A Study for Adapting a Human Reliability Analysis Technique to Marine Accidents

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Abstract: The deck officer who has the duty of navigation and keeping watch on a ship's bridge is known as the officer of the watch (OOW). The OOW is a qualified and capable person with knowledge of ship navigation. According to the Japan Marine Accidents Inquiry Agency, however, "inadequate lookout" is the cause of 84% of collision accidents. In 41% of accidents, "the OOW couldn't find the target until collision," and in 32% of collisions, "even though the OOW had found the target, they didn't maintain a proper lookout." Many of the causes behind accidents pertain to not only the OOW's knowledge and capability, but background factors.

The Japan Transport Safety Board (JTSB) has been established in order to prevent recurrences and to mitigate damages caused by accidents. The JTSB considers introducing analysis method with objective/scientific processes.

The Cognitive Reliability and Error Analysis Method (CREAM) is a technique for analysing human reliability. CREAM organizes interactions between humans and the environment using the human-technology-organization triad. CREAM defines common performance conditions (CPC), the dependencies between them, and the links between antecedents and consequences to clarify the background factors that affect human performance.

This method has mainly been used in the nuclear industry. When analysing the causes of accidents, it is necessary to clarify how much influence conditions have on human performance and the dependencies between CPCs. Since these conditions change across domains, the CPCs will apply differently to domains other than the nuclear industry. For example, in comparing the nuclear industry and the maritime industry, there are significant differences in the influence the work environment has on behaviour and human performance. Therefore, the dependencies between CPCs and priority are now evaluated according to the expert judgment of each domain. To facilitate simple and objective analysis, the CPCs and the dependencies, and the links need to be fitted to each domain.

From a point of view described above, we first proposed CPCs adapted to maritime collision accidents. Secondly, we administered a questionnaire to OOWs for the purpose of quantifying the priority of CPCs.

Though our research is ongoing, we have reached certain conclusions. We herein provide an outline of our findings and the results of the questionnaire survey. We also specifically discuss the priority of the CPCs that were adapted to maritime collision accidents.

Keywords: CREAM, Common Performance Conditions, Pairwise Comparison Method

1. INTRODUCTION

The deck officer who has the duty of navigation and keeping watch on a ship's bridge is known as the *officer of the watch* (OOW). The OOW is a qualified and capable person with knowledge of ship navigation. According to the Japan Marine Accidents Inquiry Agency [1], however, "inadequate lookout" is the cause of 84% of collision accidents. In 41% of accidents, "the OOW couldn't find the target until collision," and in 32% of collisions, "even though the OOW had found the target, they didn't maintain a proper lookout." Many of the causes behind accidents pertain to not only the OOW's knowledge and capability, but background factors.

The *cognitive reliability and error analysis method* (CREAM) is a technique for analyzing human reliability [2]. CREAM organizes interactions between humans and the environment using the *human-technology-organization* triad. CREAM defines *common performance conditions* (CPC) and the dependencies between them to arrange the background factors that affect performance. Fig.1 shows the dependencies. This method has mainly been used in the nuclear industry. When analyzing the causes of accidents, it is necessary to clarify how much influence conditions have on performance and the dependencies between CPCs. Since these conditions change across domains, the CPCs will apply differently to domains other than the nuclear industry. For example, in comparing the nuclear industry and the maritime industry, there are significant differences in the influence the work environment has on behavior and performance [3]. Therefore, the dependencies between CPCs are now evaluated according to the expert judgment of each domain.

To facilitate simple and objective analysis, the dependencies between CPCs and the priority of CPCs need to be fitted to each domain. In principle, all background factors should be investigated. Given our limited resources, however, it is difficult to investigate all background factors. Therefore, we propose that adopt method of pairwise comparisons to define the priority and the weight of CPCs.

