Development of a Method and Questionnaire to Quantify the Resilience of the Emergency Response Organizations

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1. Introduction

The emergency response organizations (ERO) for the radiation emergency are established to 1) quickly suppress incidents or accidents, 2) minimize the casualties, and 3) prevent the leakage of radioactive materials to the environment and public. The ERO must sustain the required function under both expected and unexpected conditions.

Organizational resilience, which focuses on how to cope with complexity under pressure or disturbance to achieve success [1]. In this respect, a resilient organization can be said to be reliable. However, it is difficult to know whether the ERO can sustain the required function under the several potential challenges and disturbances. Moreover, there have been few studies trying to quantify whether the ERO is “reliable”.

This study aims to suggest a method to quantify the resilience of EROs including a questionnaire to be used by experts. This study consists of four steps. First, the contributing factors to the resilience of the ERO were identified by a literature survey on organizational resilience. Second, the contributing factors were modified and added to the initial structure of contributing factors. Thus, Delphi method was used to determine a final structure of thecontributing factors to the resilience of ERO. Third, the relative importance between the revised factors was evaluated to assess the resilience quantitatively by using the AHP (analytic hierarchy process) method. Finally, the questionnaire that can quantify the resilience of the ERO is developed.

2. Methods

2.1 Literature Survey

In this study, a literature survey has been conducted to identify the structure of contributing factors to the resilience of ERO. A total of 69 pieces of literature were reviewed and divided into seven domains (i.e., General, Process Plant, Business, Medical & Healthcare, Transportation, Infrastructure, and The Others) according to the application area.

At first, all the contributing factors included in the literature were accumulated. Then, the factors not relevant to the emergency response are deleted and the factors with duplicating meanings are merged into one factor. As a result of this step, the initial structure of contributing factors consists of 55 factors with a three-level hierarchy structure identified as shown in the Figure 1. Level-1 factors adopt the resilience analysis grid (RAG) factors proposed by Erik Hollnagel (i.e., Responding, Monitoring, Learning, and Anticipating) suggested by Erik Hollnagel [2]. In the structure, Level-3 factors have the most specific meaning and Level-1 factors have the broadest meaning.

2.2 Delphi method

In this study, the Delphi method is used to derive absolute importance values and modify the initial structure of the contributing factors. The Delphi is a very flexible decision-making method that can reach consensus through the collection of experts’ opinions on a given issue. [3] It makes us reach a consensus through repetitive surveys (referred to as “rounds”). In the process, feedback on the response is provided at every round, allowing experts to modify or change their opinions.

In this study, a total of two rounds of surveys on the contributing factors to resilience are conducted with 20 experts. The experts are from the regulatory body, research institutes, the utility, some universities, and government agencies. The survey asked the importance of the contributing factors to the resilience of ERO using five Likert scale (1 ~ 5). The factors with a Likert score of 3 or more are regarded as important factors.

As a result of the Delphi survey, the final structure of the contributing factors is determined as shown in Figure 2. Details of the six modifications in the contributing factors due to the Delphi process is shown on Table I. For a clear comparison, the differences between Figures1 and 2 are highlighted in yellow color.

Table I: Modifications conducted in the Delphi process

No.	Modifications
1	Move the “Communication” (Level-2) from the “Monitoring” (Level-1) to bottom of the “Anticipating” (Level-1)
2	Modified the definition of the “Clarity” (Level-3) under the “Communication” (Level-2)
3	Modified the definition of the “Support System” (Level-3) under the “Support” (Level-2)
4	Modified the definition of the “Availability” (Level-3) under the “Information” (Level-2)
5	Modified the definition of the “Reporting” (Level-3) under the “Experience Dissemination” (Level-2)
6	Added the “Effectiveness” (Level-3) as a new subfactor of the “Performance” (Level-2)

