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Method for Enhancing Evaluation of the Human Error Probability in Disaster Risk Assessment for Industrial Plants

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ABSTRACT

For the proposal of adequate safety measures in industrial plants, it is very important to conduct an accurate risk assessment. A conventional risk assessment aims to eliminate hazards in the hardware aspects, which have a large impact. In contrast, human factors, which has a smaller impact, is not analyzed in detail, and is evaluated only qualitatively or by using a constant value. However, as the number of hazards is decreasing, it is necessary to analyze human factors as well. The purpose of this study is to support the enhancement of incident-level risk assessment. We examine the assessment method of human error probability that can be conducted by those with limited knowledge of human factors.

Keywords: Human reliability, Risk assessment, Accident report analysis

BACKGROUND

The following three points are necessary to incorporate the impact of human factors in a risk assessment.

(i) Identification of the success scenario for the subject work
(ii) Identification and analysis of factors in the failure scenario (including PSF analysis)
(iii) Determination of the impact of the factors on human error

(i) is performed in a current risk assessment. (ii) is performed by Root Cause Analysis (RCA), etc. For (iii), Success Likelihood Index Method (SLIM), Pair Comparison, and other methods are studied but there is no simple method that can be used practically. The purpose of this study is to support the enhancement of incident-level risk assessment. We examine the assessment method of human error probability that can be conducted by those with limited knowledge of human factors.

INTRODUCTION

Figure 1 shows a current risk assessment flow. In general, risk is assessed based on two indicators: harm severity and probability. First, candidate countermeasures are selected based on harm severity. Next, the specifications of

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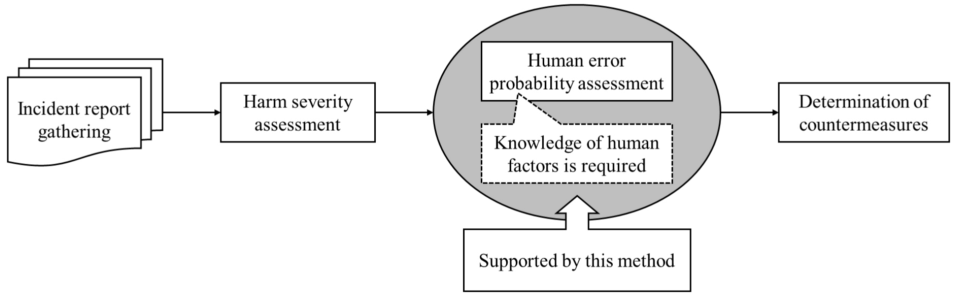

Figure 1: Relations between this method and a practical risk assessment.

countermeasures such as the scope of application, expected lifetime and cost are determined, considering probability. As a result, appropriate countermeasures are introduced in the field that can control risks within acceptable limits. Various countermeasures for accidents caused by human error are considered similarly and introduced in the field. In order to evaluate human error probability, it is necessary to analyze the factors related to human error, which are called Performance Shaping Factor (PSF). However, it requires advanced knowledge of human factors.

Figure 2 shows the work of an analyst. Among them, “Identification and extraction of factors” and “Evaluation of factors” require a high level of knowledge, time and effort. Therefore, this study aims to support these two processes by text mining and creating FIHER database.

In Human Reliability Analysis (HRA), human error probability is evaluated by modifying the Basic Human Error Probability (BHEP) to a value that takes PSF into account. One of the methods is the Cognitive Reliability and Error Analysis Method (CREAM), which is called 2nd generation HRA. CREAM is characterized by the fact that it evaluates the characteristics of the situation/environment based on the following nine concepts called Common Performance Condition (CPC).

