Identification of Contributing Factors to Organizational Resilience in the Emergency Response Organization: A Literature Review on the Applications to Other Fields

Tae Ki Bae [a, b], Sungheon Lee [b], Jaehyun Kim [b], and Jonghyun Kim [b *]
[a] *Korea Hydro & Nuclear Power Co.LTD., 743 Seongsan-ri, Hongnong-eup, Yeonggwang-gun, Jeollanam-do, 57001, Republic of Korea*
[b] *Department of Nuclear Engineering, Chosun University, 309 Pilmun-daero, Doung-gu, Gwangju 501-709, Republic*
[*] *Corresponding author: jonghyun.kim@chosun.ac.kr*

1. Introduction

Since the Fukushima accident, the international atomic energy agency (IAEA) has highlighted the importance of enhancing organizational resilience to adapt to unexpected situations [1]. Resilience can be defined as the intrinsic ability of a system or an organization to adjust its functioning before, during, or following changes and disturbances so that it can maintain required operations under both expected and unexpected situations [2]. Following the resilience concept, organizational resilience can be defined as the ability of the organization to face disruption and unexpected events thanks to the strategic awareness and linked operational management of internal and external shocks [3].

The concept of resilience has been applied to enhance safety in many fields such as aviation, healthcare, railways, power plant, and social infrastructure. However, very few studies have been conducted for nuclear power plants (NPPs).

This study aims at identifying contributing factors to the resilience of emergency response organizations in NPPs by a literature survey on the application of resilience to other fields. This study is based on the Resilience Analysis Grid (RAG) suggested by Erik Hollnagel [4]. In this study, a review is performed for the literatures from many sources to identify which factors are considered as contributing factors to the resilience in other fields. Then, based on the literature review, the factors for the resilience of emergency response have been derived under the structure of RAG.

2. The Resilience Analysis Grid

Erik Hollnagel suggested four set of questions where the answers can be used to construct a resilience profile, named the RAG [4]. The four essential capabilities of resilience are as follows;

1) Respond:
   - Knowing what to do, or being able to respond to regular and irregular variability, disturbances, and opportunities, either by adjusting the way things are done or by activating readymade responses. This is the capability to address the *actual*.
2) Monitor:
   - Knowing what to look for, or being able to monitor that which in the near term changes, or could change, so much that it would require a response. The monitoring must cover the system's performance, as well as changes in the environment. This is capability to address the *critical*.
3) Learn:
   - Knowing what has happened, or being able to learn from experience, in particular, to learn the right lessons from the right experience. This is the capability to address the *factual.*
4) Anticipate
   - Knowing what to expect, or being able to anticipate developments, threats, and opportunities further into the future, such as potential disruptions or changing operating conditions. This is the capability to address the potential.

3. Literature Review

This section presents which factors are considered as contributing factors in other fields. The results from reviewing 17 documents are shown in Table I. In fact, more literatures have been reviewed in this study, but, due to the limitation of the number of pages and references in the proceeding, only the result from 17 documents are given here.

The domains and number of the reviewed documents are as follows:

- Power plants (3)
- Transportation (5)
- Social-technical systems (6)
- Others (3)

As shown in the table, a total of 236 factors were identified, and those factors are categorized into the RAG framework, i.e., Respond [R], Monitor [M], Learn [L], Anticipate [A], and Not Applicable [-].

4. Identification of Contributing Factors to the Resilience of Emergency Response Organization: A Preliminary Result

This study identified contributing factors to the RAG capabilities of emergency response in NPPs. For processing the 236 factors from the literature, two tasks have been performed as follows;

– Similar factors are merged, e.g. “Indicator” in [5] and “Indicator Type” in [15] were merged into “Indication”.
– Domain specific factors in other areas are removed, e.g. threat neutralization [12].

Fig.1 shows a suggested process of classifying the factors to the RAG capabilities in the NPP resilience. The process is as follows;

– The first step (green dotted box) is identifying whether this factor can be applied to the NPP resilience. Three aspects were considered; 1) is the factor addressed implicitly or explicitly in the law, manual, procedure, and plan regarding the emergency response?, 2) is the factor addressed in any study and document targeting NPPs, and 3) is the factor affecting human performances in the emergency response?.
– The second step (red dotted box) is identifying which capability in the RAG the factor is the most related to. In this step, we merged similar factors into a representative factor for NPPs. Then, the most appropriate RAG capability is selected for the factor.