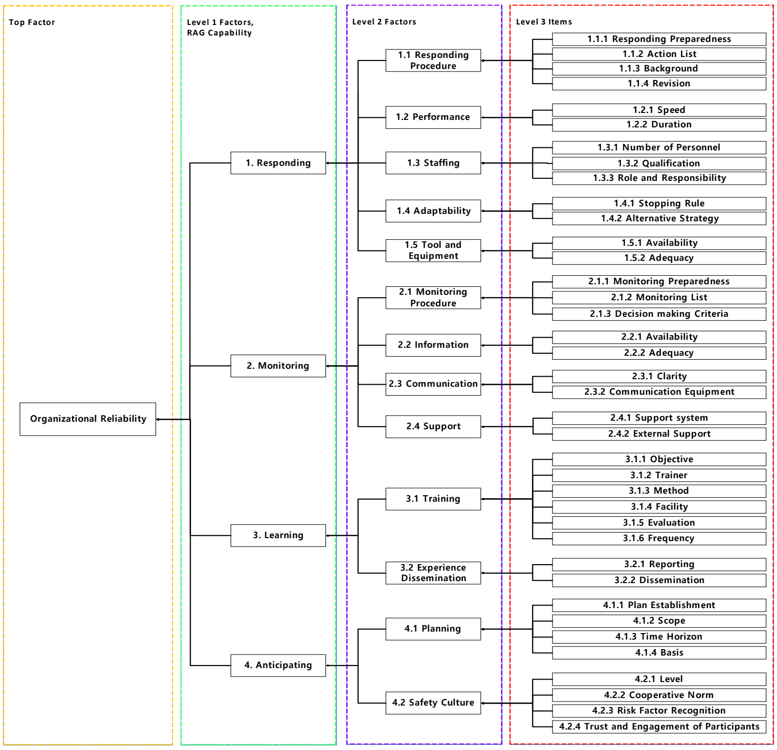


Fig. 1. The initial structure of the contributing factors

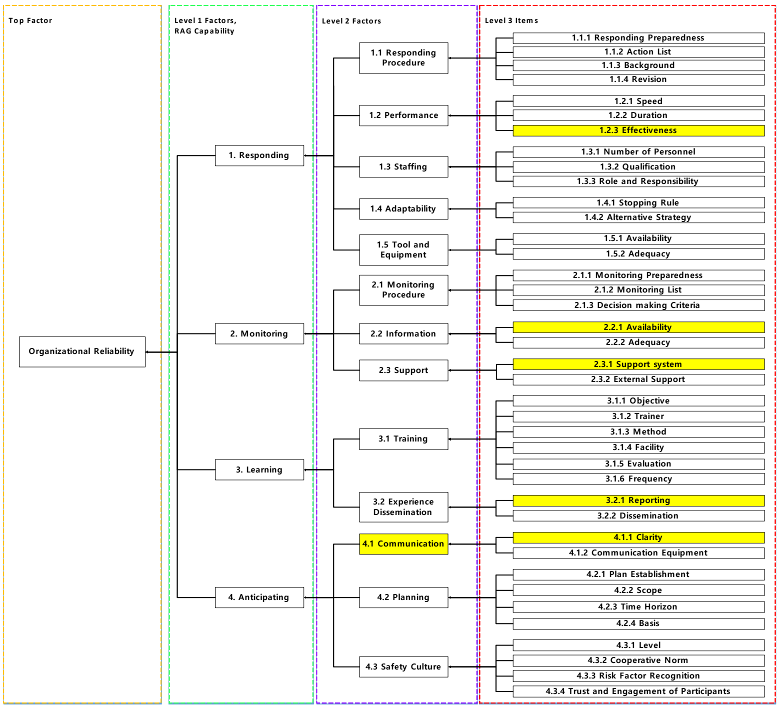


Fig. 2. The final structure of the contributing factors

2.3 AHP Method

In this study, the AHP method is used to derive the weightings (relative importance) of the contributing factors. The AHP is one of the multi-criteria decision-making methods of using eigenvalue approaches through pairwise comparison [4]. The AHP allows for the integration of quantitative and qualitative aspects of decision-making, which is an efficient method in complex problems.

Pairwise comparisons are carried out by asking; how valuable is an alternative A to criterion C compared to another alternative B?. These judgments are then transformed into a form of matrix. Weightings are then determined using this matrix.

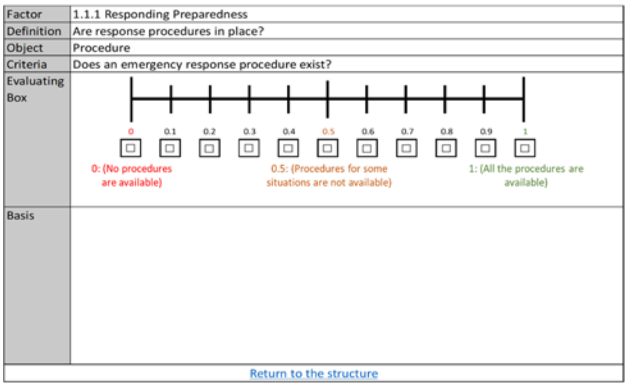
The results of the pairwise comparison by the six experts were averaged using the geometric mean. The reason for using geometric means is that the geometric mean is less influenced by extremely biased values of the variance compared to the arithmetic or harmonic means. The weightings of the contributing factors are shown in Table II.

