Safety-critical human factors issues derived from analysis of the TEPCO Fukushima Daiichi accident investigation reports

SAKUDA Hiroshi¹, and TAKEUCHI Michiru²

1. Institute of Nuclear Safety Systems, Inc., 64 Sata Mihama-cho Fukui Pref., 919-1205 Japan (sakuda@inss.co.jp)

2. Institute of Nuclear Safety Systems, Inc., 64 Sata Mihama-cho Fukui Pref., 919-1205 Japan (currently Institute of Elderly Housing Sciences, 5-5-15 Nishinakajima Yodogawa-ku Osaka, 532-0011 Japan (mtakeuchi@keiyuu-kai.or.jp))

Abstract: The Fukushima Daiichi nuclear power plant accident on March 11, 2011 had a large impact both in and outside Japan, and is not yet concluded. After Tokyo Electric Power Co.'s (TEPCO's) Fukushima accident, electric power suppliers have taken measures to respond in the event that the same state of emergency occurs - deploying mobile generators, temporary pumps and hoses, and training employees in the use of this equipment. However, it is not only the "hard" problems including the design of equipment, but the "soft" problems such as organization and safety culture that have been highlighted as key contributors in this accident. Although a number of organizations have undertaken factor analysis of the accident and proposed issues to be reviewed and measures to be taken, a systematic overview about electric power suppliers' organization and safety culture has not yet been undertaken.

This study is based on three major reports: the report by the national Diet of Japan Fukushima Nuclear Accident Independent Investigation Commission (the Diet report), the report by the Investigation Committee on the Accident at Fukushima Nuclear Power Stations of Tokyo Electric Power Company (Government report), and the report by the non-government committee supported by the Rebuild Japan Initiative Foundation (Non-government report). From these reports, the sections relevant to electric power suppliers' organization and safety culture were extracted. These sections were arranged to correspond with the prerequisites for the ideal organization, and 30 issues to be reviewed by electric power suppliers were extracted using brainstorming methods.

It is expected that the identified issues will become a reference for every organization concerned to work on preventive measures hereafter.

Keyword: nuclear; TEPCO Fukushima accident; human factors

1 Introduction

On March 11, 2011 the Fukushima Daiichi nuclear power plant (NPP) of Tokyo Electric Power Company, Inc. (TEPCO) suffered severe damage from the Great East Japan Earthquake and the ensuing tsunami. The subsequent nuclear accident (TEPCO Fukushima accident) seriously impacted on the local area.

The total amount of radioactive material released into the atmosphere from the Fukushima Daiichi NPP is (to date) about 900 PBq iodine equivalent, and about 1/6 of the 5200PBq released in the Chernobyl NPP accident^[1]. About 78,000 residents in the Access Restricted Area within a radius of 20km from the NPP have been evacuated. In the evacuation zone of areas with a possible annual cumulative dose of 20mSv or higher in the area beyond the 20-km zone, about 10,010 persons have been evacuated, while in the emergency evacuation zone outside the Deliberate Evacuation Area and the zone where indoor evacuation directives were canceled 20 to 30 km from the NPP, about 58,510 persons were evacuated, making the total 146,520 persons^[2] (as of August 29, 2011). Even now, many residents are obliged to live as refugees. The corresponding area of contaminated land which may cause a space dose of 5 or more mSv per year and 20 mSv is estimated to be 1,778 km² and 515 km², respectively^[3]. This contamination diffuses to the extensive area of not only Fukushima Prefecture but across a large part of Eastern Japan. The problem of radioactive contamination causes many people, including children, anxiety over the potential health impacts. Moreover, it has caused extensive damage to the producers of agricultural, livestock and marine products; and caused anxiety among the consumers of those products.

Regarding the TEPCO Fukushima accident which caused such an unprecedented disaster, three

organizations - the national Diet, the government, and a non-government organization - each investigated and issued reports. (An outline of these reports is shown in Table 1.) Besides these, TEPCO itself and several international organizations also submitted investigation reports and proposed various kinds of measures for improvement.

Utility companies contend with pursuing hard measures based on the knowledge acquired from this accident. The approaches have much in common at the general level although it is apparent that the specific content of proposals change with the type of plant (PWR, BWR), and the specific electric company. For example:

(1) Regarding the total loss of AC power, the power supply by means of air cooled emergency generators *etc.* and (2) loss of ultimate heat sink, provision of sea water cooling by deployment of portable type engine drive seawater pumps, and (3) the submergence of important equipment, implementation of measures against flooding by means of waterproofing seal construction on buildings and doors. Moreover, the structure for persons to operate the additionally deployed equipment appropriately - manuals, and training, *etc.* are reinforced.

As mentioned above, although the utility companies are advancing measures to improve the hardware side in response to the TEPCO Fukushima accident, it is pointed out in each report that this accident was not only a problem of hardware but also a problem of the soft side of the operation, such as organizational aspects and safety culture of TEPCO.

The reports have areas where they share a common view, and other areas where they may differ. To contribute to the examination of measures to prevent recurrence, it is thought necessary to extract and arrange issues from these reports to be reviewed systematically around the organization and safety culture of utility companies.

