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A Study of Methodology to Examine Organizational Root Causes through the Retrospect Error Analysis of Railroad Accident Cases

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Objective: This study proposes a systematic process to present the analysis methods and solutions of organizational root causes to human errors on the railroad.

Background: In fact, organizational root cause such as organizational culture is an important factor in the safety concerns on human errors in the nuclear power plant, railroad and aircraft.

Method: The proposed process is as follows: 1) define analysis boundary 2) select human error taxonomy 3) perform accident analysis 4) draw root causes with FGI 5) review root causes analysis with survey 6) chart analysis of root causes, and 7) propose alternatives and solutions.

Results: As a result, root causes of the organizations like railroad and nuclear power plant came from the educational problems, violations, payoff system, safety culture and so forth.

Conclusion: The proposed process does predict potential railroad accident through retrospect error analysis by building new human error taxonomies and problem solution.

Application: This study would contribute to examination of the relationship between human error-based accidents and organizational root causes.

Keywords: Organizational culture, Human error, Root cause, Safety culture

1. Introduction

A fire that broke out at JungAng-ro Station of Daegu Subway Line 1 in February 2003, due to arson, caused 192 deaths, 21 missing people and 151 injured people. The fire also caused KRW 57.9 billion of physical damages and operation suspension for recovery. The accident at Fukushima Nuclear Power Plant in March 2011 recorded level 7, the highest level of INES (International Nuclear Event Scale), and radioactive substances are still leaking. In April 2014, an offshore ferry, Sewol, departed Incheon for Jeju capsized, which caused 295 deaths and 9 missing people out of 476 embarked crew and passengers.

Due to common phenomena in human-machine system operated in various fields,

machines become intelligent, and systems become automated, because of humans having many errors. As a result, goal conflicts between humans and machines often occur, and new system errors take place, which are connected to big accidents (Cha, 2013). As the importance of human errors was reported by an accident at TMI Nuclear Power Plant in 1979, studies have been carried out, centered on nuclear power field. Actually, many studies report that various accidents in many fields including aviation, railroad, ship, chemical plant and nuclear power plant are caused by human's wrong judgment or action, namely, by human errors (Kim, 2006). Because human errors are regarded as personal failure, the human errors have been analyzed mainly through personal characteristics such as worker's physical or cognitive limitation revealed by the characteristics of work and environment. However, it is well known that the background of human errors is related with organizational and cultural characteristics (Lee, 2011). Nonetheless, studies on the improvement of human errors, centered on organizational and cultural characteristics are insufficient. One reason can be that organizations of Korean society respond in a very closed way, but the cause not recognizing it as a problem is much bigger. Although, organizational root causes on actual railroad accidents were found through the accident analyses and questionnaire surveys of railroad organizations, the items recognized by the railroad members were only 28% among such causes. As such, solutions to the root causes of accidents cannot be presented properly, because of organizational root causes that have not been recognized well.

According to the statistical data of IAEA (2004) or Boeing (2005), human errors take up a huge portion in the human-machine system accidents (Cha, 2013). Even though the causes of human errors are addressed in many models and taxonomies including accident causation model of Reason (1990), CREAM of Hollnagel (1998) and HFACS of Wiegmann (2001), concerning the organizational root causes working as human error causes, an approach to human error improvement method is not easy.

This study aims to present the methodology to find and analyze railroad organizational root cause types and forms through cases.

2. Method

2.1 Organization's root cause identifying process

This study made an accident causation model as shown in Figure 1 by classifying the organizational root causes in the accident causation model of Reason (1990) into types and forms. Here, actual cause (type), as human error type, refers to easily classified error type through general accident investigation files. Organizational cause (type), as organizational error type, means the error type predicted to be related, although it is not revealed in an accident investigation file. Organizational root cause (form) means the error form revealed in actual site of organizational cause (type).