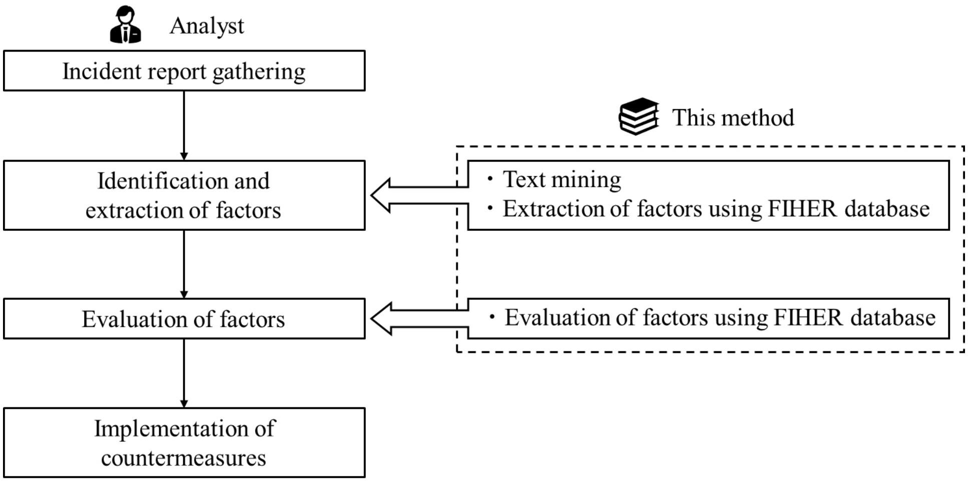

Figure 2: Workflow of an analyst.

- Adequacy of organization
- Working conditions
- Adequacy of MMI and operational support
- Availability of procedures/plans
- Number of simultaneous goals
- Available time
- Time of day
- Adequacy of training and preparation
- Crew collaboration quality

However, CREAM is not suitable for the analysis of incidents in daily work, which is the subject of this analysis. This is because CREAM targets operations in which the result of human error leads to an accident. The purpose of this study is to support incident-level risk assessment in daily work by simplifying the concept of human reliability analysis considering PSF.

We attempted to evaluate human error probability on a scale of six (5: Certain, 4: Likely, 3: Possible, 2: Unlikely, 1: Rare, and 0: Eliminated), which are commonly used in a risk assessment, rather than to calculate detailed values.

PROPOSAL OF THE METHOD

Reference lists of PSF are prepared for various industries but they contain industry-specific items and lack comprehensiveness. Therefore, we created "the database of Factors Influencing on Human Error Risk" (FIHER database). FIHER database consists of three columns: "PSF item column", "influence column" that indicates the influence of each PSF item on human error, and "standard state column" that indicates the state with an influence of 1.

Organize PSF Items

We surveyed previous studies and collected 392 PSF items. These were organized and 85 PSF items were extracted. We collected "constant factors", which are present in work regularly because this study focused on daily work. Specifically, temporary physiological factors such as hunger, drowsiness, and non-routine factors such as an emergency work, temporary shortage of personnel were excluded. Finally, 85 PSF items were classified into 15 major categories and defined as "PSF item column" in FIHER database.

Determine the Degree of Influence on Human Error

An index x_i indicating the influence of each PSF was assigned based on Human Error Assessment and Reduction Technique (HEART) and Tecnica Empirica Stima Errori Operatori (TESEO). These were defined as "influence column" in FIHER database.

We built a system to evaluate the likelihood of human error by matching keywords extracted from incident reports with FIHER database. The system consists of the functions shown in Figure 3. A specific explanation of Figure 3 follows.