2 Purpose of the study

The purpose of this study is to analyze the accident investigation reports about the TEPCO Fukushima accident by three main organizations: the national Diet, the government, and a non-government organization. Next it is to derive issues to be reviewed systematically about the organization and safety culture of utility companies. It is expected that the derived issues to be reviewed will become a reference when a concerned organization examines measures to prevent recurrence.

3 Methods

The accident investigation reports applicable to this analysis were the official report of The Fukushima Nuclear Accident Independent Investigation Commission reported by the Diet^[4] (the Diet report), the report of the Investigation Committee on the Accident at Fukushima Nuclear Power Stations of

	The Diet report	Government report (Interim)	Government report (Final)	Non-government report
	The official report of The	Investigation Committee	Investigation Committee	Investigation and verification
Name	Fukushima Nuclear Accident	on the Accident at	on the Accident at	report of Independent
Tunio	Independent Investigation	Fukushima Nuclear	Fukushima Nuclear Power	Investigation Commission on
	Commission	Power Stations of Tokyo	Stations of Tokyo Electric	the Fukushima Daiichi
		Electric Power Company	Power Company	Nuclear Accident
		Interim Report	Final Report	
Issued	July 5, 2012	December 26, 2011	July 23, 2012	February 28, 2012
	Chairman:	Chairman:		Chairman:
Members	Kiyoshi Kurokawa	Yotaro Hatanaka		Koichi Kitazawa
Wielinders	No. of members:	No. of members:		No. of members:
	9 persons	9 persons		5 persons
	To investigate the causes of		nendations on measures to	To verify the responsibility of
	the accident, and the causes of	prevent further spread of	the government and TEPCO	
	the damage sustained from the	accident and a recurrence of similar accidents in the		by making truth,
	accident.	future. This is done by conducting a multifaceted		independence, and the world
Investigation	To investigate and verify the	investigation to determine	into a motto.	
policy	policy emergency response and the and the causes that contributed to the damage inflicted			
	history of nuclear policies.	by the accident.		
	To recommend measures			
	based on the findings of the			
	above investigations.			

Table 1 Reports by the 3 committees of the Fukushima nuclear accident investigation (general outline)

Tokyo Electric Power Company reported by the government (the Interim^[5] government report, and Final^[6] government report), and the investigation and verification report of the Independent Investigation Commission on the Fukushima Daiichi Nuclear Accident^[7] (non-government report). The accident investigation report made by TEPCO^[8] (made public on June 20, 2012) was utilized for comprehending the facts. Authors (1) extracted and (2) arranged the sections which are relevant to the organization and safety culture of utility companies, and then (3) derived issues to be reviewed from them. Hereinafter, these are explained in full detail.

3.1 Extraction of relevant sections

For the Diet report and the government report, relevant sections were extracted from the discussion on the issues to be reviewed and the measures to be taken. For the non-government report, since the issues to be reviewed and the measures to be taken are contained in various sections of the report, relevant sections were extracted by means of keyword retrieval from the electronic file. The keywords utilized were: "problem", "issue", "appropriate", "sufficient", "point out" ("pointed out"), "necessary", "should", "presume", "guess," "cause", "remote cause", "factor", "culture", "view", "constitution", and "thinking". (Specifically refer to Table 2.)

Moreover, from the extracts, the items relevant to the organization and safety culture of utility companies were selected, as well as items indirectly relevant.

3.2 Arrangement of relevant sections

In order to arrange the extracted contents and classify them by similarity of content, the framework^[9] of "nine prerequisites for the ideal organization" was adopted. This framework was developed by reviewing (as referred to in the KJ method) the research on organizations with regard to: safety culture, high reliability organizations, resilient organizations, leadership in safety-critical organizations. This framework was thought to be the most appropriate as a classification system.

The nine prerequisites are, (1) The organization provides systematic resources and infrastructure to ensure safety. (2) The organization has a sharable vision. (3) Management attaches importance to safety. (4) Employees openly communicate issues and share wide-ranging information with each other. (5) Adjustments and improvements are made as the organization's situation changes. (6) Learning activities from mistakes and failures are performed. (7) Management creates a positive work environment and promotes good relations in the workplace. (8) Workers have good relations in the workplace. (9) Employees have all the necessary requirements to undertake their own functions, and act conservatively. The extracted sections were classified and arranged by their contents into the nine prerequisites. Since each section may have two or more meanings, in this case, they were subdivided. Here, each subsection is called a "file."