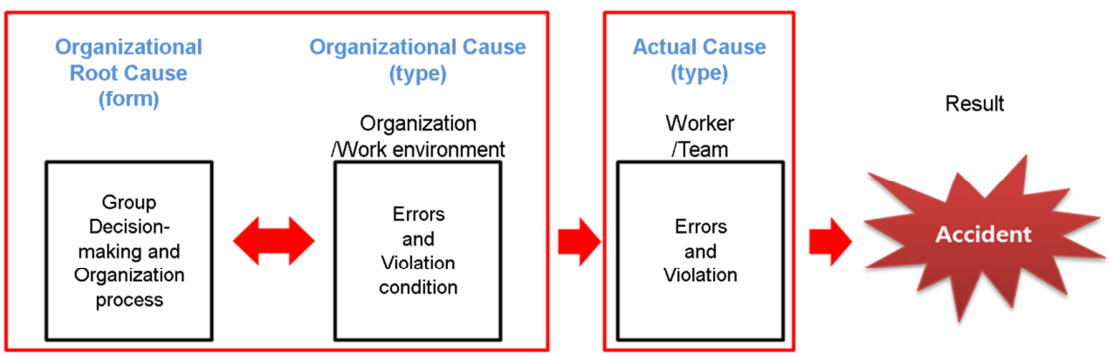

Figure 1. Model of accident causation

It was not easy to classify the accident investigation files of railroads and nuclear power plants in Korea in line with error taxonomies of CREAM or HFACS. Despite classification, the items corresponding to organizational causes (types) were not revealed in accident investigation files well in general. This study used a process as shown in Figure 2 to solve such a problem. This is the method connecting actual causes (types) (human error types) and organizational root causes (forms) as shown in Figure 1, and it is approached through accident analysis, FGI (focus group interview) and questionnaire survey.

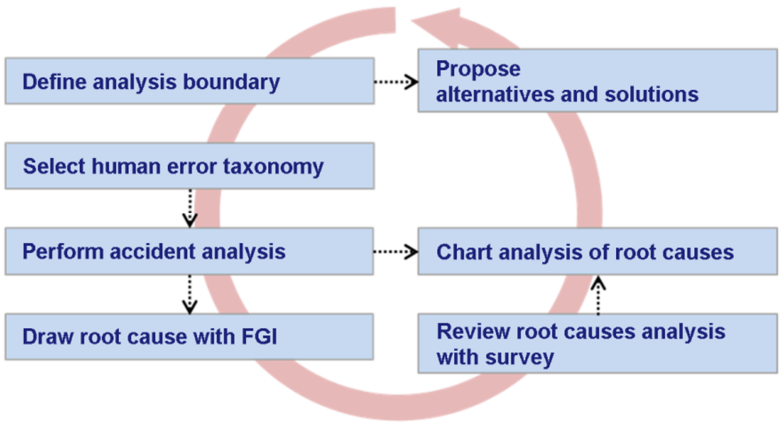

Figure 2. Organizational root cause identifying process

First, judge actual causes (types) through the accident investigation files. Because, organizational causes (types) are not revealed in the accident investigation files well (In the case of railroad organization, problems on team atmosphere or reward and punishment system were not described in the file), identify actual causes (types) first, and then find organizational causes (types) thought to be related with actual causes (types). However, judgment on whether the organizational causes (types) identified at this stage are appropriate is not important. The purpose is to identify many organizational causes (types) that can be generated by each actual cause (type), and make them the keywords for FGI. Conduct FGI targeting the keywords made in such a manner, identify organizational root causes (forms) corresponding to forms of organizational causes (type) (Figure 3). Conduct a questionnaire survey to quantify the causes, after regarding the results obtained through FGI as organizational root causes. Make a chart and present alternatives, based on the results of the accident analysis, FGI and questionnaire survey. The details of the accident analysis, and the results of FGI and questionnaire survey have all mutual supplementary relations, and the cause type and form on one accident are all connected.