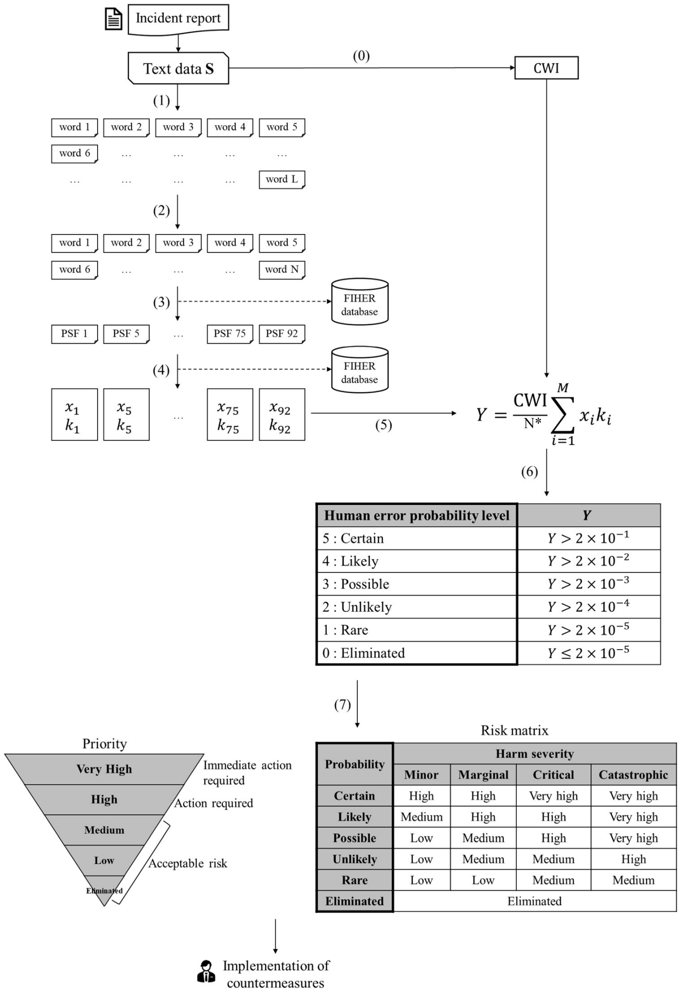

Figure 3: Procedures of the method.

(0) Define the variables.

• CWI (Characteristic of the Work Index): A value representing the characteristics of the work. Select from Table 1.
• M: Number of PSF items present in the FIHER database. ($M = 85$ now)
• x_i ($1 \leq i \leq M$, i is a natural number): The influence of the i-th PSF.
• k_i ($1 \leq i \leq M$, i is a natural number): The state of the i-th PSF. (i-th PSF not exists: $k_i = 0$, i-th PSF exists: $k_i > 0$)

Table 1. Value of CWI.

Characteristic of the work	CWI
Totally unfamiliar	0.55
Required high skills	0.16
Not required high skills	0.02
Completely familiar	0.0004

- $Y = \frac{\mathrm{CWI}}{N^*} \sum_{i=1}^{M} x_i k_i$: human error possibility index

(1) Text mining
Text data S is text-mined to obtain L words.
(2) Data formatting
In order to analyse easily, reduce L^* words by grouping synonyms and deleting words unnecessary for analysis and obtain $N = L - L^*$ words.
(3) Extraction of PSF items
From the N words, select N^* PSF items by referring to PSF item column of FIHER database.
(4) Evaluation of PSF
For the selected N^* PSF items,
•refer to "influence column" of FIHER database and obtain x_i.
•determine state index k_i with the standard state written in "standard state column" as 1.
(5) Evaluate comprehensively
Calculate $Y = \frac{\mathrm{CWI}}{N^*} \sum_{i=1}^{M} x_i k_i$.
(6) Evaluate human error probability level
Based on the result of Y, evaluate human error probability level (HEP level) on a scale of six (5: Certain, 4: Likely, 3: Possible, 2: Unlikely, 1: Rare, and 0: Eliminated).
(7) Adapt to risk matrix
Adapt HEP level and the separately entered harm severity to a commonly used risk matrix and determine countermeasures according to the magnitude of risk.

VERIFICATION

We applied this method to 8 incident reports as test data written in Japanese collected at an oil plant X. The result is shown in Table 2. Combining these results with risk matrix will help determine the priority of countermeasures.