Table 2 Extraction of sections relevant to the organization and the safety culture of the utilities

The Diet report	The section where the problems are pointed out in the Executive Summary
Governmen t report (Interim)	The section where the problems are pointed out in VIL Observations and Proposals Regarding Problems Identified through Investigations and Inquiries to Date and IV. Accident response at TEPCO's Fukushima Dai-ichi NPS
Governmen t report (Final)	The section where the problems are pointed out in Executive Summary of the Final Report
Non-govemment report	The sections retrieved by keywords in the main text. Keyword: problem; issue; appropriate; sufficient; point out; (pointed out); necessary; should; presume; guess; cause; remote cause; factor; culture; view; constitution; thinking

3.3 Derivation of issues to be reviewed

The files arranged according to the nine prerequisites for the ideal organization were grouped by their similarity. If there were causal relationship between groups, they were connected by drawing an arrowed line. Moreover, in the case where the content of a file was related to the "background factor" which caused a problem, a dotted enclosure frame and dotted arrow line were drawn. Finally, every group was given a name expressing the contents inside the group. This name serves as an "issue to be reviewed" This derivation work was done using a brainstorming method.

4 Results

4.1 Results of extraction of relevant sections

The sections, which were relevant to the organization and safety culture of utility companies, were extracted from the contents of the above reports. 21 sections were extracted from the Diet report, 36 from the government report (Interim and Final), and 60 from the non-government report, for a total of 117 extracts. An example is shown in Fig. 1.

Report	No. of referred place	Description
Dict	1	The fundamental causes of the accident already existed prior to March 11, 2011 (3, 11), According to the investigation of the Commission, as of 3.11, the Fukushima Daiichi Nuclear Power Plant was presumably in a vulnerable condition, incapable of withstanding an earthquake and tsunani. Tokyo Electric Power Company (TEPCO) as the nuclear operator, the Nuclear Safety Commission (NSC) and the Nuclear and Industrial Safety Agency (NISA) as the regulatory authorities, and the Ministry of Economy, Trade and Industry (METI), as the government body promoting nuclear power, all failed to correctly prepare and implement the most basic safety requirements, such as assessments of the probability of damage by earthquakes and tsumanis, countermeasures toward preparing for a severe accident caused by nutural disasters, and safety must be public in case of a large release of radiation.
Diet	2	In 2006, NSC revised the old guidelines for anti-seismic standards, while NISA requested the nuclear power operators in Japan to carry out the Seismic Safety Assessment (antiseismic backcheck) as new guidelines. TEPCO notified NISA that the deadline for their final report on the anti-seismic backcheck would be June 2009. However, the anti-seismic backcheck did not proceed, and within the company, it was postponed to January 2016. Although TEPCO and NISA were aware of the need for structural reinforcement in order to conform to new guidelines, no part of the requirate lenitorcements had been implemented on Units 1 through 3 at the time of the accident. After the accident, TEPCO claimed that there was no significant damage to Unit 5 according to a visual survey, but this did not mean that there had been no damage caused by the earthquake to Units 1 through 3.
Diet	21	Concerning the rise in pressure in the containment vessel at Unit 3 at 08:00 on March 14, TEPCO records state that it did not make this public because it had received instructions from NISA to stop issuing press releases. However, according to the Kantei, it had merely instructed TEPCO to at least inform the Kantei(official residence) when issuing a press release. For TEPCO to act according to instructions from the Kantei and the supervising authorities may be considered sensible. However, it attanpired that the company apparently was placing higher importance on its public appearances vis-à-vis the government than transparency of information in a situation where residents in the vicinity and other people were being placed in danger.

Fig.1 An example of extraction result (the Diet report).

4.2 Results of classification of extracted sections

Regarding the content of the 117 extracts described in section 4.1, the text that expresses the meaning directly was marked, and was named a "file". As a result, 140 files were able to be extracted from 117 sections. An example is shown in Fig. 2.

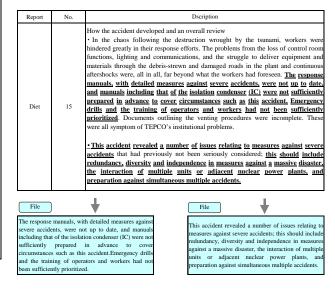
4.3 Results of derivation of issues to be reviewed

The 140 files extracted as described in section 4.2 were classified according to the nine prerequisites for the ideal organization, and Table 3 was obtained as a result. For the classifications: (2) The organization has a sharable vision, (7) Management creates a positive work environment and promotes good relations in the workplace, and (8) Workers have good relations in the workplace, no file fell into these prerequisites. During the stage of classifying the files, since there were files which could not be settled into any of the nine prerequisites, the category (10) "The relations, communication, and information sharing between stakeholders, are good."

Next, with four researchers' cooperation,

brainstorming was performed and the classified files of similar content were grouped. If necessary, in the process of grouping, the file was subdivided.

For example, as for the prerequisite "(1) The organization provides systematic resources and infrastructure to ensure safety.", every file was sorted into four groups. The files listed below are one of these groups.



