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Original article

Risk Assessment of Man Overboard and Suicide Accidents on a Passenger Ship

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Abstract

In recent years, deaths and missing people have continuously occurred due to man overboard (MOB) and suicide on passenger ships. However, due to the complex deck structure and enlargement of passenger ships, closed-circuit television (CCTV) coverage is limited, and it is difficult to prevent accidents for all passengers with limited crews. Therefore, a real-time system for detecting high-risk blind spots on passenger ships is needed through risk analysis. This study used a combination of the following three risk factors to calculate and evaluate the risk of MOB and suicide by deck area of the passenger ship: 1) distance away from guard rails, 2) the visibility of CCTV, and 3) ship operating conditions. Based on the survey from experts, risk scores of MOB and suicide accidents by deck area on a passenger ship were yielded.

Keywords: Maritime safety, Man overboard, Suicide accident, Passenger ship, Risk assessment

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1. Introduction

Man overboard (MOB) refers to a shipboard accident where a passenger falls into the water and needs rescue (Lucas & Lincoln, 2007; Örtlund & Larsson, 2018; Roberts, 2010; Sevin et al., 2016). It has been reported that MOBs occur on most types of vessels (Chen & Chen, 2019; Örtlund & Larsson, 2018; Pitman et al., 2019; Sevin et al., 2016). In particular, shipping companies and control centers of the government monitor passenger ships in real-time, but human damage due to MOBs and suicides continues to occur (Örtlund & Larsson, 2018; Sevin et al., 2016). In a study, 22 people fall off cruise ships yearly, and only about 20% survive (Örtlund & Larsson, 2018). MOBs and suicides are the leading causes of passenger and crew deaths (Heggie & Burton-Heggie, 2020; Wittlinger & Papathanassis, 2019). Such accidents can cause several problems, such as finding the cause, searching for missing people, and filing a lawsuit against the bereaved families of the victims. These make it challenging to deal with afterward and incur enormous social costs.

Due to the complex deck structure of the passenger ship, closed-circuit television (CCTV) surveillance cameras are limited in their coverage range, and as the passenger ship enlarges, the number of blind spots increases. This makes preventing and rescuing passengers from MOBs and suicides more difficult. Specifically, passengers falling overboard in CCTV's blind spot are impossible to restrain and are hard to search because they have no idea where or when they fell overboard. Additionally, since there is a limit to preventing all safety accidents with limited crew members, MOBs and suicides are difficult to control individually. Thus, it is necessary to develop a system that can detect high-risk areas on passenger ships in real-time through risk analysis.

Despite the importance of MOB research activities, research on pre-emptive measures to improve passenger ship safety through MOB prevention still needs to be completed. Developing proactive methods for quantifying MOBs in routine ship operations is essential. Previous studies (Domeh et al., 2021; Lucas & Lincoln, 2007; Roberts, 2010; Thomas et al., 2001; Yoo, 2019) used post-accident and qualitative analysis methods for MOB scenario analysis. Based on these methods, MOB statistical results can be derived, but it is not predictable how likely MOB will occur during ship operations. Although these methods have successfully identified risk factors at least, most of these studies were for risk analysis of fishing vessels. Only a few studies for risk assessment of passenger ships exist. The risk associated with human evacuation from passenger ships was quantified and ranked by Wang et al. (2023). To date, no published studies have assessed risks for MOBs and suicides deck-by-deck on passenger ships.

Therefore, the purpose of this study is to investigate the risk assessment of MOBs and suicides in deck areas on a passenger ship. We specifically aim to examine the risk factors for the risk assessment of the MOB and suicide accidents and to identify the most dangerous deck area of the passenger ship. To achieve these goals, we interviewed experts in this field to list the risk factors and quantify the risk scores and the importance of each risk factor.

The rest of this paper is organized as follows. Section 2 describes hazard identification through a literature review, brainstorming, and research methods applied in this study. Section 3 presents the analysis results, and Section 4 discusses the findings of this study. Section 5 concludes the study by summarizing and synthesizing its key findings.