2. FACTOR ANALYSIS METHOD FOR MARINE ACCIDENTS

2.1. Overview of CREAM

Applying a human reliability analysis method to analyze marine accidents requires an assessment of decision-making errors made during emergencies. Second-generation human reliability analysis methods are appropriate since they can assess cognitive processes during emergencies. Methods such as CREAM and ATHEANA [6] are examples of second-generation human reliability analysis. CREAM in particular has been utilized for analyzing some marine accidents. There are two techniques associated with CREAM: one involves analysis by screening and the other involves detailed analysis. Analysis by screening is used in this study. The concept of CPCs is introduced to qualitatively analyze human behavioral environments. Nine categories of CPCs are defined. In addition, dependencies are defined between each of the CPCs. Figure 1 shows CPCs and dependencies. Since CREAM is utilized for general working tasks, it cannot apply directly to marine accidents. For the purposes of this study, we have adapted CPCs for marine accidents as in Table 1.

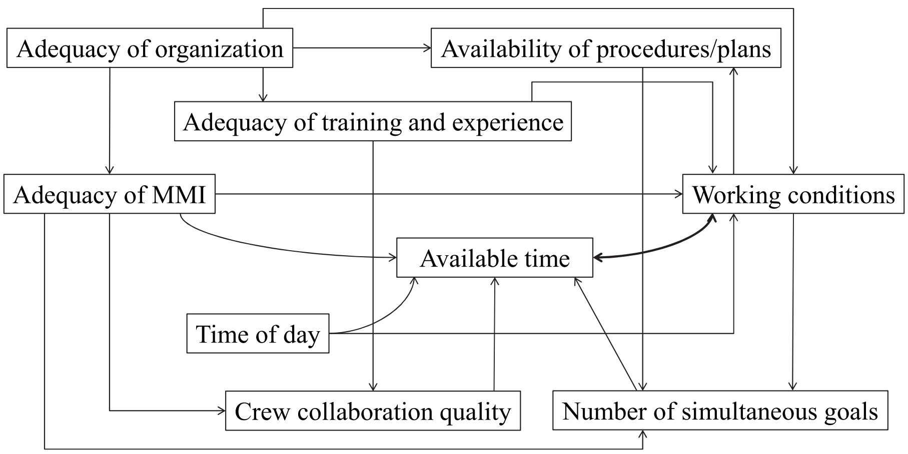

Figure 1: The dependencies between CPCs defined by CREAM

Table 1: Adapted CPC for marine accidents

CPC	Adapted CPC for marine accidents
Adequacy of organization	**Adequacy of safety management** Contents of educational training Systems of educational training Management of navigational watch Outside support and communication
Working conditions	**Navigation conditions** Traffic density Weather conditions Visibility Area in which the vessel is navigating Ship maneuvering characteristics Watch condition on the bridge
Adequacy of MMI and operational support	**Adequacy of human-machine interface** Installed navigational equipment Accessibility of navigational aids
Availability of procedures / plans	**Adequacy of navigation manuals** Chain of command Criteria for avoiding action Navigational conditions Standards, procedures, and guidance Unification of terminology Readability of manual
Number of simultaneous goals	**Number of simultaneous goals** Traffic density Weather conditions Visibility Area in which the vessel is navigating Additional workload
Available time	**Available time** Traffic density Weather conditions Visibility Area in which the vessel is navigating Additional workload
Time of day *(circadian rhythm)*	**Time of day** Day or night
Adequacy of training and experience	**Resource of the officer** Contents of educational training Systems of educational training Knowledge of and confidence in the professional watch Experience of the officer of the watch
Crew collaboration quality	**Communication and information sharing** Communication and information sharing with the bridge team Communication and information sharing with other ships External assistant communication and information sharing

2.2. Human Error in Navigational Watch

Human error in navigational watch is considered the same mechanism of human malfunction proposed by Rasmussen [7]. "Mechanisms of human malfunction" and "internal human malfunction" are affected by external conditions such as "performance shaping factors," "situation factors," and "personnel task."

These categories may be adapt to marine accidents as follows: Causes of human malfunction; bad weather conditions (effect of tide, wind, and visibility), traffic density, and illness. External mode of malfunction; not taking evasive action (asleep, invisible), take wrong evasive action (inadequate knowledge of regulation, own ship handling character, and weather conditions), take evasive action appropriately but couldn't avoid collision (other ship movement). Situation factors; excessive demand, conflict problem, inadequate education and training, lack of manual.

Rothblum [8] summarized that human factors issues in the maritime industry as follows, Fatigue, Inadequate Communications, Inadequate General Technical Knowledge, Inadequate Knowledge of Own Ship Systems, Poor design of Automation, Decision based on Inadequate Information, Faulty standards, policies, or practices, Poor maintenance, and Hazardous natural environment.