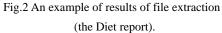


Table 3 Results of classification				
 The organization provides systematic resources and infrastructure to ensure safety. 	7	16	13	36
(2) The organization has a sharable vision.	0	0	0	0
(3) M anagement attaches importance to safety.	9	2	2	13
(4) Employees openly communicate issues and share wide-ranging information with each other.	4	6	13	23
(5) Adju stments and improvements are made as the organization's situation changes.	2	0	2	4
(6) Learning activities from mistakes and failures are performed.	1	2	6	9
(7) M anagement creates a positive work environment and promotes good relations in the workplace.	0	0	0	0
(8) Workers have good relations in the workplace.	0	0	0	0
(9) Employees have all the necessary requirements to undertake their own functions, and act conservatively	1	11	2	14
(10) The relation, communication, and information sharing between stakeholders, are good	11	4	26	41
Total	35	41	64	140

Table 3 Results of classification

Safety-critical human factors issues derived from analysis of the TEPCO Fukushima Daiichi accident investigation reports

[Diet-14]

• External events such as earthquakes and tsunamis were not postulated.

[Gov.Final-3]

- External events such as earthquakes and tsunamis were not viewed as targets for specific consideration.
- The PSA for external events established prior to the Fukushima nuclear accident was only the seismic PSA and was still limited as a means.
- Periodic Safety Review (PSR) failed to offer opportunities for improving severe accident measures.
- The early introduction of the PSA had not been considered due to factors such as work on seismic back checks.

[Gov.Final-4]

• Nuclear utilities should actively utilize currently available methods in their analyses of such external events.

[Gov.Final-5]

• External events should be identified by comprehensive safety analysis, and appropriate measures (severe accident management) against such vulnerability should be examined and placed in shape.

[Gov.Final-18]

- An institutional framework is needed to ensure continued in-depth examination of "residual risks" or "remaining issues" without leaving them behind. [Gov.Final-21]
- Scientific knowledge of earthquakes is not sufficient yet. The latest research results should be continually incorporated in disaster preparedness. [Non-Gov.-52]
- The safety assessment of the whole of plant was insufficient.
- The probabilistic safety assessment for incidents arising as a result of external events was delayed because its methods were not well established.
- The frequency of unplanned outage was low, and as a result the myth of safety was originated.

[Non-Gov.-53]

• An examination of "residual risk" of tsunami

• The accumulated scientific knowledge of tsunamis is far smaller than that of earthquakes.

After examining above eight files, this group was named "(1) Reviews of external events and residual risks". Other groups were examined and named, and issues to be reviewed were derived. The result is shown in Fig.3 – Fig.9. Let us point out that the contents of some files are omitted for the readability of the figures.

Issues to be reviewed were derived as below.

[(1) The organization provides systematic resources and infrastructure to ensure safety.]

- (1) Reviews of external events and residual risks
- (2) To improve the management culture giving priority to costs
- (3) To assume the occurrence of events of low probability
- (4) Thoroughgoing measures against severe accidents

[(3) Management attaches importance to safety.]

(5) To create the organization's posture to safety precedence

- (6) Appropriate cognition concerning the risk of earthquake and tsunami
- (7) To put importance on cost efficiency and effects on existing reactors and lawsuits, rather than safety (background factor)

[(4) Employees openly communicate issues and share wide-ranging information with each other.]

- (8) Thorough information disclosure
- (9) To strengthen individual competence to deal with an emergency
- (10) Studies of what an organization should be to function in an emergency

[(5) Adjustments and improvements are made as the organization's situation changes.]

- (11) Definite implementation of seismic measures
- (12) Continuous revision of tsunami countermeasures

(1) Reviews of external events and residual risks	(3) To assume the occurrence of events of low probability		
Diet- 14 External events such as earthquakes and tsunamis were not postulated. Gov.(F)- 3 ·External events such as earthquakes and tsunamis were not viewed as targets for specific consideration. ·The PSA for external events established prior to the Fukushima	Gov.(F)- 17A new approach to safety measures and disaster preparedness should be established for a disaster which potentially brings serious damage in broad areas, regardless of its probability of occurrence.Non gov 45 Preparations against nuclear terrorism are insufficient.Non gov 48 The problem is that the with the problem is that the with the		
nuclear accident was only the seismic PSA and was still limited as a means. •Periodic Safety Review (PSR) failed to offer opportunities for improving severe accident measures. •The early introduction of the PSA had not been considered due to factors such as work on seismic back checks.	Gov.(F)- 19 If nuclear utilities and regulatory bodies over-estimate the safety of the "system core domain" within only those design assumptions, for which it was designed, safety measures will fail.		
Gov.(F)- 18 An institutional framework is needed to ensure continued in-depth examination of "residual risks" or "remaining issues"	(4) Thoroughgoing measures against severe accidents		
without leaving them behind. Non gov 53 · An examination of "residual risk" of tsunami. · The accumulated scientific knowledge of tsunamis is far smaller than that of earthquakes.	Diet- 15 This accident revealed a number of issues relating to measures against severe accidents; this should include redundancy, diversity and independence in measures against a massive disaster, the interaction of multiple units or adjacent nuclear power plants, and preparation against simultaneous multiple accidents.		
Gov.(F)- 4 Gov.(F)- 5 Gov.(F)- 21 Non gov 52 (2) To improve the management culture giving priority to costs	Gov.(I)- 7 The accident management measures that ended up being promoted focused only on internal events. External events were not raised as a specific subject to be examined.		
Diet- 20 • The conditions for one of their major premises: that "existing reactors should not be stopped." • To avert the risk of shutting existing reactors down due to	Gov.(F)- 12 TEPCO was not sufficiently prepared for such an accident, that natural disasters including tsunami may lead to large-scale core damage.		
criticism <i>e.g.</i> lawsuits. • The utilities stubbornly refused any moves toward backfitting for the assessment of seismic safety or strengthened regulations, including the regulation of severe accident countermeasures.	Non gov 60 •Prepared measures against tsunami were insufficient. •Prepared measures against severe accidents were insufficient.		
Non gov 41 •The issues of the governance and the risk management, which are	Diet-16 Diet-21 Gov.(I)- 5 Gov.(I)- 6		
inherent to Japanese society. •The accident, and the incomplete handling of it.	Gov.(I)- 8(1), 9(1), 10(1), 11(1) Gov.(I)- 8(2) Gov.(I)- 9(2)		
Diet-1 Diet-11 Non gov 16 Non gov 57	Gov.(I)- 10(2) Gov.(I)- 11(2) Gov.(F)- 20 Non gov 5 Non gov 17 Non gov 37 Non gov 55 Non gov 59		
Fig.3 Extraction of issues to be reviewed. [(1) The organization provides systematic resources and infrastructure to ensure safety.] (5) To create the organization's posture to safety precedence			
(c) to orbate the organiza			