2. Methods

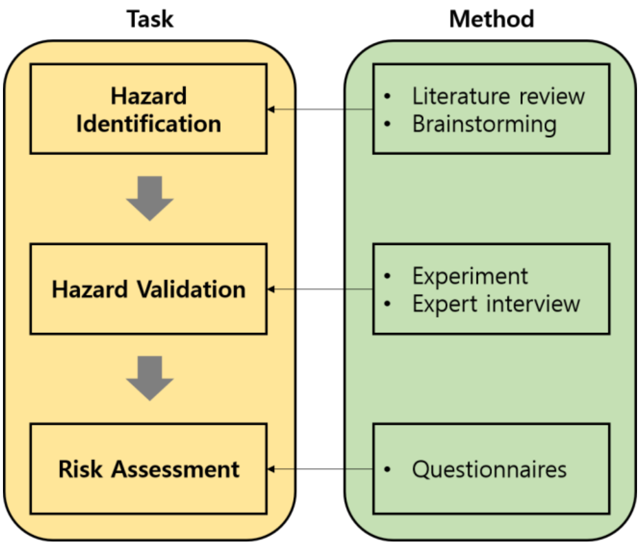


Figure 1. Work Flowchart of the Study

We explored the risk assessment for the MOB and suicide using the training ship of Mokpo National Maritime University (MMU) as a pilot study for a passenger ship. In this section, we introduced the profile of the training ship and study and the methodology for this study. Figure 1 illustrates the workflow of the methodology in this study.

2.1. Ship Profile and Study Area

The training ship "SAENURI", one of the training ships in MMU, was used to carry out the risk assessment for the MOB and suicide in this study. Table 1 summarizes the basic information of the training ship "SAENURI". To mimic the passenger ship, we chose the recreation area on the forecastle deck of "SAENURI", which is similar to the environment of the passenger ship, as shown in Figure 2.

Table 1: Specification of the training ship "SAENURI"

Category	Information	Category	Information
Ship name	SAENURI	Ship type	Training ship
Built year	2003	Main engine / Output	Diesel engine / 4,400 kw
Gross tonnage	4,701 tons	Speed	16.8 knots
Length	103 m	Beam	15.6 m
Depth	9.9 m	Capacity	208 people

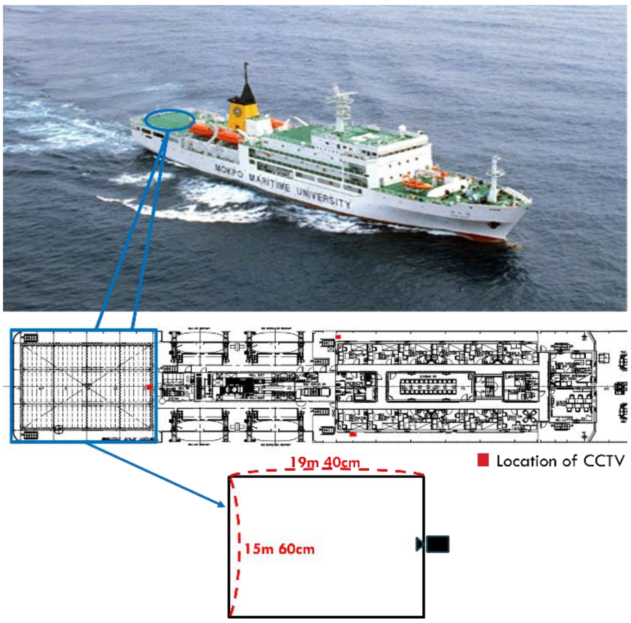


Figure 2. Study Area for the Risk Assessment at the Training Ship "SAENURI"

2.2. Hazard Identification

A literature review and brainstorming were utilized to identify the risk factors that cause MOB and suicide accidents. To pinpoint the relevant literature, we used a combination of the keywords "MOB", "fall overboard", "ship", "passenger ship", and "cruise ship", and in order not to miss out on the relevant risk factors, we explored all possible literature (Bakalos et al., 2021; Domeh et al., 2021; Feraru et al., 2020; Gürüler et al., 2022; Hunter & Hunter, 2013; Lucas & Lincoln, 2007; Örtlund & Larsson, 2018; Qin et al., 2011; Roberts, 2010; Sevin et al., 2016; Tsekenis et al., 2021; Yoo, 2019), including journal and conference papers. In addition to the literature review, further risk factors were determined by brainstorming with our research team. Through this process, we identified the following three hazards for risk assessment of MOB and suicide accidents: 1) a distance away from the guard rail, 2) the visibility of CCTV, and 3) the conditions of ship operation. These three risk factors are parameterized as *d*, *v*, and *c*, respectively

2.3. Hazard Validation

Based on the identified hazards through the literature review and brainstorming, a preliminary experiment and an interview with experts were conducted to validate the hazards specifically.

