multiple manning and it is believed that a sufficient reserve crew will help to ensure consistent decision making by the vessel organization. Typically, a crew member joins a vessel for a period of 6 to 9 months, and at the end of their contract they apply to leave and are granted leave. It is possible to rejoin the same vessel after a leave of absence, but this is extremely rare due to personnel rotation, and crew members will usually be assigned to a different vessel from the one they were on immediately before. This frequent change in organizational structure is likely to lead to inadequate decision-making processes due to the negligence or responsibility of predecessors and to unclear accountability in the event of an accident, which requires institutional strengthening.

Second, as a theoretical implication, it seems that a decision-making process that can adequately control the subjective knowledge and experience of the top decision maker by fully accepting the opinions of middle managers and subordinate employees who are responsible for and perform the actual work in the decision-making process of a vessel organization is complementary. Since all the accidents in this study were caused by the subjectivity and bias of the top decision maker based on the Garbage Can model, it seems that the Carnegie Decision model, which requires communication and cooperation with many people, or the Management Science model, which is systemized according to rules, is complementary.

In particular, in the case of vessel organizations, the master, who is the top decision maker, has a strong tendency to insist on carrying out their own opinions and orders [70], and wrong decisions by individuals can cause catastrophic financial losses to the company. To prevent this, it is believed that the best decisions should be made through sufficient communication with organizational members and shore-based organizations, and possibly through the introduction and development of decision support systems, such as autonomous navigation [34,37,56,57].

Third, as a practical implication, it is believed that situational awareness is fundamental to decision making in vessel organizations. Situational awareness is defined as 'the ability to perceive what is happening around you in a given space and time, to integrate the information you perceive to understand the current situation, and to predict how the situation will change in the future' [71]. Human error due to poor decision making is actually a problem of situational awareness, not of choice and action in the decision-making process [72,73]. Furthermore, vessel accidents are described as a failure of the safety system, which consists of multiple defenses designed to prevent accidents, rather than a separate system that causes accidents [73,74]. It is no exaggeration to say that the main cause of vessel accidents is the failure of situational awareness combined with human error. However, situational awareness in the maritime field is complex and dynamic and has many applications in mission resource management where human factors are numerous. Particularly on vessels with crews of different nationalities and environments, the level of situational awareness depends on the mutual trust between members of the vessel's organization, the mix of languages, and the understanding of different cultural backgrounds. Seafarers of different nationalities have different values and communication styles. This can lead to gaps in situational awareness, such as the distortion of information. The safe and successful operation of a vessel requires careful planning and decision-making. To make the right decisions for safe operations, a decision-making process similar to voyage planning is required: appraisal → planning → execution → monitoring. It is believed that such a process will contribute significantly to the safe operation of the vessel.

Fourthly, a vessel's rational organization requires the parties performing the work to communicate the circumstances and information relevant to the decision to the top decision maker beyond the hierarchy. For optimum vessel operation, the master and the chief engineer, hereafter referred to as the navigation officer and the engineer, must cooperate and communicate with each other and make decisions based on this cooperation. The master and the chief engineer are formally empowered by law and corporate responsibility. However, there has traditionally been a strong tendency in vessel organizations to create a hierarchical decision-making structure based on personal authority rather than formal authority in decision-making situations. Perhaps the most important factor in making the right decisions is the experience, involvement, and understanding of the members of the organization [75]. In all situations, logical and optimal vessel operations require the cooperation of the master and the chief engineer, and subsequently the navigation officers and the engineers to make decisions based on their cooperation with each other.

The contributions of this study include the fact that this research was conducted on a specific organization, a vessel organization, rather than a general land-based organization, and the analysis of accident case studies of Korean-flagged vessels with strong hierarchical organizational cultures. This differs from previous studies of decision-making processes, which were conducted in general organizations or institutions rather than vessel organizations, and will help to broaden the scope of sustained research on vessel organizations in the future. In addition, the fact that the decision-making process in Korean vessels with a strong hierarchical order was studied can expand the scope of sustainable research on decision-making processes in vessel organizations of different nationalities in the future.

As a limitation of this study, the case studies were conducted only on Korean-flagged vessels, and the study was limited to vessel accidents that occurred in the waters off Korea, China, and Japan, so there is a problem in generalizing the research findings. Therefore, in order to overcome the limitations of this study, it would be interesting to conduct a follow-up study to include vessel accidents of different nationalities or to further investigate the characteristics of the decision-making process in vessel accidents by country. In addition, it is suggested that it is necessary to expand the sample of vessel accidents to include cases involving different types and sizes of vessels.

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