Diet- 10(1) TEPCO prioritized the intentions of the Kantei (official residence) over those of on-site technicians. TEPCO maintained an ambiguous attitude, seemingly trying to guess the intentions of the Kantei (official residence) in consulting about evacuation.			
Gov.(F)- 10 Diet- 16 Gov.(F)- 11 There was also a problem of the attitude of TEPCO management personnel, who tried to stop the injection of seawater without giving much consideration. Diet- 16 Gov.(F)- 11			
(6) Appropriate cognition concerning the risk of earthquake and tsunami	(7) To put importance on cost efficiency and effects on existing reactors and lawsuits, rather than safety		
Diet- 19 ·(TEPCO) failed in preparing against earthquakes and tsunamis, despite repeated warnings about the potential for such catastrophes. ·TEPCO postponed putting any measures into place for the other	Diet- 10(2) TEPCO regarded as management risks situations that might cause the halting of existing reactors or disadvantages in litigation.		
 verse, using the scientific improbability of such events as an excuse. verse, verse, ver	Non gov 30 TEPCO raised the purpose of the cost cut and the improvement of a financial condition, and promoted the rationalizing measures.		
Diet- 3 Diet- 5 Diet- 8 Diet- 13	Diet- 7 Diet- 22		

Fig.4 Extraction of issues to be reviewed. [(3) Management attaches importance to safety]

Safety-critical human factors issues derived from analysis of the TEPCO Fukushima Daiichi accident investigation reports

(8) Thorough information disclosure	(10) Studies of what an organization should
	be to function in an emergency
Diet- 23 The disclosure of information by TEPCO was far from sufficient, and wounded up increasing the overall negative impact. Non gov 60(2) • The influence of complex disasters existed. • The means of communication and transportation was limited. Diet- 10 Diet- 18 Non gov 11	Diet-16 (1) The TEPCO head office failed to provide technical assistance. Masao Yoshida, Site Superintendent of the Fukushima Daiichi Nuclear Power Plant, asked TEPCO Representative Director and Executive Vice President Sakae Muto for technical advice when the situation at Unit 2 became serious, but Muto was unable to respond, as he was en route from the Offsite Center. TEPCO lacked the awareness and organization to support people at the front line of the accident site; the TEPCO head office did nothing to change the situation in which the Kantei asked elementary technical questions directly to Site Superintendent Yoshida, and the TEPCO president endorsed instructions from
(9) To strengthen individual competence to deal with an emergency	Nuclear Safety Commission (NSC) Chairman Haruki Madarame that were in conflict with the judgment of people at the accident site.
Diet- 16(2) The ingrained singular management culture of TEPCO is one in which TEPCO wields a strong influence over energy policies and nuclear power regulations, yet does not take on responsibility itself, instead manipulating situations behind the scenes and passing on responsibility to government agencies, and this distorted its response. The "full withdrawal" issue and the problem of intense intervention by the Kantei were symbolic of that. The root cause of the misunderstanding can be traced to the fact that TEPCO President Shimizu, despite being the top executive of	 Gov.(I)- 12 They did not assume that a situation in which multiple nuclear reactors losing all power sources almost simultaneously would occur and thus did not provide the training and education necessary to implement measures to control such a serious situation. Top leadership (<i>e.g.</i> how to put out an instruction) as well as an organizational structure necessary to realize the top idea, was not developed and prepared sufficiently. They did not realize it as their roles and responsibilities to implement the instructions from their top.
a private company, was responsible for a corporate culture that exhibited little sense of independence and responsibility, and simply maintained ambiguous communication. It was as if he was trying to take the pulse of the Kantei even in this extremely grave situation.	Gov.(F)- 9 • The insufficient ability of each individual in functional teams in the Emergency Response Center to make decisions and judgments in a timely manner, and to fulfill his or her function as a member of the functional team.
Gov.(F)- 12 The accident showed quite a number of problems with TEPCO such as insufficient capability in organizational crisis management; hierarchical organization structure being problematic in emergency	•Inadequate education and training that gives a view to extreme situations such as the complete and simultaneous loss of AC power supply at multiple nuclear reactor units.
responses.	Non gov 7 Efficient information sharing and an organization suitable for decision-making should be examined immediately.
The manuals failed to prepare for complex disasters.	Non gov 1 Non gov 2(2), 10(2) Non gov 4 Non gov 9 Non gov 14 Non gov 42
Gov.(F)- 8 Gov.(F)- 10 Gov.(F)- 14 Non gov 21 Non gov 46(1)	Non gov 46(2) Non gov 47 Non gov 60(1)