2.3.1. Distance Away from the Guard Rail (d)

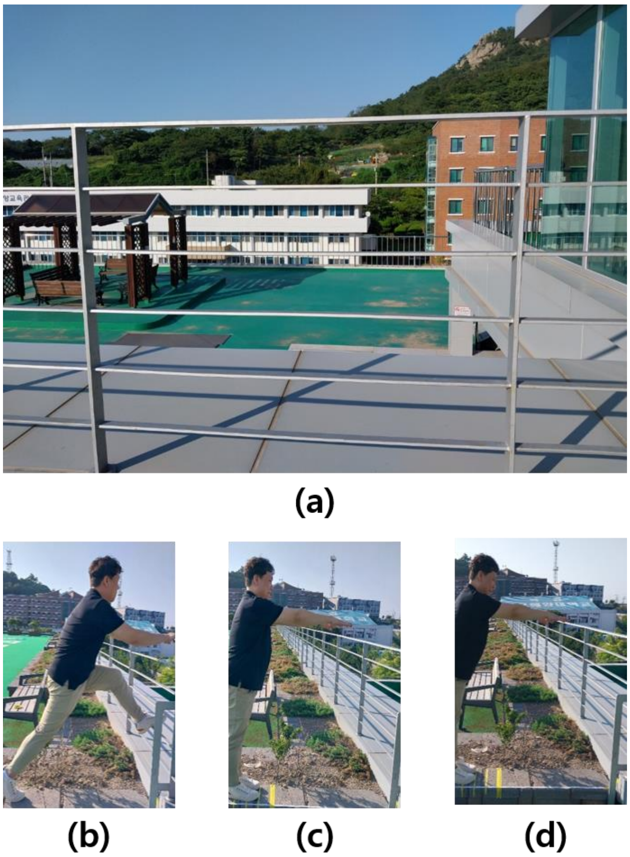


Figure 3. The preliminary experimental settings: (a) the picture of the guard rail (height of the guard rail: 0.95 m), and the sample experimental pictures based on different distances away from the guard rail: (b) distance 1 m, (c) distance 1.1 m, and (d) distance 1.2 m

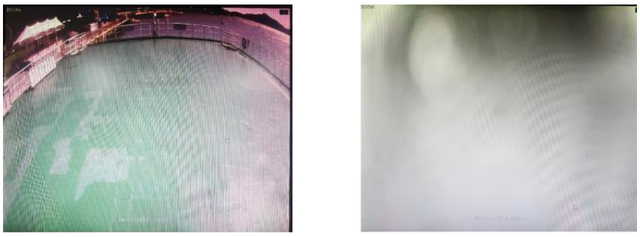
It is obvious that the closer you get to the guard rail, the more dangerous it is for a MOB or suicide on a passenger ship. However, setting distance criteria for risk assessment is a challenge. In this study, we conducted a preliminary experiment to investigate the possible distances for jumping over the guard rail. Figure 3 shows the preliminary experimental settings. We found that jumping over the guard rail at a distance of more than 1.0 m is not easy, as shown in Table 2. Based on the experiment, we finalized the criteria for the distance from the guard rail as <= 0.6 m, 0.6 - 1.0 m, and > 1.0 m.

Table 2: Results of preliminary experiment

Distance	Result
0.6 m	Hands can reach for the rail while standing, which can be jumped over sufficiently.
1.0 m	Hands can reach for the rail by leaning the body and stepping one foot over it, which can be jumped over sufficiently.
1.1 m	Hands can reach for the rail if leaning body entirely, but it is somewhat challenging to jump over the rail.
1.2 m	Hands cannot reach for the rail even if leaning body, and it is difficult to jump over.

2.3.2. Visibility of CCTV (v)

CCTV is the most straightforward camera-based system common to all cruise ships. The CCTV system may not be able to detect an accident by itself, but continuous monitoring by the crew in charge can reveal the exact accident point or time. Alternatively, after receiving notification of the missing person, the crew should review it to see if it fell off the ship. They should also review when and where it occurred, which makes for a poor MOB system (Örtlund & Larsson, 2018). According to one of the experts from a ferry company, passengers who intentionally kill themselves on a passenger ship often jump from blind spots without CCTV or places not viewed by other passengers. Indeed, CCTV cannot cover all areas, so blind spots inevitably exist. Moreover, the image quality of recorded videos varies depending on the performance of CCTV, weather, and day and night. Figure 4 illustrates the visibility of CCTV in "SAENURI" during day and night. We noted that there are blind spots, and the video quality is relatively low at night. Therefore, we included the visibility of CCTV as one of the risk factors for risk assessment of MOBs and suicides.