We reported the dependencies between CPCs that were adapted to marine collision accidents based on the results of a questionnaire survey [9]. As in Figure 2, these results confirm the essence and character of the maritime industry, the details of which are described below. The dependencies that were common in the definition of CREAM—such as the influence of "Adequacy of human-machine interface"—were extracted. "Available time" affects many other conditions. The influence of "Navigation conditions" is restrictive. The OOW's knowledge and capabilities are influenced by many conditions that differ from those of other industrial domains.

As mentioned above, CREAM organizes interactions between humans and the environment using the human-technology-organization triad. These studies pointed out that various factors affect the human error process. Especially, it supposed that the working conditions of navigational watch is affected by great fluctuation of natural environment than other working conditions.

3. METHOD

The questionnaire survey for the OOWs, including OOWs on training ships, was administered in cooperation with the National Institute for Sea Training, Japan. We created the pairwise comparison

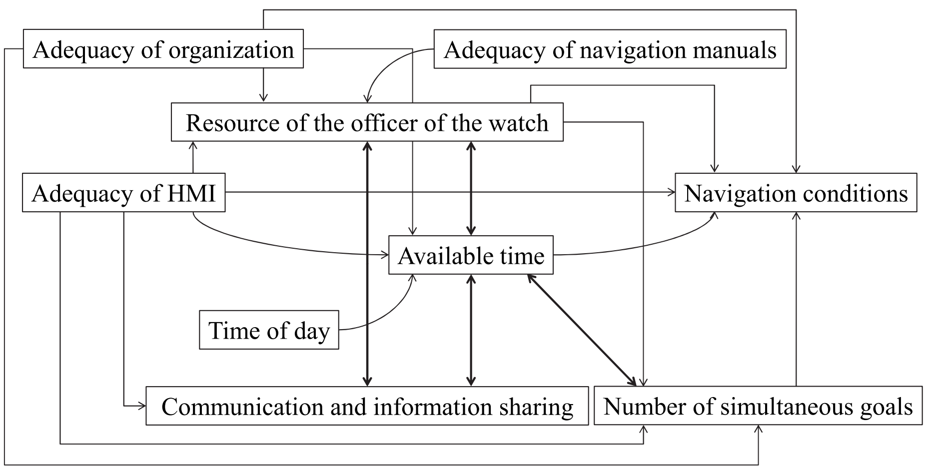

Figure 2: The dependencies between CPCs

questionnaire to clarify the priority of CPCs that were adapted to marine collision accidents. There were 36 combinations. The participants compared and answered that which is more important for prevention of collision accident. Twenty-eight copies were distributed; all copies were collected. The time period for tallying the results of the questionnaires was July 2013 through September 2013.

4. RESULTS AND DISCUSSION

Table 2 shows the profile of the participants. The results which were obtained in the way described above are shown in Table 3. Table 3 shows a pairwise comparison matrix that is based on the Thurstone model. The numbers in the table represent the inverse of the cumulative distribution function of the standard normal distribution. Figure 3 shows the ranking and the weights calculated from pairwise comparison matrix. The weights represent along X-axis. This paper will consider that the ranking and the weights. The highest ranking was "Resource of the officer", and the weight of CPC was exceptionally high. "Available time", "Communication and information sharing", "Number of simultaneous goals" becomes lower in the order of descending priorities. These high weight CPC are presumed to be relating to human or organization. These results shows that CPCs related human or organization are considered to be important factor to prevent collision accident.

On the contrary, the lowest evaluated CPC was "Time of day". This results is similar to the results of preceding survey. For example, "Time of day" was not affected by any CPCs as shown in Figure 2. The number of affected CPC corresponds to the ranking of the CPC. On the other hand, "Resource of the officer" was affected by 5 CPCs, and "Available time" was affected by 6 CPCs. These results showed that the number of affected CPC and the ranking of the CPC having high correlation.

As a result, we may conclude that it may be started investigate background factor at CPCs related human and organization, such as "Knowledge of and confidence in the professional watch", or "Experience of the officer". Considering that the ranking and weight of CPCs, the background factor can investigate more efficiency.