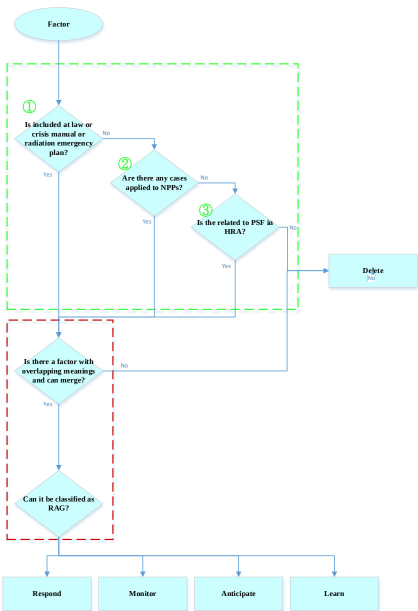

Fig. 1. Process for identifying factors to RAG capability

Following the above tasks, Fig. 2 shows the contributing factors to the RAG capabilities as a result of processing the data.

4.1 Respond

“Respond” is related to how the emergency response organization reacts to the situation. Five factors are identified in this capability.

– Control [5]: device, tool, equipment
– Procedure [5, 6, 7, 11]: event, response
– Speed [15, 16]
– Duration [15, 16]
– Adaptability [5, 6, 15, 16]: stop rule, verification, alternative selection
– Cooperation [21]:

4.2 Monitor

“Monitor” is related to how to gather and interpret the information about the situation. Regarding this capability, four factors are identified as follows

– Indication [5, 6, 7, 15, 16]: sensor, indicator
– Procedure [5]: alarm, symptom, and criteria
– Communication [7, 8, 20, 21]: leadership, and reporting
– Interpretation [15, 16, 19]: delay, meaningfulness, accuracy

4.3 Learn

“Learn” is about how the organization learns and trains itself. Total 8 factors are identified here:

– Learning organization [5, 6]
– Learning contents [6, 15, 18]: expertise, purpose, knowledge
– Frequency [15, 16, 18]
– Delay [15]
– Learning target [15, 16]
– Evaluation [7, 20]
– Resources [15, 16, 18]
– Implementation [15, 16, 18]

4.4 Anticipate

“Anticipate” is how well the organization is prepared for the situation in advance. Five factors are identified in this capability.

– Human-system interface design [5]
– Staffing [5, 6, 7, 13, 15]: number, qualification, role, responsibility
– Safety culture [6, 8, 15, 16]
– Tool & equipment [5, 6, 7, 13, 14]
– Accident management plant [13, 15, 18]

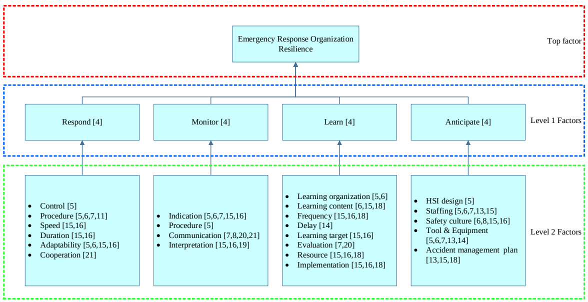

Fig. 2. Structure for evaluation of emergency response organization resilience

5. Conclusion

This study identified the factors that can contribute to the resilience of emergency response organization in NPPs. The literature from other areas was reviewed and the contributing factors were identified based on the capabilities in the RAG concept as a result of a preliminary study. These factors will be elaborated in the future work and applied to the evaluation of organization reliability for the emergency response organization of NPPs.