(a) (b)

Figure 4. Example of the Visibility of CCTV during (a) Day and (b) Night

2.3.3. Condition of Ship Operation (c)

The severity of MOB and suicide accidents depends on various ship operating conditions, such as the location and time of the accident, the weather, and whether the ship is sailing or berthing. For example, if the accident location is far from land, the dispatch time of personnel helping search and rescue, like the Coast Guard, may take a long time. Furthermore, propeller accidents happen when sailing or ships are difficult to stop quickly, which can lead to more severe consequences than when berth. If the weather is bad or the view is poor at night, it can be more difficult to find victims than during the day or in good weather. We adopted the four most influential and predictable conditions for ship operation based on experts' opinions, except for unpredictable factors like weather. The conditions used in this study are 1) sailing/day, 2) sailing/night, 3) at berth/day, and 4) at berth/night.

2.4. Risk Assessment

Based on the derived risk factors, we assessed the risk for MOB and suicide accidents in the study area. The numeric assessment score of the risk (Risk) is defined as follows:

$$Risk = (L_d \times W_d) + (L_v \times W_v) + (S_c \times W_c) \tag{1}$$

where L_d is an average likelihood of risk according to the distance away from the guard rail, L_v is an average likelihood of risk according to the visibility of CCTV, S_c is the average severity of risk when the accidents occur in different conditions of ship operation, and W is the average weight of each risk factor (i.e., W_d, W_v, and W_c are average weights of d, v, and c, respectively). The formulas for L_d, L_v, S_c, and $W_{d,v,c}$ are defined as follows:

$$L_d = \frac{1}{n}\sum_{i=1}^{n} l_{di} \tag{2}$$

$$L_v = \frac{1}{n}\sum_{i=1}^{n} l_{vi} \tag{3}$$

$$S_c = \frac{1}{n}\sum_{i=1}^{n} s_{ci} \tag{4}$$

$$W_{d,v,c} = \frac{1}{n}\sum_{i=1}^{n} w_{di,vi,ci} \tag{5}$$

where *n* is the number of all respondents, l_{di} is a likelihood of risk according to the distance away from the guard rail of respondent *i*, l_{vi} is a likelihood of risk according to the visibility of CCTV of respondent *i*, s_{ci} is the severity of risk when the accidents occur in different conditions of ship operation of respondent *i*, and *w* is a weight for each risk factor of respondent *i*.

Table 3: Respondents' background

No.	Position	Work experience	No.	Position	Work experience
1	Captain	10 – 15 years	9	Professor	20 – 25 years
2	Chief Officer	5 – 10 years	10	2nd Officer	5 – 10 years
3	2nd Officer	5 – 10 years	11	Teaching Assistant	< 5 years
4	2nd Engineer	10 – 15 years	12	Captain	25 – 30 years
5	Chief Officer	15 – 20 years	13	2nd Engineer	5 – 10 years
6	Lecturer	5 – 10 years	14	Chief Engineer	10 – 15 years
7	Chief Engineer	10 – 15 years	15	3rd Engineer	5 – 10 years
8	Captain	20 – 25 years			

To obtain the opinions of experts in relevant fields, a questionnaire was designed using the finalized hazards. A total of 15 experts participated in the survey, and their backgrounds are listed in Table 3. The experts responded to the questionnaire for the likelihood and severity of risk factors using a 5-point Likert scale. Table 4 presents the linguistic terms used for each factor. The experts also answered the weight of each factor for calculating the importance of factors. The sum of each risk factor's weight should be 1.0.

Table 4: Linguistic scale for each parameter

Parameter	1	2	3	4	5
likelihood	very low	low	average	frequent	highly frequent
severity	negligible	marginal	Moderate	critical	catastrophic

Source: Adapted from Chang et al. (2021)

3. Results

We calculated the average values of experts' responses for each risk factor. Tables 5-7 present the average risk score of each hazard based on the experts' opinions. Firstly, for the likelihood of MOB and suicide occurrence according to the distance from the guard rail, as we expected, the closer it is to the guard rail, the riskier it is for MOB and suicide accidents. The average scores for distances <= 0.6 m, 0.6 - 1.0 m, and > 1.0 m were 4.27, 3.73, and 3.00, respectively. Secondly, for the likelihood of MOB and suicide occurrence according to the visibility of CCTV, the average scores were 4.27 when CCTV visibility was out of range and 2.93 when CCTV visibility was in range. Lastly, for the severity of risk based on the condition of ship operation, the average scores were 4.27 when a ship is sailing during the day, 4.93 when a ship is sailing at night, 3.40 when a ship is at berth during the day, and 4.27 when a ship is at berth at night.