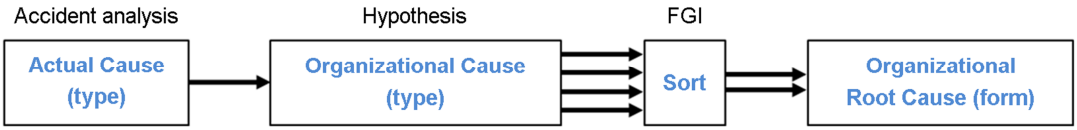

Figure 3. Step to draw organizational root cause

2.2 Select human error taxonomy

Since there is a difficulty to find organizational causes (types) through accident analysis, a taxonomy in which organizational causes (types) through which actual causes (types) can be selected, is necessary in order to apply the process. The taxonomies classifying organizational causes (types) include HFACS, CREAM and HEAR. HFACS categorizes organizational causes (types) into such three categories as resource management, organizational culture and organizational process, and also classifies them into 36 sub-categories in detail (Shappell and Wiegmann, 2011). CREAM categorizes organizational causes (types) into communications, organizational culture, training, ambient conditions and working conditions, and classifies them into 32 sub-categories in detail. (Hollnagel, 1998). HEAR categorizes organizational causes (types) into five categories, namely, regulations & procedures, human resources management (worker selection, deployment, education & training and evaluation), group and team characteristics, management and supervision and organizational process (policy and culture), and classifies them into 51 sub-categories in detail (Yoon, 2010). This study used HEAR taxonomy designed to be suitable for the railroad environment.

2.3 Perform accident analysis

Concerning accident analysis, this study read accident investigation files, identified and classified cause types. Because an accident file is a document recording objective fact, the organizational causes (types) not directly revealed are not recorded well. HEAR connected actual causes (types) with organizational causes (types) through the item of relevant cause (For example, low confidence 1.7 and past accident experience 3.8 as relevant causes of tension/fear 1.1). Based on the taxonomy of HEAR, select all organizational causes (types) corresponding to actual causes (type)s in the accident investigation file, and make the keywords of FGI (Focus Group Interview) targeting classified organizational causes (types). For the selected keywords, a verification procedure needs to be undergone. Although, this study easily approached using HEAR that defined the relationship between actual cause (type) and organizational cause (type) in the case in this study, keywords need to be selected extensively by using brainstorming or Delphi technique.

2.4 Draw root cause with FGI

Perform FGI targeting the keywords obtained through the accident analysis, and find all organizational root causes (forms) revealed in each organization. Conclude that the organizational root causes (forms) shown through FGI process are the root causes of organizational cause form of accidents revealed in the current organization.

2.5 Review root causes analysis with survey

The content of questionnaire survey is made on the basis of organizational root causes obtained through FGI. The questions are to identify cognizance degree of the actual organizational root causes through FGI, not surveying generally set items like safety inspection, and each item is actual questions corresponding to real operators and managers. For the questions, it is good to apply AHP method for objectivity and the identification of problem priorities.

2.6 Chart analysis of root causes

Figure 4 is a chart analyzing organizational root causes. The X axis means the number of accidents analyzed through accident analysis, and the vertical axis shows cognizance degree on organizational root causes analyzed through the questionnaire analysis. When high result value (very so) is revealed, it means cognizance on organizational root causes is high, otherwise, it is regarded as low. The X axis located the most number of accidents by equally dividing them on the coordinate (In this case, relative interpretation is required, according to domain). Using the analyzed information so far, the following information can be ascertained,

when organizational root causes are located on the quadrant. First, as the degree of organizational (manager and operator) cognizance on and interest in each organizational root cause, it can be used as safety culture yardstick. Second, it is the information of major organizational root causes affecting accidents. Not all organizational root causes occurring in organizations do not affect accidents, but accidents can occur by several specific causes. Namely, the basis for selection and concentration of problem solving can be presented. Third, the currently applied solutions to problems can be evaluated. This is the part corresponding to category II: cognizance on the problem is high, but many accidents occur continually. In this case, a suggestion can be presented to change a solution to a problem.