Fig. 5 Extraction of issues to be reviewed.

[(4) Employees openly communicate issues and share wide-ranging information with each other.]

(11) Definite implementation of seismic measures		(12) Continuous revision of tsunami countermeasures
Diet- 2 Although TEPCO and NISA were aware of the need f reinforcement in order to conform to new guidelines, no required reinforcements had been implemented on Units 1	part of the It prough 3.	Non gov 22 t is obvious that several equipments critical for nuclear afety were severely damaged, therefore preparation for the tsunami was insufficient.
Diet-12 No further seismic backcheck reports were released by T those interim reports. Although the original deadline for reports was June 2009, TEPCO made an internal reschedule the deadline to January 2016. Our investiga that, although TEPCO recognized from the interim calcui that many anti-seismic reinforcements would be necessar comply with the revised Guide, it had not conducted a Units 1 through 3 at the time of the Great East Japan Earth	r the final ecision to on verified tion results in order to y work on	Von gov 31 TEPCO had not revised measures for tsunamis of the 'ukushima NPP since 2002. TEPCO was at the position of leading company among apanese utilities, and its activities gave big influence on ll of the others.

Fig. 6 Extraction of issues to be reviewed.

[(5) Adjustments and improvements are made as the organization's situation changes.]

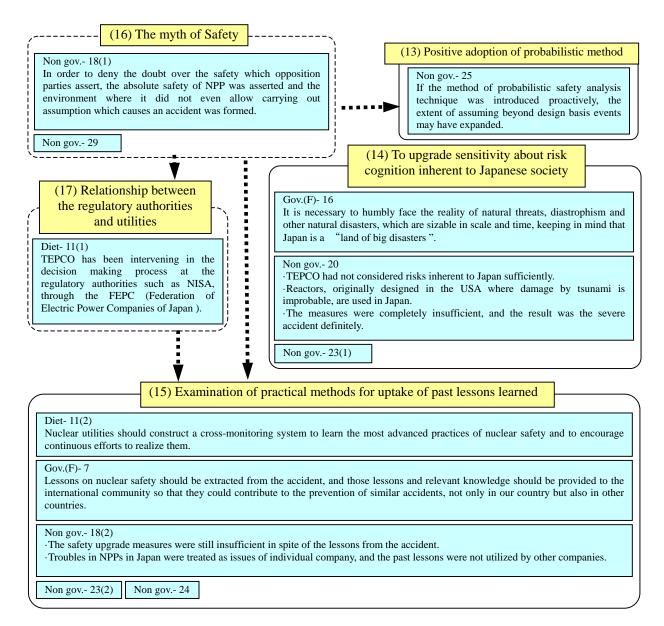


Fig. 7 Extraction of issues to be reviewed.

[(6) Learning activities from mistakes and failures are performed.]

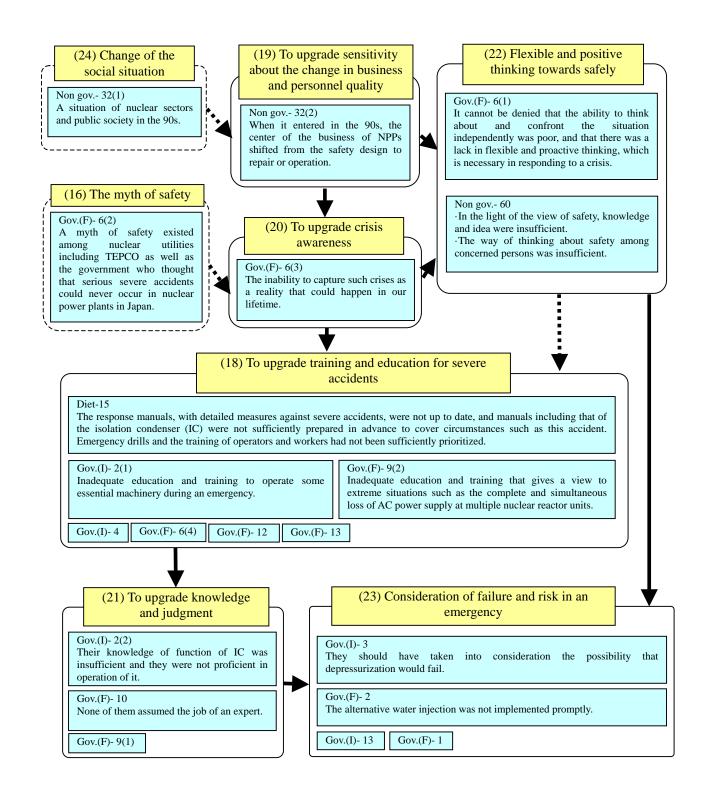


Fig. 8 Extraction of issues to be reviewed.