Table II: The weightings of the contributing factors

Level 1	Weightings	Level 2	Weightings	Level 3	Weightings
Responding	0.2307	Responding Procedure	0.3143	Responding Preparedness	0.4127
				Action List	0.3212
				Background	0.1051
				Revision	0.1610
		Performance	0.2416	Speed	0.3176
				Duration	0.1704
				Effectiveness	0.5121
		Staffing	0.1369	Number of Personnel	0.2905
				Qualification	0.3026
				Role & Responsibility	0.4069
		Adaptability	0.1272	Stopping Rule	0.4544
				Alternative Strategy	0.5456
		Tool & Equipment	0.1800	Availability	0.5120
				Adequacy	0.4880
Monitoring	0.3983	Monitoring Procedure	0.2826	Monitoring Preparedness	0.3514
				Monitoring List	0.2827
				Decision-Making Criteria	0.3659
		Information	0.4763	Availability	0.5905
				Adequacy	0.4095
		Support	0.2412	Support System	0.6182
				External Support	0.3818
Learning	0.1286	Training	0.7212	Objective	0.0896
				Trainer	0.1965
				Method	0.2259
				Facility	0.1905
				Evaluation	0.1054
				Frequency	0.1920
		Experience Dissemination	0.2788	Reporting	0.3731
				Dissemination	0.6269
Anticipating	0.2424	Communication	0.2681	Clarity	0.4569
				Communication Equipment	0.5431
		Planning	0.3521	Plan Establishment	0.4985
				Scope	0.1543
				Time Horizon	0.1928
				Basis	0.1544
		Safety Culture	0.3798	Level	0.2991
				Cooperative Norms	0.1078
				Risk Factor Recognition	0.3863
				Trust & Engagement of Participants	0.2068

3. Questionnaire to Quantify the Resilience of ERO

To quantify the resilience of EROs, an evaluation of the level 3 factors is necessary. Accordingly, a questionnaire to evaluate the Level 3 factors is suggested. The example of the questionnaire suggested in this study is shown in Fig. 4.



Factor	1.1.1 Responding Preparedness
Definition	Are response procedures in place?
Object	Procedure
Criteria	Does an emergency response procedure exist?
Evaluating Box	0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1 0: (No procedures are available) 0.5: (Procedures for some situations are not available) 1: (All the procedures are available)
Basis	
Return to the structure	

Fig. 4. An example of the questionnaire

Each factor can be evaluated from 0 to 1 using a questionnaire. Also, notice from the example in Figure 4 that there are anchors presented corresponding to minimum value (0), intermediate value (0.5), and maximum value (1). Finally, the resilience of the ERO can be calculated with Eq. (1).

$$\sum_{i} \boldsymbol{w_i}(\sum_{j} \boldsymbol{w_{ij}}\,(\sum_{k}(\boldsymbol{w_{ijk}} \times \boldsymbol{R_{ijk}}))) \qquad (1)$$

Where w_i = weightings of Level 1 factors, w_{ij} = weightings of Level 2 factors, w_{ijk} = weightings of Level 3 factors, and R_{ijk} = evaluation values of Level 3 factors from the questionnaire. The resilience of the ERO will have a value from 0 to 1.

4. Conclusion

This study suggested a questionnaire and method to quantify the resilience of EROs. The structure of the contributing factors to the resilience of the ERO were identified and modified by the literature survey on resilience and using Delphi method. Then, the relative importance of each factor was determined before presenting the questionnaire and equation for final resilience evaluation. The result of this study is expected to make significant contribution to nuclear safety and regulation.

Acknowledgement

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REFERENCES

[1] Erik Hollnagel, David Woods and Nancy Leveson; International Symposium on Resilience Engineering, Soderoping Sweden, October 20-25, 2004.
[2] Hollnagel, E. (2015). RAG-resilience analysis grid. Introduction to the Resilience Analysis Grid (RAG).
[3] Goodman, C. M. (1987). The Delphi technique: a critique. Journal of advanced nursing, 12(6), 729-734.
[4] Pramanik, Dipika, et al. Resilient supplier selection using AHP-TOPSIS-QFD under a fuzzy environment. International Journal of Management Science and Engineering Management, 12.1: 45-54, 2017