Development of an Evaluation Method for Team Safety Culture Competencies using Social Network Analysis

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1. Introduction

1.1 Nuclear safety culture

Safety culture has received attention in all safety-critical industries including nuclear power plants (NPPs) due to various prominent accidents, such as the concealment of a Station Black Out (SBO) at the Kori NPP unit 1 in 2012, the Sewol ferry accident in 2014 and the Chernobyl accident in 1986. In various reports, it has been pointed out that one of the major contributors to cause those accidents is a "lack of safety culture". The Inter-national Atomic Energy Agency (IAEA), one of the most influential organizations in the nuclear industry, defined nuclear safety culture in the International Nuclear Safety Advisory Group (INSAG) report No. 4 published after the Chernobyl accident occurred.

"Safety culture is 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 their significance." [1]

Although the definitions of safety culture are different among nuclear-related organizations, the assessment of safety culture clearly targets the management and improvement of the characteristics and attitudes of individuals and organizations. Moreover, there is a wide consensus among academic researchers that safety culture should be evaluated and managed in a prescribed manner.

To manage and improve the characteristics and attitudes of individuals and organizations, several methods have been developed from various nuclear-related organizations so far. There are three representative methods: 1) the Independent Safety Culture Self-Assessment (ISCA) developed by the IAEA, 2) the Independent NRC Safety Culture Assessment from the United States Nuclear Regulatory Commission (US-NRC), and 3) a Nuclear Safety Culture Assessment (NSCA) survey process developed by the Nuclear Energy Institute (NEI). [2-4]

However, team safety culture has not been evaluated separately so far, even team is the basic working unit in NPPs. The target of safety culture evaluation are mainly the organization, and the evaluation is qualitatively performed. Even the evaluation of safety culture is performed quantitatively; the evaluation of safety culture is made based on summing or averaging the results of interview and survey performed to individuals. Therefore, the safety culture of an organization could be only described vaguely from the individuals' results of safety culture. Moreover, team members easily overlook their required actions to improve nuclear safety culture, since there is no explicit statements for each team member. Therefore, in this study, the quantitative evaluation method of team safety culture will be developed by using the 'competency' concept and SNA.

1.2 Team safety culture competency

Throughout this paper, the term, 'team safety culture competency' will be used. Generally, the competency is mainly focused on individuals to achieve a given goal. Competency has a clear difference to ability or capacity. Competency is behaviorally seen, so that can be observable. Competency is not a skill or a knowledge that individual possess, but revelation of skill and knowledge by behavior. Moreover, competency is highly connected to the performance of a goal, and it is situation-specified [5].

The first step to derive competencies is to define the range and the goal of competency. Literature review should be accompanied to define competency. After defining the range and the goal of competency, derivation of competency list is performed generally by Behavioral Event Interview (BEI), Subject Matter Expert (SME), or Strategic Success Modelling (SSM). All the methods are merely different in methodology, but they are the same in finding a behavioral characteristics from a high-performed subjects.

In this study, competency is narrowed down to safety culture competency. The competency of individual is commonly defined as the "underlying characteristics of an individual that are causally related to effective or superior performance in a given job" [6]. Similar to safety culture, the definition of competency focuses on characteristics and attitudes of individuals to achieve the goal. Therefore, we defined that 'team safety culture competency' as, 'Team safety culture competencies are underlying and sharing characteristics, outward attitudes, and patterns of behavior of team members and individuals that are causally related to a healthy and strong nuclear safety culture. in a safety plant that are

causally related to a healthy and strong nuclear safety culture'.

In case of team safety culture, the most important property of competencies is 'shared among team members'. Therefore, we chose evaluation method as SNA, which will be introduced in the next section, in detail. SNA is a powerful method that can represent 'sharing' among elements, without structural modelling of the elements.

1.3 Social network analysis

As mentioned briefly above, SNA is a strategy for investigating the relationship through the use of network and graphical elements. Existing analysis methods were mainly individualistic, variable-centric. However currently, the structural and relational characteristics between variables are considered as important, and SNA is one of the method that reflects. The first study of SNA has been developed from 1940s and 1950s. Concepts of social psychology, such as group and social circle, were started to be described with network terms to figure out the spontaneously produced relationship from network raw data. [8] Also, the group networks laboratory in MIT studied the how the network structure of communication of a group affects to the speed and accuracy of problem solving. [9] After 1980s, SNA became a dominant area in social science. SNA was applied to various fields, such as management consulting, public health, or prevention of crime. [10-12]

SNA result can be represented in both matrix form and graphical form, but graphical form is more preferable due to the legibility and the intuitiveness. Depending on the presence of the directivity of lines and measurability of nodes, graphs can be divided into directed graph and non-directed graph, and binary graph and valued graph, respectively.