[(9) Employees have all the necessary requirements to undertake their own functions, and act conservatively.]

 (25) To establish good relationships between operators and regulators (26) To upgrade information sharing with overseas authorities Diet- 5(2), 20 The regulatory authorities gradually became the "capture" of electric power utilities. Non gov 33 The system in which private sectors implement the national policy has spoiled the soundness of utility companies. Non gov 38 ·Utilities were not cooperative to the peer reviews by IAEA. ·The excessive inspection in accordance with peer reviews promoted the operators' concealment constitution. 	(28) To improve the sensitivity to changes of society or workplace environment. Non gov 32 • As the result of nuclear environment change, safety consciousness and risk sensitivity have degraded. • The center of the business of NPPs shifted from the safety design to repair or operation.
Diet- 4 Diet- 5(1), 11, 14(2) Diet- 6 Diet- 10, 24 Diet- 14(1) Non gov 26 Non gov 34 Non gov 56(1) Non gov 40	(29) To revise the governance system of nuclear regulation
(27) To upgrade information sharing and cooperation in an emergency Diet- 9 •NISA's dysfunction •Insufficiency of information available at the TEPCO headquarters •The Prime Minister made his way to the Fukushima Nuclear Power Plant to direct the workers on-site. •The boundaries defining the responsibilities of the nuclear operator and the government were ambiguous through the course of emergency responses.	The structure of governance of nuclear regulation is complex. Confusion of responsibilities.Non gov 27(2), 35(1), 43(1)Non gov 28(1)Non gov 28(2), 43(3), 44(1)Non gov 28(2), 43(3), 44(1)Non gov 44(2)Non gov 43(2)
Gov.(I)- 1 For information on progress in preparations to pressure venting at the Unit 1, TEPCO personnel stationed in the ERC were not able to give accurate, prompt responses.	(30) To improve the working environment to put a high
Gov.(F)- 22(1) Questions and doubts as to whether the information had been communicated in a prompt and accurate manner to people. Non gov 14 •Water injection into the reactor was carried out without deliberate decision of the policy.	Gov.(F)- 23 They were captured in technically insignificant checking business and hardly afforded to take an overall view
·Information of water injection was not sufficiently shared among related organizations. Diet- 16(1), Non gov6(2) Diet- 16(2), Non gov6(1) Diet- 17 Gov.(F)- 22(2) Non gov 3 Non gov 8 Non gov 12(1) Non gov 12(2), 49(1) Non gov 13, 15(2) Non gov 15(1) Non gov 19 Non gov 49(2), 50(2) Non gov 50(1) Non gov 51	of safety. Non gov 56(2) A receiving end of the regulation is apt not to comply more than the standard. Non gov 58

Fig. 9 Extraction of issues to be reviewed. [(10) The relation, communication, and information sharing between stakeholders, are good.]

[(6) Learning activities from mistakes and failures are performed.]

- (13) Positive adoption of probabilistic method
- (14) To upgrade sensitivity about risk cognition inherent to Japanese society
- (15) Examination of practical methods for uptake of past lessons learned
- (16) The myth of safety (background factor)
- (17) Relationship between the regulatory authorities and utilities (background factor)
- [(9) Employees have all the necessary requirements to undertake their own functions, and act conservatively.]
- (18) To upgrade training and education for severe accidents
- (19) To upgrade sensitivity about the change in business and personnel quality
- (20) To upgrade crisis awareness
- (21) To upgrade knowledge and judgment
- (22) Flexible and positive thinking towards safely
- (23) Consideration of failure and risk in an emergency
- (24) Change of the social situation (background factor)

[(10) The relation, communication, and information sharing between stakeholders, are good.]

- (25) To establish good relationships between operators and regulators
- (26) To upgrade information sharing with overseas authorities
- (27) To upgrade information sharing and cooperation in an emergency
- (28) To improve the sensitivity to changes of society or workplace environment.
- (29) To revise the governance system of nuclear regulation
- (30) To improve the working environment to put a high priority on safety

Among these, 4 issues, *i.e.* (7) To put importance on cost efficiency and effects on existing reactors and lawsuits, rather than safety, (16) The myth of safety, (17) Relationship between the regulatory authorities and utilities, (24) Change of the social situation, were positioned as "background factors". A background factor means that these issues are more fundamental factors, broadly-based or underlying organizational

cultural issues and tend to cause effects on other issues but do not obviously lie in the direct chain of causality. For example, "the myth of safety" has an inverse effect on the relevant persons' consciousness and actions to upgrade safety which would otherwise be taken with a greater level of concern. Moreover, such a background factor is difficult to be solved inside an organization in isolation as it may also relate to the general social culture.