Table 2: Characteristics of survey participants

	No (%) of respondents
Ranks	
Captain	2 (7)
Instructor	3 (11)
Chief Officer	11 (39)
2nd Officer	4 (14)
3rd Officer	8 (29)
Age	
60-	0 (0)
50-59	2 (7)
40-49	9 (32)
30-39	8 (29)
20-29	9 (32)
-19	0 (0)

Table 3: Pairwise comparison matrix for criteria and weights

	Adequacy of safety management	Navigation conditions	Adequacy of Human Machine Interface	Adequacy of navigation manuals	Number of simultaneous goals	Available time	Time of day	Resource of the officer	Communication and Information sharing
Adequacy of safety management	0.00	0.57	0.46	0.37	0.79	1.07	-0.37	1.07	0.79
Navigation conditions	-0.57	0.00	-0.37	-0.57	-0.09	0.18	-0.57	1.24	0.37
Adequacy of Human Machine Interface	-0.46	0.37	0.00	-0.09	0.67	0.57	-0.92	1.07	0.37
Adequacy of navigation manuals	-0.37	0.57	0.09	0.00	0.67	0.79	-0.46	0.92	0.79
Number of simultaneous goals	-0.79	0.09	-0.67	-0.67	0.00	-0.09	-0.92	0.67	0.00
Available time	-1.07	-0.18	-0.57	-0.79	0.09	0.00	-1.80	0.67	0.09
Time of day	0.37	0.57	0.92	0.46	0.92	1.80	0.00	1.24	1.07
Resource of the officer	-1.07	-1.24	-1.07	-0.92	-0.67	-0.67	-1.24	0.00	-0.57
Communication and Information sharing	-0.79	-0.37	-0.37	-0.79	0.00	-0.09	-1.07	0.57	0.00
Total	-4.75	0.37	-1.57	-3.00	2.39	3.55	-7.35	7.45	2.91
Average	-0.95	0.07	-0.31	-0.60	0.48	0.71	-1.47	1.49	0.58

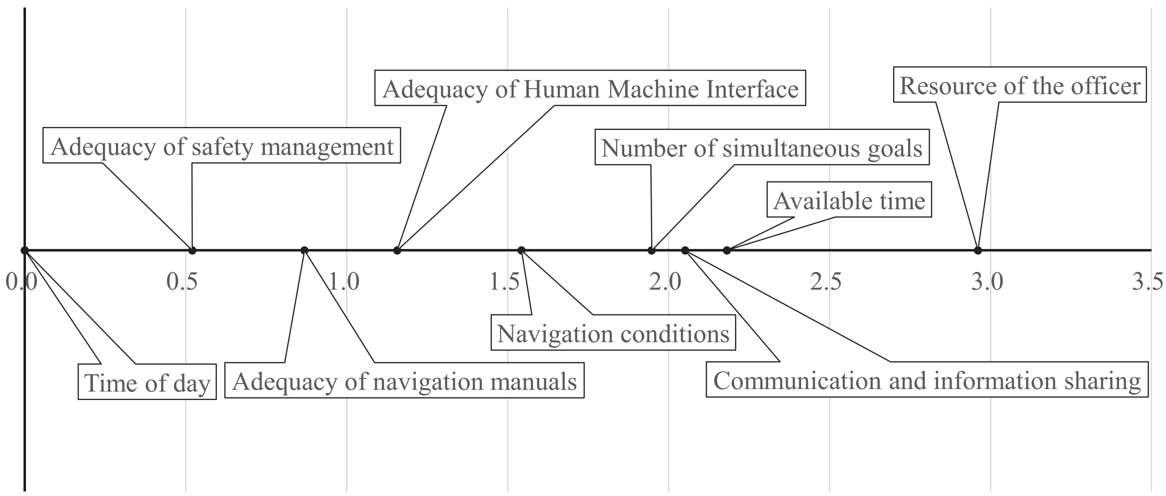

Figure 3: The ranking and weights of CPCs

5. CONCLUSION

To improve reliability assessment, we propose CPCs that are adapted to collision accidents. In addition, we report the results of the questionnaire for clarifying the priority of CPCs for marine collision accidents. These results indicate possibilities that will improve the reliability of CREAM when it is fitted to each domain.

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