A Quantification Method Evaluating Difficulty of Safety Culture Factors

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.
Email address: jeeya@unist.ac.kr

** Corresponding Author*

1. Introduction

There is a growing recognition that organizational factors such as safety culture significantly contribute to the safe operation of nuclear facilities. It was found that safety culture influences human/organizational safety performance, as organizations with higher maturity safety culture have lower accident rates [1-3]. By the necessity of this, various definitions of the concept of safety culture have been proposed according to different viewpoints [4-10]. In the nuclear field, the IAEA has defined safety culture as "That assembly of characteristics and attitudes in organizations and individuals which establishes that, as an overriding priority, nuclear plant safety issues receive the attention warranted by their significance" [6].

The purpose of addressing safety culture is to develop safety outcomes to achieve a higher level of safety. To effectively promote safety culture, an in-depth analysis of safety culture is required, such as to analyze how certain aspects or elements of safety culture (hereinafter referred to as safety culture elements) affect certain aspects of safety, what characteristics of safety culture elements have, and how these characteristics affect safety performance. Characteristics for each safety culture element can be analyzed as a deductive method.

In this study, the concept of degree of difficulty is introduced as a generic term for the extent and difficulty of efforts made to meet safety culture principles. By introducing the concept of degree of difficulty for each element of safety culture, it is possible to analyze the safety culture from a decomposable point of view. For example, it is possible to determine whether a safety culture element that is frequently an issue is because it is difficult to comply with related principles. And it can help to establish an effective and appropriate level of response strategy according to the analysis result. In addition, safety culture represents the culture of the organization from a safety point of view, each organization has its own unique characteristics. In other words, the viewpoint on safety culture may differ depending on the characteristics or role of the organization. For example, regulatory agencies and operating agencies may have different views on a safety culture principle. To achieve high nuclear safety at the national level, communication between various organizations such as operating agencies and regulatory agencies is essential. However, if each organization has a different view on which of the various elements constituting the safety culture is an obstacle to achieving a high level of safety culture, it will be difficult to gather consensus in establishing appropriate strategies. It is required to understand at what point their views differ on safety culture. The introduced method can reveal the safety culture factors in which the differences in viewpoints are large and will help to promote mutual understanding between organizations.

2. Methods and Results

The safety culture factors refer to the components of the safety culture model that are considered to constitute the safety culture. In this study, the Harmonized safety culture (HSC) model, developed in collaboration with IAEA, INPO, WANO, and other regulatory agencies, was utilized, and the traits and attributes of the model were assumed as safety culture factors (Table **1**).

It seems that actions or some subordinates are required to comply with the principles of safety culture, according to the cases related to lack of safety culture. For example, complying with the safety culture principle of complying with procedures may be considered to be inconveniently performed according to the procedure, depending on the point of view, which may appear to be easily performed with flexibility. Likewise, complying with the safety culture principle, whether right or wrong, may cause potential inconvenience or difficulties. Including all these kinds of hindrance factors, it was defined as the difficulty of safety culture factors, and the degree of difficulty was quantified.

Table 1 Harmonized Safety Culture: Traits & Attributes [11]

Traits	Attributes	
IR Individual Responsibility	IR.1	Adherence
	IR.2	Ownership
	IR.3	Collaboration
QA Questioning Attitude	QA.1	Recognize Unique Risks
	QA.2	Avoid Complacency
	QA.3	Question Uncertainty
	QA.4	Recognize and Question Assumption
CO Communication	CO.1	Free flow of information
	CO.2	Transparency
	CO.3	Reasons for Decisions
	CO.4	Expectations
	CO.5	Workplace Communication

LR Leader Responsibility	LR.1	Strategic Alignment
	LR.2	Leader Behavior
	LR.3	Employee Engagement
	LR.4	Resources
	LR.5	Field Presence
	LR.6	Rewards and Sanctions
	LR.7	Change Management
	LR.8	Authorities, Roles, and Responsibilities
DM Decision-Making	DM.1	Systemic Approach
	DM.2	Conservative Approach
	DM.3	Clear Responsibility
	DM.4	Resilience
WE Work Environment	WE.1	Respect is Evident
	WE.2	Opinions are Valued
	WE.3	Trust is Cultivated
	WE.4	Conflicts are Resolved
	WE.5	Facilities Reflect Respect
CL Continuous Learning	CL.1	Constant Examination
	CL.2	Learning from Experience
	CL.3	Training
	CL.4	Leadership Development
	CL.5	Benchmarking
PI Problem Identification and Resolution	PI.1	Identification
	PI.2	Evaluation
	PI.3	Resolution
	PI.4	Trending
RC Raising Concerns	RC.1	Supportive Policies are Implemented
	RC.2	Confidentiality is Possible
WP Work Planning	WP.1	Work Management
	WP.2	Safety Margins
	WP.3	Documentation and Procedures

