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A Quantitative Index to Support Recurrence Prevention Plans of Human-Related Events

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1. Introduction

It is well recognized that human reliability is a critical contributor of the safety of large-scale complex systems such as nuclear power plants [1, 2]. As a cardinal effort to reduce inappropriate human actions in those systems, several articles have emphasized the importance of establishing a report system of occurred events, discovering root-causes of the events, and developing databases for managing information regarding the investigated events [3-6]. In Korea, HuRAM+ (Human related event Root cause Analysis Method plus) was developed to scrutinize the causes of the human-related events [7]. The information of the human-related events investigated by the HuRAM+ method has been also managed by a database management system, R-tracer [8].

It is obvious that accumulating data of human error causes aims to support plans that reduce recurrences of similar events. However, in spite of the efforts for the development of the human error database, it was indicated that the database does not provide useful empirical basis for establishment of the recurrence prevention plans, because the framework to interpret the collected data and apply the insights from the data into the prevention plants has not been developed yet.

In this paper, in order to support establishment of the recurrence prevention plans, a quantitative index, Human Error Repeat Interval (HERI), was proposed and its applications to human error prevention were introduced.

2. HuRAM+ and R-Tracer System

2.1 HuRAM+

The HuRAM+ was developed to identify human error and systematically investigate the error causes during an early investigation of human-related events in nuclear power plants [7]. Fig. 1 shows the process of HuRAM+. In the basic information gathering phase, various information regarding tasks, systems, supervision, and safety culture is collected by operator interviews, document reviews or field inspections. The event outline is then reviewed and the human sub-events (HSEs), which mean inappropriate human actions contributing the occurrence of the event, are identified. During the error type analysis, the types of the HSEs such as slip/mistake or omission/commission and types of tasks such as work domain or operator types are determined. In the final phase, the causes of each HSE are identified using the error cause taxonomy. In this taxonomy, there are the fourteen error categories and the sixty-two detailed causes related with the tasks or systems such as the procedure, workload, training, human system interface, communication, team/operator, supervision, and work plan. The error causes regarding the organizational factors or safety culture also exist in the taxonomy. For the error causes related with the organizational factors, there are the seventeen error categories and the forty detailed causes.

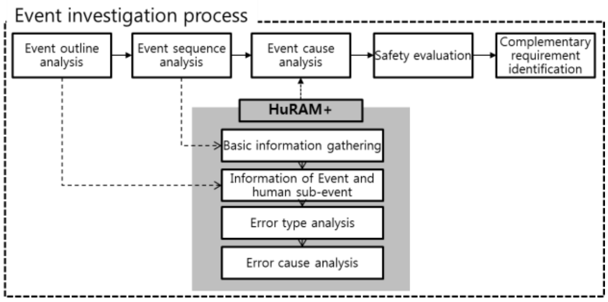

Fig. 1. HuRAM+ process during investigation of human-related events.

2.2 R-Tracer System

As mentioned previously, all information produced by HuRAM+ is managed by R-tracer system. R-tracer system comprises 128 human-related events investigated from 1978 to 2013. There are 160 HSEs and their error causes in the human-related events. This system also provides several basic statistics and graphs for the interpretation of the obtained information. For example, annual frequencies of HSEs for each error type or for each error cause category are calculated and then displayed in tables and graphs.

Although the statistics presented by R-tracer system are essential to understand the overall tendencies or characteristics of human errors, evaluating effects of ongoing recurrence prevention plans using this system is still limited. Hence, it is required to develop an intuitive index which shows a trend or average level of each error cause.

3. Repeat Interval of Human Error

The HERI is defined as a distance of occurrence dates between a HSE and a subsequent HSE that are contributed by a same error cause. A low HERI level relevant with a certain problem implies that HSEs caused by the problem are frequently observed. The HERI can be plotted in a graph and the trend of the HERI can be also estimated via a regression analysis. To assess the trend and average level of each type of error causes, the following statistics of HERIs are basically calculated:

- Mean HERI score: average of all HERI scores
- Slope of linear regression: linear tendency of the HERIs (a high slope score indicates that the relevant HSEs occur less and less frequently)
- Correlation coefficient (r) or coefficient of determination: fitness of the linear trend (absolute value of correlation coefficient over 0.3 can be recognized as significance of the linear trend)

If necessary, the trend of HERIs can be fitted to quadratic, exponential or other types of models.

