Development of an Evaluation Method for Nuclear Safety Culture Competency using Social Network Analysis

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Abstract: The aim of this study is to propose an evaluation method for Nuclear Safety Culture (NSC) competency using Social Network Analysis (SNA). NSC Competency has been defined and its behavioral characteristics are derived from procedures in nuclear power plant. SNA was applied to evaluate NSC competency of an operation team. The example of an analysis and its validity for application has been addressed in the paper.

Keyword: Nuclear Safety Culture, Competency, Social Network Analysis

1 Introduction

The term Nuclear Safety Culture (NSC) was first-introduced after the Chernobyl accident under the auspice of International Atomic Energy Agency (IAEA) investigated and discussed about the accident. In the report, that International Nuclear Safety Advisory Group (INSAG) published for IAEA Safety Report Series, No.75, INSAG-4, the concept of NSC is well defined:

"Safety culture is that the assembly of characteristics and attitude in organizations and individuals which establishes that, as an overriding priority, protection and safety issues receive the attention warranted by their significance" [1]

One field of efforts to enhance NSC was to develop NSC assessment methods. Independent Safety Culture Self-Assessment (ISCA) developed by IAEA, Independent NRC Safety Culture Assessment from the United States Nuclear Regulatory Commission (US. NRC), and the Nuclear Safety Culture Assessment (NSCA) survey process developed by Nuclear Energy Institute (NEI) are generally adopted NSC assessment methods throughout the world. [2][3][4] These methods commonly utilize interview, survey, and observation modules to assess NSC. Since all methods have the similar frameworks, result forms are more or less the same; qualitative and subjective. In addition, the reliabilities of results are often dependent on respondents.

This paper considered to represent NSC into competencies, which could be specified into behavioral characteristics, and to apply observation as the most objective assessment method. Then we analyzed observed results with Social Network Analysis to provide the tendency, characteristic and improvement points of team and team members.

2 Development of an Evaluation Method for Nuclear Safety Culture Competency

2.1 Nuclear Safety Culture Competency

2.1.1 Definition of Nuclear Safety Culture Competency

NSC has a goal-oriented characteristic of safety, which is a great similarity with competency that competency represents the goal-oriented behavioral characteristics.[5] A competency researcher Spencer defined competency as follows:

"Competency is underlying characteristic of an individual that are causally related to effective or superior performance in a job." [6]

In this regard, we newly defined Nuclear Safety Culture Competency (NSCC), by integrating

safety-oriented characteristics from nuclear safety culture and behavioral characteristics from competency. NSCC definition is as follows:

"Nuclear safety culture competencies are underlying and sharing characteristics, outward attitudes, and pattern of behaviour of team members and individuals that are causally related to a healthy and strong nuclear safety culture"

NSCC has its foundation in behavior of team members and individuals. Such characteristics make advantages that NSSC to have a synergy with assessment method of observation. Therefore, in this study, observation will be used to assess NSSC, as mentioned in the introduction section.

2.1.2 Nuclear Safety Culture Competency and observation guideline

From section 2.1.1, we newly defined NSSC. In this section, NSSCs and their relationships with behavioral characteristics will be identified. and observation guideline will be given to assess NSSC of an operation team.

In order to derive NSSC, strategic success modeling (SSM) was applied among various competency-extracting techniques. SSM extracts core competencies from highly-performed subjects. Standard performance can be obtained from general interview, survey, or workshop, however in this study, procedures are used, since procedures are the behavioral standard to perform the task successfully and safely, that every nuclear power plants have. Through SSM, total 8 core NSSCs and their behavioral characteristics were derived. Table 1 shows 8 core NSSCs and behavioral characteristics of 8 core NSSCs.