Table 3 shows the factors extracted in X's current risk assessment and in the risk assessment applying this study. In a current risk assessment, factors are specific to individuals and the work environment. It is impossible to evaluate organizational problems or problems with other organizations. However,

Table 2. Result of application.

Text data	Number of characters	Number of PSF extracted	Y	HEP level
Text data 1	188	5	3.4×10^{-3}	3
Text data 2	216	1	1.2×10^{-3}	2
Text data 3	115	1	1.6×10^{-1}	4
Text data 4	150	2	2.2×10^{-3}	3
Text data 5	134	1	6.0×10^{-2}	4
Text data 6	209	1	4.8×10^{-1}	5
Text data 7	48	1	2.8×10^{-3}	3
Text data 8	181	1	3.2×10^{-2}	4

Table 3. Comparison of factors obtained.

Current risk assessment	
• Unpleasant factors (noise, temperature, humidity, dryness, odor, brightness) • Unclear about how to do the work • Disagreement with instructions or rules • Incorrectly read instruments, screens, displays • Not able to judge the situation well • Not visualize the results or the situation well in advance of the action • Actions or checks during the procedure in a cursory manner • Problems with work distribution, ability, or spare capacity • Insufficient meetings, preparation, and organization	
Risk assessment applying this study	
• Too dark lighting	• Narrow area
• High temperature	• Weather conditions
• Low oxygen level	• Not maintained equipment
• Lack of organization	• Inexperienced partner
• High time pressure	• Insufficient equipment
• Impatience	• Unclear scope of work

analysis applying this study makes it possible to extract factors that could not be evaluated. Some examples are shown below.

(Example 1) Request another department. Not get through to the person in charge and suspected a miscommunication.

•Extracted factor: inexperienced partner

The factor related to the relationship with other departments was extracted. This enables to work with consideration of the possibility that they may not be able to communicate with the other party properly.

(Example 2) The inventory is reduced to zero unconsciously because the department that frequently uses consumables and manages them is different.

•Extracted factor: Unclear division of roles

Organizational factor was extracted.

CONCLUSION

We attempted to support a risk assessment in industrial plants by examining human probability evaluation methods that even an analyst with limited knowledge of human factors can use. For the evaluation, we simplified the quantitative evaluation method of PSF in human reliability analysis and created database to refer to "PSF items," "influence," and "standard state". We built a system to evaluate human error probability by matching keywords extracted from incident reports with FIHER database. When this system was applied to incident reports collected at an oil plant, it became possible to evaluate factors that could not be evaluated by a current risk assessment. However, it is a problem for practical application to link with the incident report design because it is sometimes difficult to adapt to this method depending on the incident report design.

REFERENCES

Chandler F. T., Chang Y. H. J., Mosleh A., Marble J. L., Boring R. L., and Gertman D. I. (July 2006). Human reliability analysis methods: selection guidance for NASA, NASA/OSMA Technical Report,

Hollnagel E. (1998). Cognitive Reliability and Error Analysis Method (CREAM), Elsevier.

K Okudaira, C Kojima, S HEMMI, T Takemoto. (2020) "A Study of Identify the Occurrence Factors for Prevention of Seafarer's Disasters" (in Japanese), The Journal of Japan Institute of Navigation, Vol. 142, pp. 45–52

Swain A. D. and Guttmann H. G. (1983). Handbook of Human. Reliability Analysis with Emphasis on Nuclear Power Plant Applications Final Report, NUREG/CR-1278, U. S. Nuclear Regulatory Commission.

T Takemoto, N Mitomo, K Hikita, K Yoshimura. (2012) "A Study on Human Factors Analysis for Possible Factors of Marine Accident -Modifying CPC for Marine Accident Analysis-" (in Japanese), The Journal of Japan Institute of Navigation, Vol. 127, pp. 95–101.

T Yukimachi and M Nagata. (July 2004) "Reference List on Basis of GAP-W Concept and a Case Study" (in Japanese), Human Factors in Japan, Vol. 9, No. 1, pp. 46–62.