Transactions of the Korean Nuclear Society Autumn Meeting
Changwon, Korea, October 20-21, 2022

Application of Difficulty Evaluation Method on Safety Culture Attributes

Jeeyea Ahn, Wooseok Jo, Byung Joo Min, and Seung Jun Lee*
Ulsan National Institute of Science and Technology, 50 UNIST-gil, Ulju-gun, Ulsan, 44919, Republic of Korea.
**Corresponding author: sjlee420@unist.ac.kr*

1. Introduction

The importance of human and organizational factors such as safety culture is increasing in the safety of large systems such as the nuclear industry. It is essential to have an effective integrated management system for larger and more complex systems such as nuclear power plant operation organizations [1-2]. An effective management system requires systematic methods and criteria for decision-making.

Unlike mechanical failures and equipment failures, a complex system with human and organizational factors is hard to express as a simple process such as a linear causality model. A typical method of improving technical and facility safety is to identify (i.e., contribute more to risk) vulnerable components through risk assessment (referred to as safety assessment) and improve them. However, even in this process, human and organizational factors still remain a challenging part because they have great uncertainties to be evaluated with a linear model.

Accordingly, the authors proposed the concept of 'difficulty' and an evaluation method to provide a new perspective on human and organizational factors such as safety culture [3]. This paper shows an application of the difficulty assessment methodology through the participation of incumbents in domestic nuclear regulatory and operating organizations.

2. Methods and Results

As suggested in the previous study, an expert AHP technique is used to determine the weight of difficulty contributors [4]. The survey was conducted from period June to July 2022. The participants are incumbents from two representative organizations in the domestic nuclear industry (i.e., regulatory and operating organizations). The average tenure of the participants is about 16 years (estimated as a median value based on the responses by section. 2 people under 5 years, 6 people in 5-10 years, 10 people in 11-15 years, 18 people in 16-20 years, 20 people 13 people over the year, 1 refusal to respond). The total number of participants is 50.

2.1 Difficulty Evaluation Method

As introduced in previous studies, the difficulty evaluation process is performed in the following order. 1) Select the evaluation target. 2) Develop evaluation criteria. Develop qualitative and quantitative criteria as needed. 3) Conduct evaluation. In this paper, 43 attributes of the harmonized safety culture (HSC) model were selected as evaluation targets [5]. For the difficulty evaluation criteria, the qualitative evaluation criteria used DCHM developed through previous studies, and the expert AHP technique was used to determine the quantitative criteria. This process was conducted through the survey described above, and the difficulty evaluation results reflecting the results are described below.

For difficulty evaluation subject $x_i = \{x_1, \ldots, x_n\}$, $d_i$is the degree of difficulty (i.e., quantitively evaluated result) of x_i. Q_i is a qualitative difficulty evaluation matrix of x_i, and W is a weighting matrix of elements of Q_i (i.e., difficulty contributors).

$$d_i = Q_i \cdot W$$

The degree of difficulty does not have a meaning by itself as a quantified value, but serves to provide implications through relative comparison. Therefore, $D = \{d, \ldots, d_n\}$ is normalized for convenience so that the mean is 0.5. Normalized d_i indicates relative difficulty among all elements within the subject group, it can show which elements have higher or lower difficulty than average.

$$d_{i,normalized} = 0.5 + \left(d_i - \frac{\sum_{k=1}^{n} d_k}{n}\right) \times \left(\frac{\sum_{k=1}^{n}\left(d_k - \frac{\sum_{j=1}^{n} d_j}{n}\right)^2}{n} \times 100\right)^{-\frac{1}{2}}$$

2.2 Aggregation Results

The two organizations are labeled A and B for anonymity. A consistency ratio (CR) is widely used to check the reliability of response. If the response is based on a logical and consistent criterion, the CR has a low value. The CR value is calculated as the ratio of the consistency index and the random index of the evaluation result [6]. In this AHP process, an inverse linear scale was adopted for the judgment scale, and the random index values are shown in Table I [7]. In general, when CR<0.1, it can be considered that the consistency of the response is reliable [6]. In this application, CR<0.1 was used as the screening criterion. The degree of difficulty based on the integrated weights is shown in Fig.1. For comparison, D_X represents a set of degree of difficulty for organization X. (i.e., $D_X = \{d, \ldots, d_n | X\}$). A comparison the difficulty D_A and D_B of the safety culture attributes is shown in Fig.2.