Table 1 Eight Core NSSC and Examples of their Behavioral Characteristics

Competency	Examples of behavioral characteristics
Leadership	◆ Team members know their role and accountability clearly, and if it is insufficient, team leader alerts. ◆ Team leader clearly understands the plant situation, and delivers to team members. ◆ Team leader arbitrates the dispute when team members violate or implement procedures, regulations, and rules inappropriately. ◆ Team leader continually supervise whether team members are performing tasks within the standardized processes to perform safely. ◆ Team leader positively encourage team members to successfully perform tasks within plans.
Teamwork	◆ Team members actively help and advices to other team members. ◆ Team members consider the abilities of other team members in performing the given tasks. ◆ Team members avoid non-constructive arguments, and cooperate with other team members to perform the given tasks. ◆ Team members positively accommodate helps and advices from other team members.
Communication	◆ Team members always have questioning attitude to the issues that might degrade safety of the plant, and express their opinions to other team members. ◆ Team members clearly deliver plant state to other team members when performing the given tasks. ◆ Team members discuss about corrective actions of an event, which degrades the safety or comes close to degrading the safety. ◆ Team members mutually confirm their understandings after discussion of major safety issues. ◆ Team members actively make a question for clear understanding of major safety issues. ◆ Team members share their experiences and information of major safety issues with other team members. ◆ Team members follow the communication protocol.
Task management	◆ Team members continually concern with the activities of other team members, and alert them when they perform wrong activities. ◆ Team members cross-check the given tasks related to major safety concerns. ◆ Team members periodically inspect and manage the major safety components. ◆ Team members decide task priority consider safety. ◆ Team members manage their own tasks

	not to cause any inconvenience due to delay of performing tasks.
Situation awareness sharing	◆ Team members share the situation that might cause degradation of safety. ◆ Team members requesting information from other team members when plant state is unassured. ◆ Team members share plans and information before performing the given tasks related to major safety issues.
Motivation	◆ Team members consider safety first, besides personal relationship between colleagues or boss. ◆ Team members pursue faultless decision-making. ◆ Team members actively support other team members to raise teamwork
Decision-making	◆ Team members gather and analyze the all accessible information to understand major safety issues. ◆ Team members confirm additional opinions or suggestions before decision-making. ◆ Team members endeavor to reduce uncertainty considering all the accessible information, such as time and methodology. ◆ Team members confirm and verify the effectiveness of decision after decision-making.
Emergency preparedness and response	◆ Team members are periodically trained for emergency situations, and mitigate the emergency situation based on the trainings. ◆ Team members are continually trained, reminding the precautions of unaccustomed tasks. ◆ Team members share information to effectively manage the emergency situations and the abnormal situations. ◆ Team members judge the risk level of unaccustomed tasks, and plan the tasks to mitigate appropriately. ◆ Team members predict the latent hazards utilizing all the accessible information.

2.2 Social Network Analysis

2.2.1 General Social Network Analysis

Social Network Analysis (SNA) is a strategy for investigating the relationship through the use of network and graphical elements. 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.[7] 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. [8] 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. [9][10][11]

Generally SNA follows the steps: 1) gathering information to generate event/subject matrix, 2) visualizing the network graphically, based on the matrix, and 3) calculating the meaningful values from the matrix. In other word, SNA result can represents networked structure into both matrix form and graphical form.

Through two 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.

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, NSSC will be also represented with the two numbers.

2.2.2 Application of Social Network Analysis to NSSC

In this study, SNA is adopted to NSSC to represent the shared NSSC among team members, and the degree centrality and density of NSSC of a team.

For the first step of assessment, unit task should be identified. In case of a team proceeding a procedure, each step is the unit task. Then event/subject matrix should be made, based on the shared NSSC of team members. An example event/subject matrix of a unit task can be represented into both graphical and numerical as shown in figure 1 and 2, respectively.