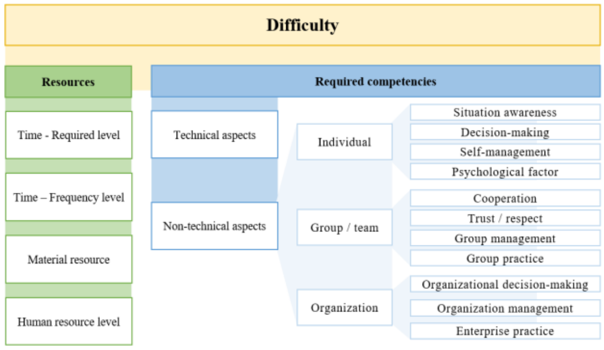

Fig. 1 The Difficulty Contributor Hierarchical Model (DCHM)

A stratified model, called DCHM, was developed by deriving contributing factors that affect the difficulty (Fig. **1**), and weights were derived for each contributor. The hierarchical model of the difficulty contributing factor was developed through literature research and expert advice, and the weight for each factor was derived by performing expert analytic hierarchy process (AHP). Since the importance can be evaluated differently depending on the point of view, the opinions of experts in various organizations were collected. The final weights were integrated through the aggregating individual priorities (AIP) method. The difficulty of safety culture factors evaluated by the integrated model is as Fig. **2**. Since individual weights reflecting their opinions were derived for each expert, the results evaluated by the individual weight of each expert were compared to examine the difference as Fig. **3**.

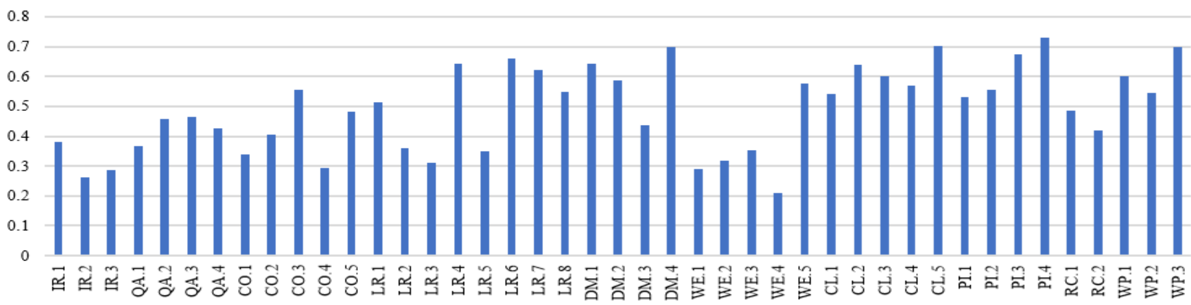

Fig. 2 Integrated Results of Degree of Difficulty for each safety culture attribute

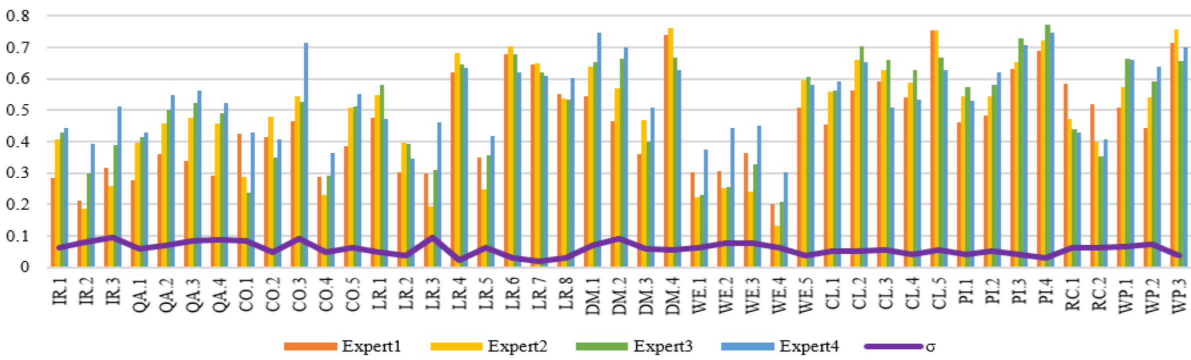

Fig. 3 Comparative Results of Degree of Difficulty with Individual Weights

Table 2 Comparative Degree of Difficulty Based on Traits

Traits	Integrate	Expert 1	Expert 2	Expert 3	Expert 4
IR	0.33514	0.27140	0.28406	0.37149	0.44994
QA	0.42867	0.31650	0.44699	0.48179	0.51620
CO	0.41592	0.39555	0.41029	0.38278	0.49248
LR	0.50062	0.49096	0.49499	0.51433	0.52032
DM	0.59121	0.52784	0.60963	0.59687	0.64551
WE	0.34888	0.33655	0.28841	0.32612	0.43016
CL	0.61055	0.57968	0.63803	0.64360	0.58249
PI	0.62202	0.56685	0.61560	0.66324	0.65110
RC	0.45180	0.55094	0.43637	0.39590	0.41802
WP	0.61466	0.55584	0.62401	0.63772	0.66567