Acknowledgment

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. 2003012)

REFERENCES

[1] IAEA, IAEA. Report on Human and Organizational Factors in Nuclear Safety in the Light of the Accident at the Fukushima Daiichi Nuclear Power Plant. 2014.
[2] Hollnagel, Erik. How resilient is your organisation? An introduction to the resilience analysis grid (RAG). 2010.
[3] Annarelli, Alessandro, Cinzia Battistella, and Fabio Nonino. A Framework to Evaluate the Effects of Organizational Resilience on Service Quality. Sustainability 12.3: 958 2020.
[4] Hollnagel, Erik. RAG-The resilience analysis grid. Resilience engineering in practice. A guidebook. Farmham, UK: Ashgate. 275-296. 2011.
[5] Park, Jooyoung, et al. Modeling Safety-II based on unexpected reactor trips. Annals of Nuclear Energy 115. 280-293. 2018
[6]Kamanja, Florah, and Kim Jonghyun. Characterization of resilience in Nuclear Power Plants. PSAM12–Probabilistic Safety Assessment and Management. 22-27. 2014.
[7] LABAKA, Leire; HERNANTES, Josune; SARRIEGI, Jose M. Resilience framework for critical infrastructures: An empirical study in a nuclear plant. Reliability Engineering & System Safety, 141: 92-105, 2015.
[8] Omer, Mayada, Ali Mostashari, and Udo Lindemann. "Resilience Analysis of Soft Infrastructure Systems." CSER. 2014.
[9] Carim Junior, Guido César, and Tarcisio Abreu Saurin. "A framework for identifying and analyzing sources of resilience and brittleness: a case study of two air taxi carriers." Production 23.4. 777-792. 2013
[10] Huber, Gilbert Jacob, Jose Orlando Gomes, and Paulo Victor Rodrigues de Carvalho. "A program to support the construction and evaluation of resilience indicators." Work 41.Supplement 1. 2810-2816. 2012
[11] Heese, Michaela, Wolfgang Kallus, and Christa Kolodej. "Assessing behaviour towards organizational resilience in aviation." 5th REA Symposium managing trade offs. 2013.
[12] Burch, Ron. "A Method for Calculation of the Resilience of a Space System." MILCOM 2013-2013 IEEE Military Communications Conference. IEEE, 2013.
[13] Rehak, David, et al. "Complex approach to assessing resilience of critical infrastructure elements." International Journal of Critical Infrastructure Protection 25. 125-138.2019.
[14] Rehak, David. "Assessing and strengthening organisational resilience in a critical infrastructure system: Case study of the Slovak Republic." Safety Science 123. 104573. 2020.
Azadeh, A., V. Salehi, and M. Kianpour. Performance evaluation of rail transportation systems by considering resilience engineering factors: Tehran railway electrification system. Transportation Letters 10.1. 12-25. 2018.
[15] Lee, Ji Hee, Hye Jin Yang, and Dong Hyun Kim. "Developing a Disaster Management Assessment Model Using a Resilience Engineering Method." Crisisonomy. 14. 73-83. 2018.
[16] Chuang, Sheuwen, Ju-Chi Ou, and Hon-Ping Ma. "Measurement of resilience potentials in emergency departments: Applications of a tailored resilience assessment grid." Safety Science 121. 385-393. 2020
[17] Saurin, Tarcisio Abreu, Carlos Torres Formoso, and Fabricio Borges Cambraia. "An analysis of construction safety best practices from a cognitive systems engineering perspective." Safety science 46.8. 1169-1183. 2008
[18] Rodríguez, Mayra, Elizabeth Lawson, and David Butler. "A study of the Resilience Analysis Grid method and its applicability to the water sector in England and Wales." Water and Environment Journal 2019.
[19] Annarelli, Alessandro, Cinzia Battistella, and Fabio Nonino. "A Framework to Evaluate the Effects of Organizational Resilience on Service Quality." Sustainability 12.3. 958. 2020.
[20] Azusa, Kikuchi, and Yamaguchi Hiroyuki. "Organizational resilience: an investigation of key factors that promote the rapid recovery of organizations." Academic Journal of Interdisciplinary Studies 2.9. 188. 2013.
[21] van der Beek, Dolf, and Jan Maarten Schraagen. "ADAPTER: Analysing and developing adaptability and performance in teams to enhance resilience." Reliability engineering & system safety 141. 33-44. 2015.