Table 5: Average score for the distance from the guard rail

Distance (m)	Average Score
> 1.0	3.00
0.6 – 1.0	3.73
<= 0.6	4.27

Table 6: Average score for the visibility of CCTV

CCTV Coverage	Average Score
In range	2.93
Out of range	4.27

Table 7: Average score for the ship operating conditions

Condition	Average Score
Sailing / Day	4.27
Sailing / Night	4.93
At berth / Day	3.40
At berth / Night	4.27

We also calculated the weight of each risk factor to see which factor was more important, as shown in Table 8. The result shows that the condition of ship operation was most important with a weight of 0.48, followed by the distance away from the guard rail with a weight of 0.29, and the visibility of CCTV with a weight of 0.23.

Based on the above results, we finally obtained the risk assessment by computing the risk using Eq. 1. The results for risk assessment are shown in Table 9. We also visualized the risk assessment results in different ship operating conditions, as shown in Figure 5.

Table 8: Average weight score for each risk factor

Risk Factor	Average Weight
Distance from the guard rail	0.29
Visibility of CCTV	0.23
Condition of Ship operation	0.48

Table 9: Risk score results of risk assessment

Distance (m)	CCTV visibility	Sailing / Day	Sailing / Night	Berth / Day	Berth / Night
> 1.0	In range	3.6	3.9	3.2	3.6
0.6 – 1.0	In range	3.8	4.1	3.4	3.8
<= 0.6	In range	4.0	4.3	3.5	4.0
> 1.0	Out of range	3.9	4.2	3.5	3.9
0.6 – 1.0	Out of range	4.1	4.4	3.7	4.1
<= 0.6	Out of range	4.3	4.6	3.9	4.3