5 Conclusion

30 issues were extracted associated with the organization and safety culture of utility companies by analyzing reports issued by three organizations, i.e. the Diet. government the and а specific non-government organization. Authors avoided evaluating the appropriateness of the contents of every report, and simply accepted the description as it is. Although the contents have the possibility to be changed hereafter, it is still thought instructive for concerned organizations to examine these appropriate measures.

In the course of arranging the contents of accident investigation reports into nine prerequisites of ideal organizations, no file was extracted related to the classification axes: (2) The organization has a sharable vision, (7) Management creates a positive work environment and promotes good relations in the workplace, and (8) Workers have good relations in the workplace. This means that in the stage of classifying the files, no file was relevant to these prerequisites. However the contents of these files are considered background factors that may be detected by deep examination of the workplace. It is presumed that there is the possibility that they were not captured adequately in the accident investigations. They are important matters for an ideal organization and should be taken into consideration for the upgrade of the safety culture of an organization, therefore it is expected that further investigations will ascertain these matters.

Besides these, the files which did not fit into the nine prerequisites were put in the additional prerequisite, *i.e.* "The relationship, communication and information sharing among stakeholders are good". The TEPCO Fukushima accident is not just an issue inside a single organization in the nuclear sector, many stakeholders,

e.g. the national government, local governments, local residents, electric power utilities, plant makers, subsidiary companies and mass media are related to each other, therefore there are thought to be many files suitable to this prerequisite. Conversely, in previous organizational research, studies of the relationship among stakeholders (*e.g.* regulatory authority, local nuclear site residents, nuclear industry organizations, and other companies) were scarce or unavailable, therefore it is thought to be an important research agenda. Revealing the need for organizational research to extend beyond the boundaries of the organization itself is one of the key contributions of this study.

In this study, the keyword retrieval method was adopted only in the non-government report, but this approach can possibly extract new classification axes and issues to be reviewed by applying it in other accident reports domestically and globally. This issue will be studied in future.

The issues that were extracted in this study are expected to be used as references for each relevant organization to consider as improvement measures in the future. At this time, it is thought difficult to infer the meaning definitively from their names only. Therefore, it is necessary to consider Fig.3 to Fig.9 simultaneously and confirm the meaning. This time, the descriptions relevant to organization and the safety culture of electric utility companies were classified and arranged, and the issues were extracted from them. However, the severe accident of this time can not be cleared up solely by electric utilities. The additional prerequisite "The relationship, communication and information sharing among stakeholders are good" is therefore important, and an examination of the measures through collaboration with stakeholders is now essential.

Acknowledgment

The authors sincerely express gratitude to Yuko Matsui, Masaru Hikono, Manabu Goto, and Kazunori Tsutsumibata, of the Institute of Nuclear Safety System, Inc. (INSS), Social System Research Institute Human Factor Research Center, who provided good cooperation at the brainstorming.

References

- [1] Tokyo Electric Power Co., Ltd.: Estimation of the released amount of radioactive materials into the atmosphere as a result of the accident in the Fukushima Daiichi Nuclear Power Station, (Estimation made as of May, 2012), May 24, 2012.
- [2] The Cabinet Office, Team in Charge of Assisting the Lives of Disaster Victims: Countermeasures for Disaster Victims References (No. 5-2), New nuclear planning council, 6th meeting, September 27, 2011. (In Japanese)
- [3] Ministry of Environment: Estimation of amount of the soil and other materials from the decontamination process, 2011. (In Japanese)
- [4] The National Diet of Japan Fukushima Nuclear Accident Independent Investigation Commission: The official report of The Fukushima Nuclear Accident Independent Investigation Commission, July 5, 2012.
- [5] Investigation Committee on the Accident at Fukushima Nuclear Power Stations of Tokyo Electric Power Company (established by the cabinet): Interim Report, December 26, 2011.
- [6] Investigation Committee on the Accident at Fukushima Nuclear Power Stations of Tokyo Electric Power Company (established by the cabinet): Final Report, July 23, 2012.
- [7] Independent Investigation Commission on the Fukushima Daiichi Nuclear Accident (established by the Rebuild Japan Initiative Foundation): Investigation and verification report of Independent Investigation Commission on the Fukushima Daiichi Nuclear Accident, Discover Twenty-one, February 28, 2012. (In Japanese)
- [8] Fukushima Nuclear Accidents Investigation Committee (established by the Tokyo Electric Power Co., Ltd.): The Fukushima Nuclear Accidents Investigation Report, June 20, 2012.
- [9] TAKEUCHI, M., HIKONO, M., MATSUI, Y., GOTO, M., and SAKUDA, H.: Prerequisites of ideal safety-critical organizations, International Journal of Nuclear Safety and Simulation, Vol.4, No.1, 2013