Through abovementioned representations, SNA aims to describe the relationship among nodes and expect the performance of group. In other words, the result of SNA can be explained depends on the direction of cause-and-effect of nodes and their relationships. Network itself can be analyzed as an independent and explanatory variable to explain the cause of relations, or network can be analyzed as an outcome variable of the relations. When SNA is adopted to nuclear industries, team safety culture competencies can be investigated as follows: since the safety culture competencies are necessary to make able to maintain the high level of safety culture, team safety culture is a result of relations among team safety culture competencies.

By matrix operation provided in SNA, several results can be derived such as density, connection, centrality, power, and cluster. Among them, two are the most widely used; density and degree centrality. Density is defined as the sum of the lines divided by the number of possible lines. If the density is high, nodes are generally having a close relationship. Degree centrality is the number of relationships that a node has, out of the relationships that a node can have. A node which has high degree centrality means, a node is generally an active player, or in an advantaged position in the network. In this study, team safety culture will be also represented with the two numbers.

1.4 Research objective and scope

The aim of this study is to evaluate safety culture of team, which is the smallest working group of NPPs. To evaluate team safety culture we defined team safety culture competency, and listed the competency lists by using SSM. By using SNA, we investigate how team safety culture competencies are linked among team members to estimate team safety culture. Density of team members will provide the degree of deficiency of team safety culture competencies, and degree centrality of team safety culture competency will showed the competency which should be improved in the first place. Graphical notation will give legible glance of the relation between team safety culture competencies.

Through this study we expect to understand the characteristics of a team safety culture and to suggest the urgent team safety culture competencies to be improved for the safe operation of NPPs.

2. Development of Evaluation Method of Team Safety Culture Competencies

2.1 Derivation of team safety culture competencies

We used SSM technique to derive the list of team safety culture competencies. Generally SSM proceeds in the following steps.

Step 1: Planning for an effective and optimized derivation of competencies. Also, the range and goal of competencies are defined. Plan the step to derive including the range and the goal of competencies.

Step 2: Information gathering from behavioral characteristics of high-performed subject. This stage is generally performed based on from the target goal, through interview, workshop, or survey. Etc.

Step 3: Defining the competencies based on the result of step 2. The list of competencies and their behavioral characteristics are derived.

Step 4: Validating the derived competencies. Validation is performed by statistical analysis and experts' judgment and modification is also performed based on the result of validation.

Through performing step 1 to step 4, 8 core competencies for team safety culture and behavioral characteristics of them were derived. 8 core team safety culture competencies are leadership, teamwork, communication, task management, situation awareness

sharing, motivation, decision making, and emergency preparedness and response.

By adopting SNA to evaluate safety culture competencies, it is necessary to measure each competency. Among various measuring techniques, we chose 'observation' from the outside of a team. Period of observation is basically 'any time', but at least once in a six-month. Also the observer could check the wrong competencies accumulatively and repeatedly within team members. Then the SNA is possible to check the team members who does not have appropriate competencies.

2.2 Application of SNA

As described in section 2-1, observed behavioral deficiencies from the safety culture competencies can be represented in the form of matrix. Matrix shows the lack of competencies shared among team members. Through matrix operation, density of team members and degree centrality of each team safety culture competency can be calculated. Equation 1 and 2 show how to calculate the value of density and degree centrality.

$$D = \frac{L}{{}_gC_2 \times i_m} = \frac{L}{\frac{g(g-1)}{2} \times i_m} \qquad (1)$$

where, D: density of team members
L: number of lines
g: number of team members
i_m : maximum number of observations in one competency

$$D_D(N_i) = \frac{\sum_{j=1}^{g} x_{ij}}{(g-1) \times i_m}, \quad i \neq j \qquad (2)$$

where, CD(Ni): degree centrality of each competency
g: number of competencies
$\sum_{j=1}^{g} x_{ij}$: number of lines with other competencies
i_m : maximum number of observations in one competency

Additionally, we could calculate team safety culture through equation 3.