What needs to be considered here is that it cannot be said, "It's not organizational problem, but relative importance is low", although the number of accidents is small, and cognizance is high as in the category III. The reason is that all organizational root causes demonstrated on the chart occur, irrelevant of many or small number of accidents, or high or low cognizance degree.

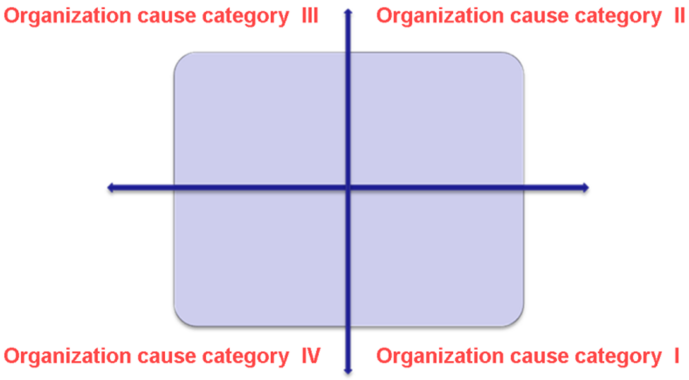

Figure 4. Chart analysis of root causes

2.7 Propose alternatives and solutions

As a result of drawing organizational root causes, this study analyzed the alternative of each problem as follows: Organizational cause category I is the case in which cognizance on the causes of problems is low, and there are many accidents. In this case, quick measures for improvement are needed, since identification of accident causes is not conducted. Organizational cause category II refers to the case that cognizance is high on the causes of problems, and there are many accidents. The currently implemented problem solving method in this case is regarded as a wrong method, because the problems continuously become the causes of accidents, despite high cognizance of problems corresponding to root causes. Organizational cause category III is the case that cognizance on the causes of problems is high, and there are small number of accidents, and this can be regarded as the last item to consider. Organizational cause category IV is the case that cognizance on the causes of problems is low, and there are small number of accidents. In this case, accidents may occur more, due to low cognizance, which can be regarded as major organizational root cause that can move to category I.

3. Results

This is the case applying the process in this study to railroad organization.

3.1 Define analysis boundary and accident analysis

For cause type analysis, 214 accidents were classified from January 2011 to December 2012, according to HEAR cause taxonomy. Since the document data at the time of accident investigation does not address organizational causes (types), this study identified organizational causes (types), based on relevant causes of the HEAR taxonomy.

This study used 3rd Delphi method to make organizational causes (types) keywords for FGI, and selected such representative keywords as organization, communication and operation (Figure 5).