Table I: Domain, sector, author, identified factors from the literature review

Domains	**Sectors**	**Authors**	**Identified factors**
Power plant	Nuclear power plant	Jooyoung Park et.al [5]	(1) Training[L], (2) Procedures[R, M], (3) Organization culture [A], (4) Human resource [A], (5) Human-system interface [R, M, A], (6) Execution [R], (7) Decision-making [M], (8) System response [R], (9) Verification [R], (10) Reconfiguration [R], (11) Teamwork [M], (12) Communication [A], and (13) Organizational learning [L]
		Florah Kamanja, and Jonghyun Kim [6]	(1) Prescription [A], (2) Human resource [A], (3) Human-machine interface [R, M, A], (4) Training [L], (5) Safety culture [A], (6) System verification [R], (7) System reconfiguration [R], (8) Decision making [M], (9) Execution [R], (10) Diagnosis [M], (11) Communication [M], (12) Teamwork [M], (13) Knowledge [L], and (14) Experience [L]
		Leire Labaka, et. al [7]	(1) Safety system [A], (2) Redundancy [A], (3) Simplicity and loose coupling [A], (4) Audits [A], (5) Preventive maintenance [R], (6) Corrective maintenance [R], (7) Data acquisition equipment [M], (8) Information monitoring equipment [A], (9) Crisis management procedures [R], (10) Incident management and evaluation [M], (11) Coordination procedures with external stakeholders [R], (12) Top manager commitment and situation awareness [M], (13) Activities to promote resilience-based culture [A], (14) Crisis manager training [L], (15) Crisis manager situation awareness and commitment [R], (16) Operator training [L], (17) Operator situation awareness and commitment [M], (18) First responder training [L], (19) First responder situation awareness and commitment [L], (20) Government situation awareness and commitment [M], (21) Government training [L], (22) Government communication capacity [M], (23) Government leadership capacity [M], (24) Coordination of the response agents [L], (25) Shared information systems and databases [M], (26) Trust and engagement of the participants [-], (27) Regulation and law revision and update [A], (28) Regulation and law compliance level [A], (29) Societal situation awareness and commitment [M], and (30) Societal training [L].
Transportation	Intelligent transportation system	Mayada Omer et.al [8]	(1) Leadership [M], (2) Awareness [M], (3) Flexibility [R], (4) Preparedness/emergency planning [A], and (5) Culture [A]
	Air taxi	Tarcisio Abreu Saurin, et.al[9]	(1) Top management commitment [A], (2) Learning [L], (3) Flexibility [R], and (4) Awareness [M]
		Gilbert Jacob Huber et.al [10]	(1) Awareness [M], (2) Efficiency [A], (3) Commitment [A], and (4) Adaptability [R]
	Aviation	Michaela Heese et.al [11]	(1) Goal trade-offs [-], (2) Coordination [-], (3) Timing/Pacing/Synchronization [A], (4) Approximate adjustments [A], (5) Actual practice/techniques [L], (6) Buffering capacity [-], margins [A], tolerance [-], (7) Adaptive capacity [R], (8) Complexity/Procedures [R, M], (9) Under specification [-].
	Aerospace	Ron Burch [12]	(1) Countermeasures [A], (2) Deterrence [-], (3) Mobility [A], (4) Maneuverability covertness [-], (5) Active redundancy [A], (6) Overcapacity [R], (7) Excess margin [A], (8) High damage thresholds [A], (9) Passive redundancy [A], (10) Repair [R] (11) Reset/restart [L], (12) Self-healing [R], (13) Threat neutralization [-], (14) Replace [R], and (15) Rebuild [R]
Social-technical system	Critical Infrastructure System	David Rehak, et.al [13]	(1) Crisis Preparedness [A], (2) Redundancy [A], (3) Detection capability [M], (4) Responsiveness [R], (5) Physical resistance [R], (6) Material resources [A], (7) Financial resources [A], (8) Human resources [A], (9) Recovery processes [A], (10) Risk management [M], (11) Innovation processes [R] , and (12) Education and development processes [L]