Table I shows an example of analyzed results for the human error causes in R-tracer system using HERI scores. Fig. 2 also presents the trend estimations on the scatter plots for the two error causes. Via this analysis, it was observed that the unskilledness or unfamiliarity of operators was the most frequent causes in human errors of nuclear plants; in addition, there was no significant trend of the HSEs. Meanwhile, the HSEs regarding the description problems of cautions in procedures were getting frequent. The quadratic model for caution description problem, however, reveals that the HERI score were recently increased.

Table I: Mean HERI score, slope of linear trend, correlation coefficient (r) of error causes frequently observed (unit: days)

Error cause	Mean HERI	Slope	r
Unskilledness or unfamiliarity of operator	228.69	-0.157	~0
Carelessness or insufficient self-checking	267.69	-0.418	~0
Ambiguous or omitted instruction in procedure	471.27	-31.95	-0.356
Absence of independent supervision	624.95	-44.52	-0.422
Ambiguous or omitted caution in procedure	931.06	-145.3	-0.590
Communication omission	963.26	-106.4	-0.358

4. Discussion and Conclusion

In this paper, a quantitative index, the HERI was proposed and the statistics of HERIs were introduced. These estimations can be employed to evaluate effects of recurrence prevention plans to human errors. If a mean HERI score is low and the linear trend is not positive, it can be suspected that the recurrence prevention plans applied every human-related event has not been effectively propagated. For reducing repetitive error causes, the system design or operational culture can be reviewed [9]. If there is a strong and negative trend, systematic investigation of the root causes behind these trends is required. Likewise, we expect that the HERI index will provide significant basis for establishing or adjusting prevention plans of human errors.

To evaluate HERI scores, sufficient reliable data are required. In R-tracer system, there are many event records of human errors. However, because the systematic investigation has been established recently, lots of old records do not include sufficient data regarding error causes. Therefore, the accurate estimation and application of HERI scores is expected to be done after accumulating more data.

When a scatter plot of HERIs is fitted by two or more models, a statistical model selection method can be employed. Some criteria have been introduced by statistician, for example, adjusted R2, Mallow's Cp, AIC (Akaike Information Criterion), BIC (Bayes Information Criterion), and PRESS (Predicted Residual Sum of Squares) [11].

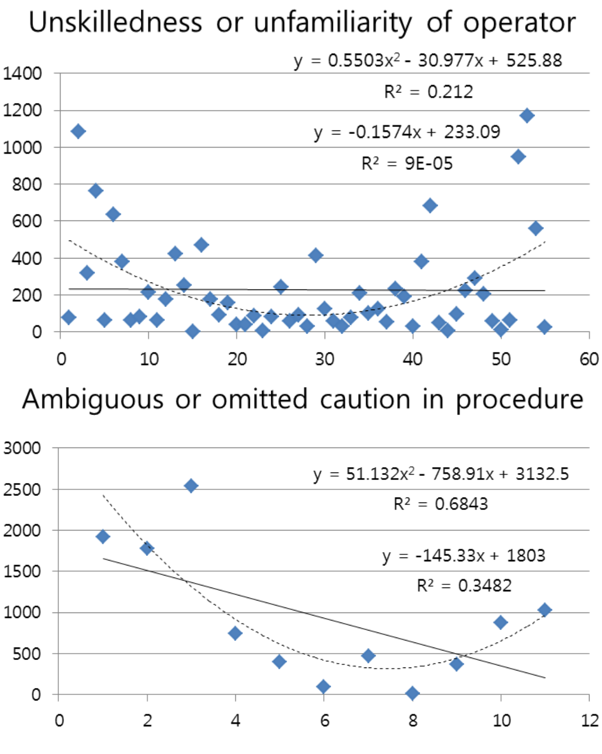

Fig. 2. Trend estimation with scatter plots of HERIs about (top) unskilledness or unfamiliarity of operator and (bottom) ambiguous or omitted caution in procedure.

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