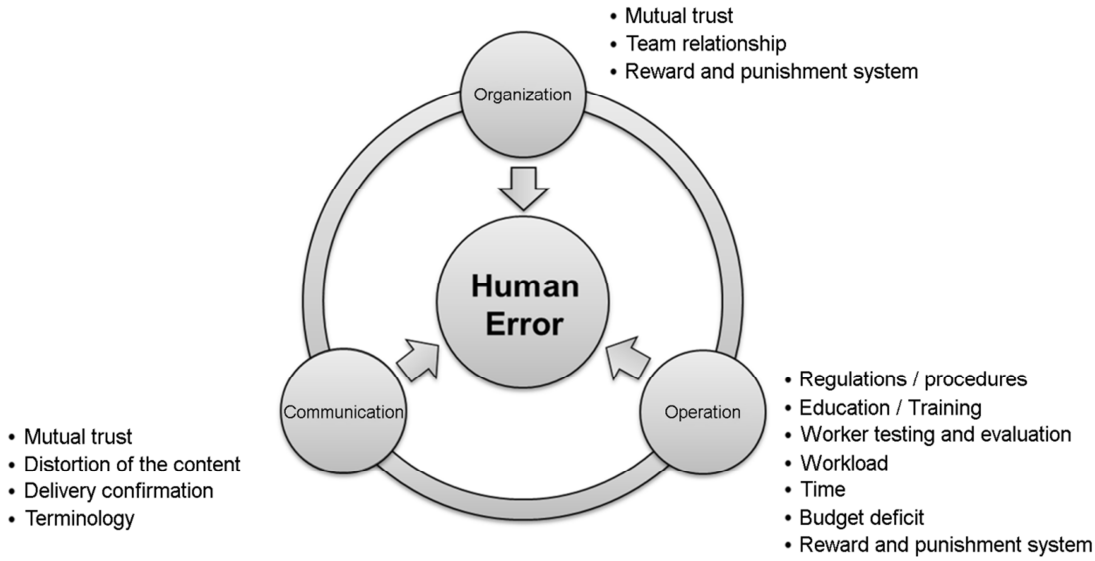

Figure 5. Validation of organization cause; FGI keyword selection

3.2 Draw root cause; FGI

This study carried out FGI to identify organizational root causes corresponding to each organization. FGI was performed by selecting six managers and operators from each organization, and this study targeted five organizations.

Therefore, this study identified organizational root causes per keyword as shown in Table 1.

Table 1. Root cause

Organization cause keyword	Root causes
Organization	Root causes 1. Misunderstanding between organizations
	Root causes 2. Closed organizational environment
	Root causes 3. Treatment of staff caused the accident
	Root causes 4. The occurrence of worry and distraction

Table 1. Root cause (Continued)

Organization cause keyword	Root causes
Organization	Root causes 5. Distrust of reward and punishment system
Operation (Education)	Root causes 6. Problems of education
	Root causes 7. Difficulties in understanding official document
	Root causes 8. Weakening expertise(promotion system)
	Root causes 9. Lower expertise
Operation (Human Resources)	Root causes 10. Tight work schedule
	Root causes 11. Confusion due to frequent reorganization of the rules
	Root causes 12. Operation system does not help field organization
	Root causes 13. Vulnerable time driving accident
	Root causes 14. Inadequate work and rest time
Communication	Root causes 15. Problem does not use a prescribed term
	Root causes 16. Communication problem due to dialect and unusual accents
	Root causes 17. Not clear communication process
	Root causes 18. Unfixed safety culture

3.3 Survey analysis

This study carried out a questionnaire survey to identify the cognizance degree of 18 items set up as organizational root causes. The subjects of the questionnaire survey were categorized, according to career, organization and region. This study identified each organization's problem cognizance degree on organizational root causes, and compared the difference of thinking between the organizations (head office, operator, control). The individual safety problem can be the reason why accidents occur, as a result of FGI, but an assumption that solutions may have been wrongly designed, due to difference in cognizance of problems (root causes) according to organization, can be made.

Figure 6 summarizes the relationship between questionnaire survey results and organizational causes. Cognizance on potential causes presented as organizational causes is not high mostly. One peculiarity is that cognizance degree on problems between managers and operators are different, respectively.

The interpretation on organizational root causes can be made as follows:

For example, concerning potential cause 1. line organization's misunderstanding on the role of control organization, the difference of information between organizations is addressed, but lower degree of cognizance than average (fair) was revealed. This means that 40% of people do not precisely identify or do not know the role of the control organization. An interpretation that no-understanding of the role of the control organization can be regarded as the problem of training or influence of closed environment can be made. Perform chart analysis to specifically analyze each item.