		David Rehak [14]	(1) Level of risk management [R], (2) level of risk assessment method applied [M], (3) Level of safety standards implemented [A], (4) Level of specification of disruptive event scenarios [R], (5) Flexibility of the organizational structure [A], (6) Method of organizational process management [A], (7) Scope of technological innovations implemented [L], (8) Level of innovation in security measures [-], (9) Level of management systems implemented [A], (10) Level of innovation in management processes [L], (11) Level of the organization's involvement in science and research [L], (12) Level of the organization's investment into specific innovations [R], (13) Level of education provided or supported to the organization's employees [L], (14) Level of employee training and maintenance of practical skills [L], and (15) Method of evaluating the effectiveness of employee training [L].
	Disaster management	Ji Hee Lee et.al [15]	(1) Expertise [A], (2) Frequency [L], (3) Communication [M], (4) Model [A], (5) Time horizon [A], (6) Responsibility [A], (7) Acceptability of risks [A], (8) Culture [A], (9) Etiology[-], (10) Efficiency [A], (11) Background [R], (12) Selection criteria[R], (13) Response list[R], (14) Verification[R], (15) Threshold[A], (16) Speed[R], (17) Duration[R], (18) Response capability[R], (19) Stop rule[R], (20) Relevance[R], (21) Selection criteria [L], (22) Training [L], (23) Resources [L], (24) Classification [L], (25) Learning style [L], (26) Delay [L], (27) Learning target [L], (28) Implementation [L], (29) Learning basis [L], (30) Indicator list [M], (31) Indicator type [M], (32) Relevance [M], (33) Validity [M], (34) Delay [M], (35) Measurement type [M], (36) Measurement frequency [M], (37) Analysis/interpretation [M], (38) Stability [M], and (39) Organizational support [M]
	Medical	Sheuwen Chuang, et.al [16]	(1) Event list [R], (2) Background [R], (3) Relevance [R], (4) Threshold [R], (5) Response list [R], (6) Speed [R], (7) Response capability [R], (8) Stop rule [R], (9) Duration [R], (10) Verification [R], (11) Indicator list [M], (12) Relevance [M], (13) Indicator characteristic [M], (14) Measurement frequency [M], (15) Organizational support [M], (16) Analysis/ interpretation [M], (17) Validity [M], (18) Selection criteria [L], (19) Learning basis [L], (20) Classification [L], (21) Formalization [L], (22) Training [L], (23) Learning style [L], (24) Resources [L], (25) Learning target [L], (26) Implementation [L], (27) Expertise [R], (28) Frequency [R], (29) Communication [R], (30) Strategy [R], (31) Model [R], and (32) Culture [R].
	Construction	Tarcisio Abreu Saurin, et.al [17]	(1) Flexibility [R], (2) Learning from both incident and normal work [L], and (3) Be aware of system status [M]
	Water sector	Mayara Rodriguez, et.al [18]	(1) Indicator list [M], (2) Validity of the indicator [M], (3) Organizational support[M], (4) Assumption about the future [-], (5) Acceptability of threats [-], (6) Time Horizon [A], (7) Learning basis [L], (8) Data collection [L], (9) Implementation and communication [M], (10) Frequency [L], (11) Event list [R], (12) Background and relevance [R], (13) Response list [R], and (14) Resources [L].
Others	Service company	Alessandro Annarelli, et.al [19]	(1) Continuous monitoring [M], (2) Anticipation ability [A], (3) Redundancy [A], (4) Simulation [L], (5) Initial vulnerability [M], (6) Focus on minor aspect [-], (7) learning from mistakes [L], (8) Internal communication [M], and (9) improvisational capabilities [M].
	Food manufacturing company	Kikuchi Azusa, et.al [20]	(1) Orientation for completing tasks [L], (2) Orientation for interpersonal relation [L], (3) Job directions [A], (4) Concern for interpersonal relation [M], (5) Information sharing [M], (6) Clarification of task [R], (6) Monitoring and coordination [M], (7) Mutual feedback [M], (8) Organizational resilience evaluation [-], (9) Affective commitment [-], (10) Normative commitment [-], and (11) Intrinsic commitment [-].
	Dutch companies	Dolf van derBeek et.al [21]	(1) Team responding behavior [R], (2) Collective (learning) behavior team [L], (3) Psychological safety team [A], (4) Preoccupation with failure [-], (5) Situation assessment [M], (6) Heedful interrelating [-], and (7) Team factors [A].