Table 2 shows the average difficulty of the attribute for each trait. The color of each cell represents the normalized relative difficulty for each column. The element that has a relatively large value is expressed as red, while the green color indicates the element has a relatively small value. And if the element has a relatively intermediate score, it is expressed as yellow. And the color is expressed as a gradient color depending on the degree.

Based on the trait, WP, PI, CL, and DM showed relatively high difficulty, and IR, WE, QA, and CO showed relatively low difficulty. LR and RC were evaluated with relatively medium difficulty. In the case of RC, there was the largest difference of opinion among experts. Comparing the results of experts 1 and 4, the RC is evaluated as relatively low difficulty according to expert 4, while the RC is evaluated as a relatively high difficulty according to expert 1. These results indicate that the difficulty level can be evaluated differently depending on the viewpoint, and through in-depth analysis of the factors showing a large difference, it is possible to find out the difference of viewpoints or opinions of experts in each institution, which promotes mutual understanding of safety culture.

When this result is decomposed based on the attribute, it appears as shown in Fig. 4. From the decomposition point of view, WP.3, CL.5, PI.3, PI.4, and DM.4 are the elements with relatively high difficulty based on the attribute, and experts' opinions on them are generally consistent. In other words, it can be expected that experts will evaluate the difficulty of Documentation and Procedures, Learning from Experience, Problem Resolution, Problem Trending, and Resilience relatively high among safety culture factors. On the other hand, the attributes that showed a large difference of opinion on difficulty by experts were CO.3, CL.3, RC.1, and RC.2. This indicates that opinions on the Implementation of Supportive Policies and Confidentiality regarding raising concerns, Communication of Reasons for Decision, and Training may differ significantly from one point of view to another.