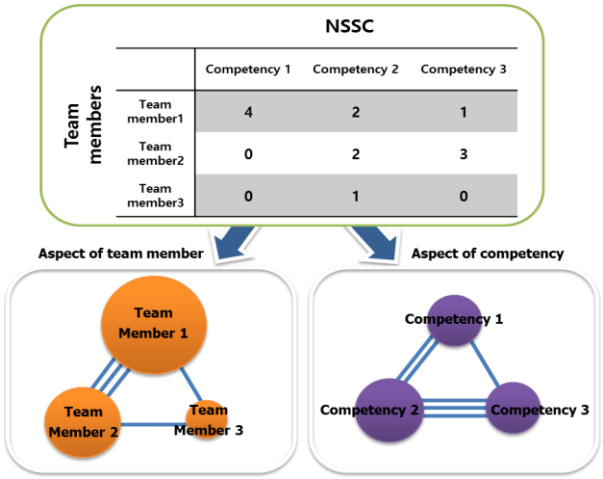


Fig 1. Graphical representation of an example event/subject matrix according to the team member and competency aspect

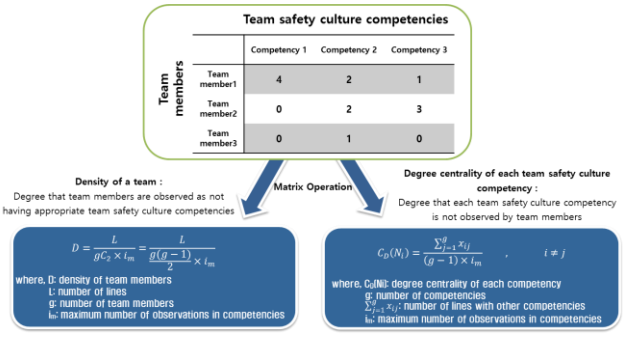


Fig 2. Numerical representation of an example event/subject matrix according to the team member and competency aspect

In graphical representation, the size of the circle represents the number of observed NSSCs or the observed team members that showed certain NSSCs, according to the representation aspects. Lines connecting team members show the shared NSSCs among team members, and lines connecting NSSCs are the NSSCs shared by certain team members.

From the lines in graphical representation, we could calculate the meaningful numerical representation, as following equations. Equation 1 and 2 show how to calculate the value of density of a team and degree centrality of .NSSCs.

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

where,

D: density of team members

L: number of lines

g: number of team members

im: maximum number of observations in one competency

$$C_D(N_i) = \frac{\sum_{j=1}^{g} x_{ij}}{(g-1)\times i_m} \quad (2)$$

where,

CD(Ni): degree centrality of each competency

g: number of competencies

$\sum_{j=1}^{g} x_{ij}$: number of lines with other competencies

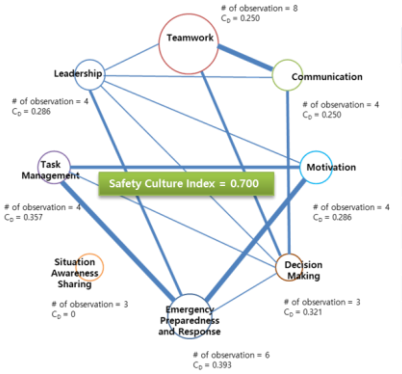
im: maximum number of observations in one competency

If the assessor made a matrix with inappropriate competencies, it could be said that NSC can be calculated through equation 3.

$$\text{Team safety culture} = 1\text{-}D \quad (3)$$

Since the density of team members represents how NSSCs are commonly insufficient among team members, NSC 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.

SNA results can be cumulated through team proceeds task units in a procedure. Then finally an overall NSC can be drawn as figure 3.



Team safety culture competencies	C_D value (urgency)
Emergency preparedness and response	0.393
Task management	0.357
Decision making	0.321
Leadership	0.286
Motivation	0.286
Teamwork	0.250
Communication	0.250
Situation Awareness Sharing	0

Fig 3. An example of SNA result for NSSC

3 Conclusion

In this study, a NSSC assessment method has been developed to overcome the qualitativeness, subjectiveness, and result-dependency on respondents of existing methods. NSSC was newly defined and derived through SSM. SNA was applied to develop the evaluation method for NSSCs analyzing 'shared value' among team members. It is expected that the developed evaluation method of team safety culture competencies can provide explicit practices to enhance NSC. To give credibility to the developed assessment method, validation and verification should be conducted for further work.

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