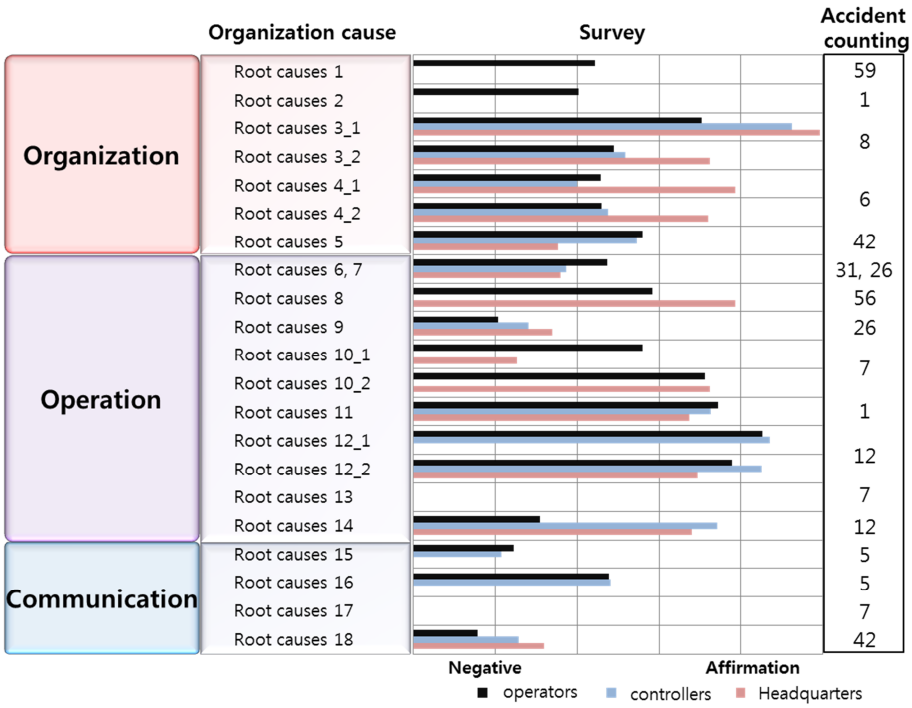

Figure 6. Survey results

3.4 Chart analysis of root causes

Draw a chart as shown in Figure 7 to easily check the problems that organizations currently have for accident analysis, FGI and questionnaire analysis, the degree of cognizance of the problems and the number of accidents according to the problems. The X axis indicates the number of accidents obtained through accident analysis. The number of accidents is smaller to the left direction, and it increases to the right direction. The Y axis shows the result of the questionnaire survey: the higher score is, the higher the item concerned is located on the graph, and the lower the score is, the lower the item concerned is located on the graph. The meaning of each quadrant is interpreted as follows:

- Cognizance was low on category I root causes, and many accidents occurred.
- Cognizance on category II root causes was high, and many accident occurred.
- Cognizance on category III root causes was high, and small number of accidents occurred.
- Cognizance on category IV root causes was low, and small number of accidents occurred.

Many occasional root causes are located at lower part (Figure 7). Also, cognizance on the causes affecting actual accidents is very low. The number of potential causes located on the right side is relatively smaller. This is conjectured that small number of organizational root causes cause many accidents.

Because cognizance on the organizational root causes classified as category IV is very low, they can be connected to accidents anytime. In this case, if the number of accidents increase, the organizational root causes can move to the category I.

The cause 8 is the case that many accidents occurred, despite high cognizance on the problems. Due to such organizational

root causes, there can be a need to improve the problem solving method.