Table I: Random index for inverse linear scale [7]

n	3	4	5	6	7	8	9	10
RI	0.205	0.333	0.417	0.475	0.517	0.547	0.572	0.590

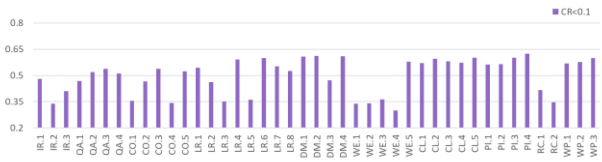

Fig. 1. Normalized degree of difficulty for forty-three safety culture attributes

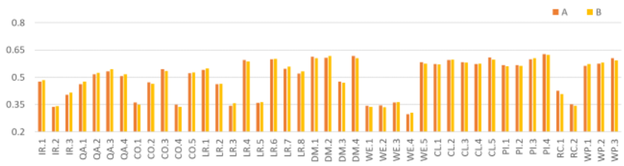

Fig. 2. Comparison of difficulty evaluation results between two representative organizations

Relative difficulty is expressed in color so that the relative size can be easily recognized. Cells in Table II express the relative difficulty in color, and the maximum is red, the minimum is green, and the middle is yellow. As can be seen, all elements show a similar color trend in different organizations.

Table II: Comparison of difficulty evaluation results by colors

Traits	D_A	D_B	D_{total}
IR			
QA			
CO			
LR			
DM			
WE			
CL			
PI			
RC			
WP			

Table III classifies relative difficulty groups based on color. The results of classifying grades based on color were the same for organizations A, B, and all (i.e., D_A, D_B, and D_{total}). The elements corresponding to the relatively high difficulty group are DM.1, DM.2, DM.4, and PI.4. In this way, it can be used as a tool for a graded approach by assigning a grade to the evaluation result.

Table III: Relative Difficulty of Safety Culture Attributes

Relative difficulty	Attributes
High	DM.1, DM.2, DM.4, PI.4
Mid-high	LR.4, LR.6, WE.5, CL.1, CL.2, CL.3, CL.4, CL.5, PI.1, PI.2, PI.3, WP.1, WP.2, WP.3
Mid	QA.2, QA,3, QA.4, CO.3, CO.5, LR.1, LR.7, LR.8
Mid-low	IR.1, IR.3, QA.1, CO.2, LR.2, DM.3, RC.1
Low	IR.2, CO.1, CO.4, LR.3, LR.5, WE.1, WE.2, WE.3, WE.4, RC.2

3. Conclusions

The difficulty assessment methodology has the following advantages and limitations. It can be performed even if the participants have no knowledge of the harmonized safety culture model. However, evaluation results may not be sufficient due to some unidentified difficulty contributing factors. Nevertheless, as a result of applying this evaluation methodology to representative domestic nuclear power organizations, its usefulness was confirmed.

ACKNOWLEDGEMENTS

This work was supported by the Nuclear Safety Research Program through the Korea Foundation Of Nuclear Safety (KoFONS) using the financial resource granted by the Nuclear Safety and Security Commission (NSSC) of the Republic of Korea. (No. 2003011)

REFERENCES

[1] IAEA, Application of the Management System for Facilities and Activities, 2006

[2] IAEA, Leadership and Management for Safety, 2016

[3] Ahn, J., Min, B.J., and Lee, S.J. "Graded approach to determine the frequency and difficulty of safety culture attributes: The FD matrix." *Nuclear Engineering and Technology*, 54.6 (2022): 2067-2076.

[4] Ahn, Jeeyea, et al. "A Quantification Method Evaluating Difficulty of Safety Culture Factors.", Transactions of the Korean Nuclear Society Autumn Meeting, 2021.

[5] IAEA, A Harmonized Safety Culture Model - IAEA Working Document, 2020.

[6] T. L. Saaty, *The analytic hierarchy process : planning, priority setting, resource allocation*, New York; London: McGraw-Hill International Book Co., 1980.

[7] J. Franek, and A. Kresta, Judgment Scales and Consistency Measure in AHP, Procedia Economics and Finance, vol. 12, pp. 164-173, 2014.