Team safety culture= 1-D (3)

Since the density of team members represents how team safety culture competencies are commonly insufficient among team members, team safety culture should be represented by subtracting density from 1. Therefore, it can be said that the density value of team members subtracted from 1, can be used as team safety culture index. Also, degree centrality of each team safety culture competency shows the priority of the competency to be improved in a team. In other words, the higher the degree centrality of competency is, the priority to be improved of the competency is urgent.

2.3 Production of the Prototype Modules

Based on the developed method, prototype module was built to evaluate team safety culture conveniently. The module is composed of a server-cum-database, sub-module for observer, and sub-module for the subjects. The operational environment is shown in Table II

The selected device for observer is 8-inch touch-screen tablet with a digital pen. The module was implemented in the device, so the observer can check the team safety culture competencies easily, and anytime. All the sub-modules are produced in Korean for effectiveness and accessibility.

Table I. Specification of Sub-modules

Module components	Operational Minimum Specification
Device for observer	Processor : Intel Atom Z3740 RAM : 1GB Capacity : 10GB OS : Windows 8 Hardware : 8-inch touch-screen tablet
PC for subjects	Processor : Intel i5 RAM : 1GB Capacity : 10GB OS : Windows 7
Server-cum-database	Processor : Intel Xeon E5-2630 RAM : 16GB Capacity : 2TB HDD x 2 OS : Ubuntu Server 14.03.3LTS

Sub-module for the subjects was made to be operated in the personal computer. High level specification for operating is not required, and the sub-module is also produced in Korean. Through the sub-module subjects can individually log-in to access their result and recommendations to improve team safety culture competencies.

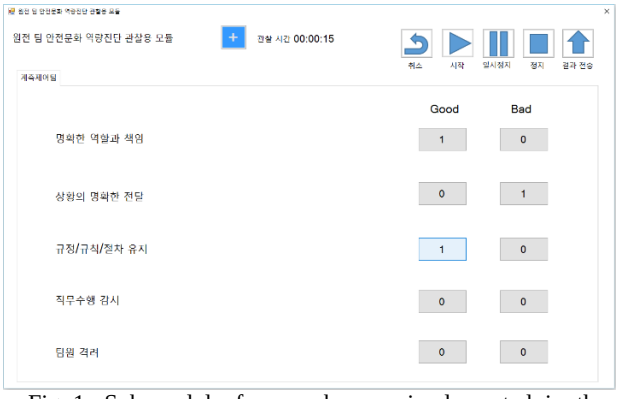

Fig 1. Sub-module for an observer implemented in the device

Figure 2. Main Page of Sub-module for Subjects

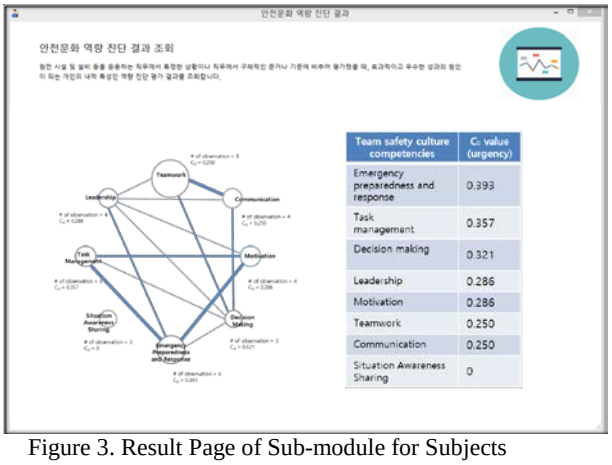

Figure 3. Result Page of Sub-module for Subjects

3. SUMMARY AND CONCLUSION

In this study, team safety culture competency of a team was estimated through SNA, as a team safety culture index. To overcome the limit of existing safety culture evaluation methods, the concept of competency and SNA were adopted.

To estimate team safety culture competency, we defined the definition, range and goal of team safety culture competencies. Derivation of core team safety culture competencies is performed and its behavioral characteristics were derived for each safety culture competency, from the procedures used in NPPs and existing criteria to assess safety culture. Then observation was chosen as a method to provide the input data for the SNA matrix of team members versus insufficient team safety culture competencies. Then through matrix operation, the matrix was converted into the two meaningful values, which are density of team members and degree centralities of each team safety culture competency. Density of tem members and degree centrality of each team safety culture competency represent the team safety culture index and the priority of team safety culture competency to be improved.

Through this research, we expect that the suggested evaluation method of team safety culture will be useful to estimate the level of team safety culture and the urgent team safety culture competencies to be improved.

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