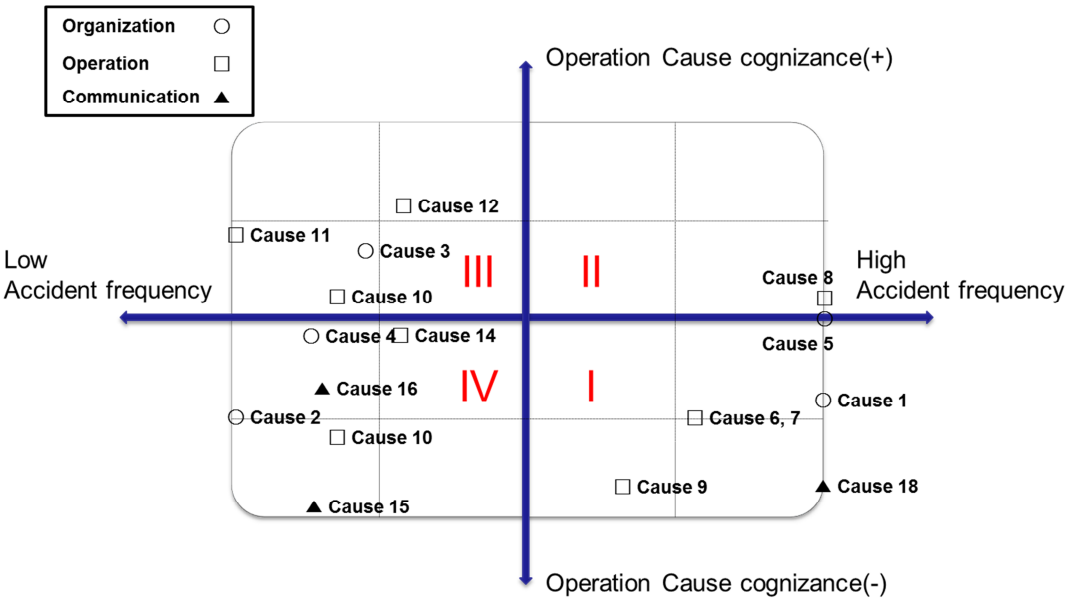

Figure 7. Organizational root causes chart analysis

4. Conclusion

4.1 Contributions

This study identified cause (error) types through accident investigation files, and grasped organizational root causes through FGI and questionnaire survey.

The contributions of this study are as follows:

First, the study result can be the cornerstone to prevent the organizational root causes of accidents. If the organizational root causes generating human errors (types) are not prevented, the organization will be continually exposed to accident risk.

Second, this study reorganized cause taxonomy. For example, existing studies have figured out what organizational causes (types) related to a human cause (type) of oblivion are, however, this study ascertained all organizational causes (types) that can affect oblivion, and categorized them as organizational root causes. This method helps users easily approach cause types (error types). Concerning the causes (types), which are difficult for onsite workers to understand, due to difficult words or vagueness, the problematic part can be found in an expert's perspective, if conversation is made through FGI.

Third, this study presented a practical method to build a tool for problem analysis and measures to improve. This study expressed the correlations of accident analysis, FGI and questionnaire survey as a chart, not just using them as independent analysis methods. By expressing organizational root causes on a chart, this study made users understand on how much current organizational causes (types) are recognized by them, and on what organizational root causes affect accidents to what degree at one glance.

Lastly, this study presented the fusion case of disciplines including engineering and business administration. This study is considered to have academic significance in that this study approached by introducing engineering cause (error) taxonomy and systematic analysis method to humanities field.

4.2 Limitation and future research

There are some difficulties to use the method in this study for general use. As a result of carrying out a process targeting accident investigation files occurred in nuclear power plants, it was not easy to obtain results, due to difference in accident scope selection or structural difference in investigation files in the process of extracting FGI items.

To solve such a problem, the following items need to be researched in the further study:

First, database building. The database required for study can be divided into two: an FGI selection method through cause (type) taxonomy, and database on solutions to organizational root causes. Through continuous study, there is a need to identify the relations between human error types (cause types) and organizational causes (types), and accurately grasp organizational root causes through a process that draws into FGI items. Second, there is a need to use various methods to enhance the objectivity of questionnaire survey. The questionnaire survey results are important values directly affecting analysis results. Therefore, a study on various methods to enhance the accuracy of questionnaire is needed.

Human errors or causes are considered to be the result generated by the lack of organizational or people's safety awareness. Because, such errors are not revealed greatly externally, cognizance on the seriousness of the problem is very low, and analysis or identification on those is very difficult. If only the causes (types) viewed externally are solved, accidents will continue to occur through other cause types (error types). In this regard, finding organizational root causes for problem solving and solutions to each cause will be very important.

Acknowledgements

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