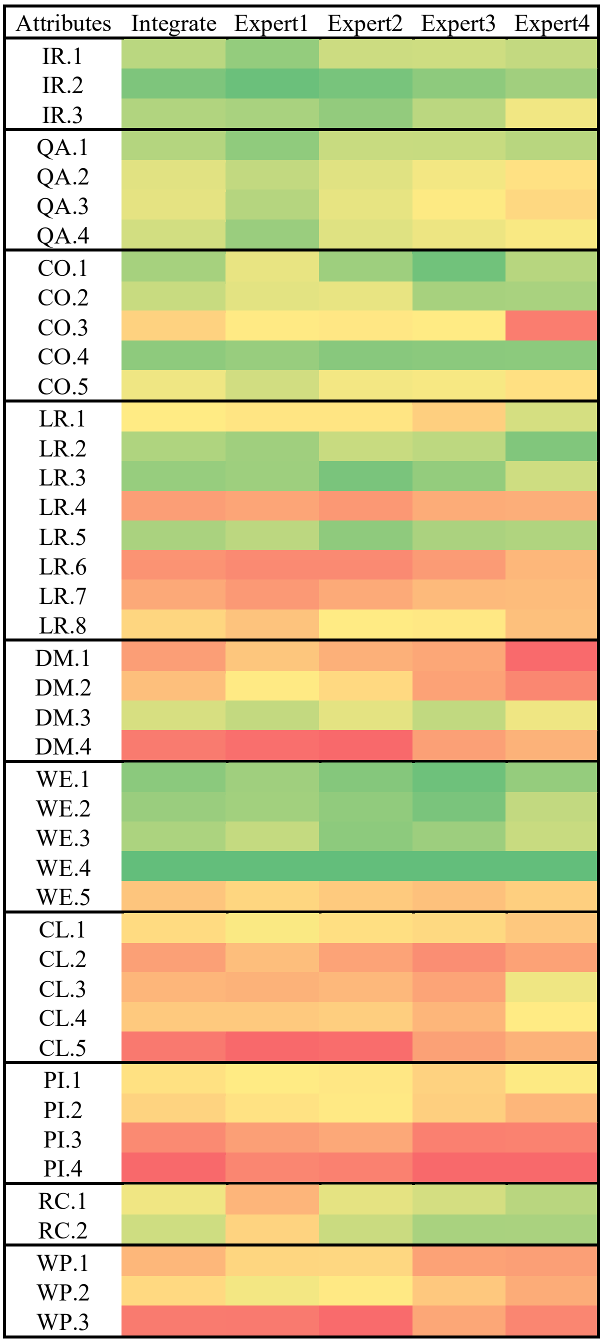

Fig. 4 Comparative Degree of Difficulty Based on Attributes

3. Conclusions

This study defined the concept of degree of difficulty as a unique characteristic of safety culture factors and attempted to quantify it. In the process of quantifying the difficulty of safety culture factors, opinions of experts from domestic organizations, a regulatory agency, an operating organization, a research institute, and an academic institution, were collected. The results of evaluating the difficulty based on the integrated weights were generally similar to the evaluation results based on the weights of individual experts. However, there were fairly large differences in some factors, indicating differences in opinions of each expert. Even though the opinions of one expert were collected for each institution, their responses are likely to be reliable, since all of the experts from domestic nuclear power agencies who participated in DCHM and the weighting of this model had research experience or field experience on safety culture. However, they may have a different view from the operators who operate the nuclear power plant in the field. Therefore, to compensate for these limitations, it is necessary to set and apply a wider pool of respondents. If the responses of experts in the field are compared with those of academic experts who plan strategies, it will be possible to reveal differences of opinion between the two and contribute to establishing a more effective strategy promoting safety culture. Also, if statistical significance is obtained by collecting the opinions of the sample groups for each institution, it will be possible to analyze the differences in the viewpoints of each institution, and the results would help enhance mutual understanding.

The HSC model used in the case study is still under development and has not been released as an official document of the IAEA. However, since this model was developed by gathering consensus among nuclear-related organizations around the world to communicate safety culture, it will serve as a basis for future discussions on nuclear safety culture. However, at present, domestic nuclear organizations are not using the HSC model. This study introduced an independent difficulty quantification method that can measure the degree of difficulty of each element of safety culture regardless of specific models of safety culture. The introduced methodology can be applied even in a transitional situation in which the safety culture model is not definitive.

ACKNOWLEDGEMENTS

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

REFERENCES

[1] K. Mearns, S. M. Whitaker, and R. Flin, "Safety climate, safety management practice and safety performance in offshore environments," *Safety Science,* vol. 41, no. 8, pp. 641-680, 2003, doi: 10.1016/s0925-7535(02)00011-5.

[2] S. L. Morrow, G. Kenneth Koves, and V. E. Barnes, "Exploring the relationship between safety culture and safety performance in U.S. nuclear power operations," *Safety Science,* vol. 69, pp. 37-47, 2014, doi: 10.1016/j.ssci.2014.02.022.

[3] E. Stemn, C. Bofinger, D. Cliff, and M. E. Hassall, "Examining the relationship between safety culture maturity and safety performance of the mining industry," *Safety Science,* vol. 113, pp. 345-355, 2019, doi: 10.1016/j.ssci.2018.12.008.

[4] IAEA, *Summary Report on the Post-accident Review Meeting on the Chernobyl Accident*. Vienna: INTERNATIONAL ATOMIC ENERGY AGENCY, 1986.

[5] S. Cox and T. Cox, "The structure of employee attitudes to safety: A European example," *Work & Stress,* vol. 5, no. 2, pp. 93-106, 1991/04/01 1991, doi: 10.1080/02678379108257007.

[6] IAEA, "Safety Culture," in "INSAG-4," INTERNATIONAL ATOMIC ENERGY AGENCY, Vienna, 1991. [Online]. Available: https://www.iaea.org/publications/3753/safety-culture

[7] N. F. Pidgeon, "Safety Culture and Risk Management in Organizations," *Journal of Cross-Cultural Psychology,* vol. 22, no. 1, pp. 129-140, 1991, doi: 10.1177/0022022191221009.

[8] HSC, "ACSNI study group on human factors. 3rd report: Organising for safety," Health and Safety Commission, London, 0 11 882104 0, 1993.

[9] M. D. Cooper, "Towards a model of safety culture," (in English), *Safety Science,* vol. 36, no. 2, pp. 111-136, Nov 2000, doi: Doi 10.1016/S0925-7535(00)00035-7.

[10] INPO, *Principles for a Strong Nuclear Safety Culture*. Institute of Nuclear Power Operations, 2004.

[11] IAEA, "A Harmonized Safety Culture Model - IAEA Working Document," International Atomic Energy Agency, 2020. [Online]. Available: https://www.iaea.org/sites/default/files/20/05/harmonization_05_05_2020-final_002.pdf