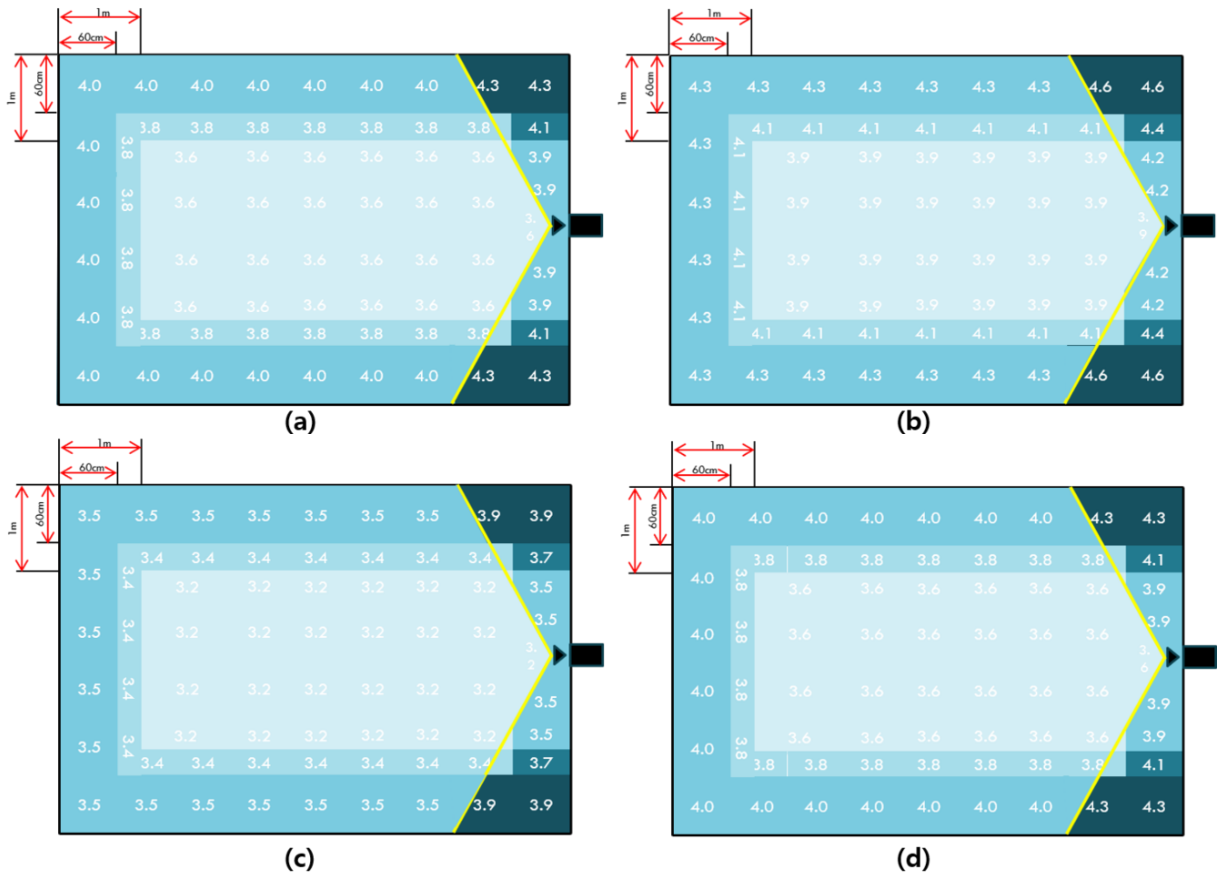


Figure 5. Visualization of the Results for the Risk Assessment by ship operating conditions: (a) Sailing/Day, (b) Sailing/Night, (c) At berth/Day, and (d) At berth/Night

4. Discussion

This study examined risk factors, such as the distance away from the guard rail, the visibility of CCTV, and the condition of ship operation. These factors were used for MOB and suicide risk assessment. The risk scores for each risk factor were calculated. The results show that a closer distance from the guard rail causes higher risk scores (see Table 5). However, most people can be assessed as risky since many people are sightseeing the scenery close to the guard rail on a passenger ship. Hence, caution is needed in the assessment, and the assessment should be made along with other methods of detecting abnormal jumping behavior.

For the visibility of CCTV, when CCTV coverage is out of range (i.e., in the blind spots of CCTV), the risk scores are higher (see Table 6). Although this is a very clear fact, it may not have much impact on the results. Because most CCTVs are fixed so that blind spots do not change significantly, installing more CCTVs to reduce blind spots is not an economically good solution.

The results for ship operation conditions show that the risk score in condition “sailing/night” was highest, followed by “sailing/day” and “at berth/night, and “at berth/day” (see Table 7). Plus, the weight results for each factor show that ship operation conditions are the most weighted factor in assessing MOB and suicide risk (see Table 8). Furthermore, we found that the sailing and night conditions impact the risk assessment equally (see Table 9 and Figure 5). Thus, when sailing at night, the shipping company and crew of the passenger ship need to pay more attention to monitor if there are people who act anomalously to prevent MOB and suicide accidents.

There are still some limitations in this study. Firstly, the number of experts who participated in this study was small. Compared with similar studies (Chang et al., 2021; Domeh et al., 2021; Qin et al., 2011), we believe that the number of experts needed for our study is appropriate for demonstrating the feasibility of the proposed method for analyzing the risk of MOB and suicide accidents on passenger ships. However, as more experts' opinions could enhance the findings, we will increase the number of experts in our future study. Secondly, this study was conducted using the training ship of MMU. Therefore, it may differ from the results of risk assessment on actual passenger ships due to differences in the structure and size of the ship, as well as the performance and number of CCTVs. Despite this, this study can be used as a basis for future verification research on actual passenger ships, as we chose an environment of the study area similar to that of a passenger ship. Lastly, the risk factors used in this research were limited, especially for ship operating conditions. Since we preferred simplifying the assessment model, unpredictable conditions were excluded. Since there are various operating conditions in the real world, it may not be suitable for evaluating the risk in actual ship operating conditions. In particular, CCTV's performance is sensitive depending on the weather, such as fog, rain, and snow, so other ways to compensate for this must be devised in the future.

5. Conclusion

MOB and suicide accidents continuously occur on passenger ships, and the social cost of handling them is considerably high. However, it is not easy to prevent accidents in advance due to the complex hull structure and limited number of crew members. In this paper, we initially investigated the risk factors of the MOB and suicide accidents on a passenger ship using a literature review, brainstorming, and expert interviews. We also assessed the risk for MOB and suicide accidents using the training ship “SAENURI”. Based on the risk assessment results, the most dangerous area was identified depending on different conditions of ship operation. Among the three risk factors, ship operating conditions have more impact on assessing the risk of MOB and suicide accidents. We found that sailing and night conditions are equally important. Our findings can be used as a basis to enhance the risk assessment of MOB and suicide accidents on a passenger ship. This study could help decrease MOB and suicide accidents and save time for search and rescue. Further studies are needed to improve the risk assessment model by using a real passenger ship and more ship operation conditions.

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