Study of Detailing Scenarios Leading directly to Core Damage in Seismic PRA(2) Method of Detailing Scenarios Utilizing Expert Judgement

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Abstract: Seismic PRA for Japanese Nuclear Power Plants (NPPs) has been utilized for identifying vulnerabilities of NPPs. Some scenarios occurred by damages of specific structures, systems and components in seismic PRA are assumed as the worst accident scenario, which is the scenario directly leading to core damage, because of the scenario's uncertainties. It is sometimes discussed that the conservative assumption might skew the risk profile in seismic PRA.
In order to detail the accident scenarios, the new methodology utilizing expert judgement based on a general expert elicitation process is developed in this study. The overview of the developed process will be discussed in this paper. This study contributes to improve the risk profile in seismic PRA and to identify true vulnerabilities of NPPs.

Keywords: Seismic PRA, Expert Judgement, Expert Elicitation, Accident Sequence

1. Introduction

Japanese utilities of NPPs are required to conduct Seismic PRA regularly and the outputs (e.g., Core Damage Frequency, Containment Failure Frequency) have been utilized for identifying vulnerabilities of NPPs. The identified vulnerabilities are considered to be improved and the improvement enhances the safety of NPPs.
Seismic PRA generally contains many assumptions and the assumptions should be recognized as uncertainties in seismic PRA. One of the assumptions in seismic PRA is to model the worst accident scenario when specific structures, systems and components(SSCs) (e.g., containment vessel, reactor building) are damaged due to earthquakes. The modeling is originated from the difficulties to develop the detailed scenario because of the lack of data for it. Accordingly, the worst scenario, which is the scenario directly leading to core damage, is assumed in seismic PRA, however there will be accident scenarios to avoid core damage. This assumption might be too conservative in seismic PRA and the conservative accident scenario sometimes contributes mainly to the risk profile. Because of the uncertainties originated from the assumptions, it might be necessary to confirm that the output can be really utilized to attract the true vulnerability of the NPPs.
The purpose of this study is to present a process of expert elicitation for detailing the accident scenarios in seismic PRA and to gain the true risk profile which can be utilized for attracting the NPPs' vulnerabilities. This paper consists of the following: Section 2 describes utilizations of an expert elicitation in PRA; Section 3 presents the process of expert elicitation for accident scenarios; Section 4 offers some insights gained through a pilot study; and Section 5 is the conclusions.

2. Outline for Utilizing Expert Judgement

Expert Judgement is the information provided by experts to a technical question. Expert judgement gained through a formal process is referred to as expert elicitation[1]. Expert elicitation has been utilized as the technical basis in some situations. The examples in which expert elicitation is utilized to estimate parameters in PRA are Probabilistic Seismic Hazard Analysis(PSHA)[2,3], Loss-of-Coolant Accident(LOCA)

frequency[4] and Human Reliability Analysis(HRA)[5]. Through the insights gained from each application, NRC issued the white paper which describes the general expert elicitation guidance[1].

3. Developed Methodology Utilizing Expert Judgement

Based on the white paper issued by NRC, the expert elicitation process for accident scenarios is developed. The developed process is shown in Figure 1. The main process is almost the same as the process described in NRC white paper. This project is focusing on the accident scenario so outputs from this project are 1) logic tree to describe the possible accident scenarios when a specific SSCs are damaged by an earthquake, 2) weights of each branch in the logic tree to calculate the total weights of each sequence. The logic tree and the weights in the logic tree are discussed through this process. This chapter provides the details of each phase in subsections.

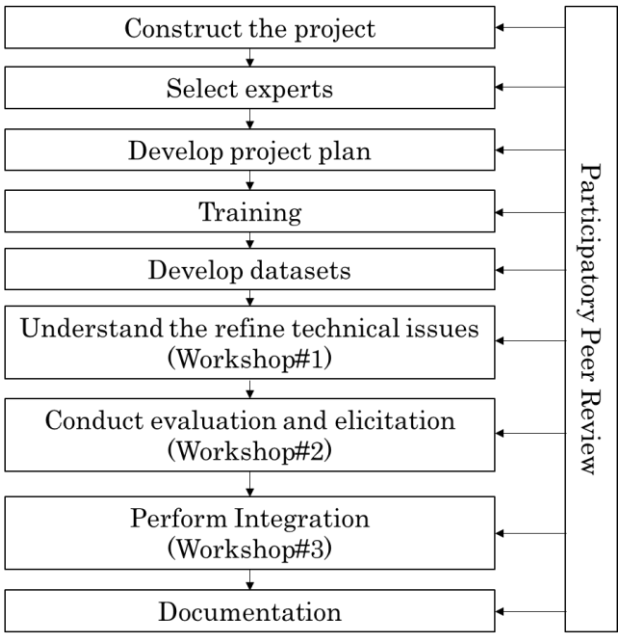

Figure 1. Expert elicitation process for accident scenarios

3.1. Construct the Project

It is necessary to form a project team and to define a subject for launching the project. The project team, who is responsible for managing entire expert elicitation process, is formed, then the subject should be determined. When determining the subject, it should be checked whether the subject is suitable for expert elicitation. The followings are the checklist for determining the subject;
1) Are there almost no available data of the subject for the conventional PRA? Or there are available data but the data shows many possibilities
2) Does the subject contributes the result in seismic PRA?
3) Is expert elicitation rationally the best way?

After determining the subject, the assumptions related to the subject should be identified. Based on the identified assumptions, the technical problem should be also clarified. The reason for this preparation is that the technical problem would be originated not only from system analysis but also from other technical fields(e.g. fragility, seismic safety evaluation), so it is important to identify the problem for selecting adequate experts in the following phase.

3.2. Select Experts

The main roles and their relationships are the same as SSHAC process[2]. Based on the identified technical problem, the project team will select experts assigned to “Technical Integrator”, “Proponent Expert”, “Resource Expert” and “Peer Reviewer”. Each role is summarized in the table 1.

Table 1 Summary of each role in expert elicitation process for accident scenarios

Role	Summary
Technical Integrator	✓ Proceed the workshop ✓ Integrate the output from proponent experts
Proponent Expert	✓ Offer the output to technical integrators based on the provided available data
Resource Expert	✓ Provide available data related to the subject
Peer Reviewer	✓ Conduct a Peer Review through the process

3.3. Develop Project Plan

The project team will develop the project plan. The main contents are the same as the contents described in NRC white paper[1]. The project plan is necessary to have common understandings of the subject among the experts. Regarding the accident scenario, the specialty of involved experts is not often seismic PRA so the assumptions in seismic PRA should be also described. For example, impacts by foreshock or aftershock are not considered in seismic PRA. Common understandings for such assumptions are sometimes important to proceed the following workshops smoothly.

3.4. Training

The project team should be provided training to have common understandings of the subject and the related technical problems, to learn how to avoid the bias in the expert elicitation process and to know the insights through the previous expert elicitation. In the pilot study, the experts who are familiar with SSHAC process conducted the training to the project members.

3.5. Develop Datasets

Datasets of the technical problems are required for expert judgements. Resource experts will offer the datasets to Proponent Experts. The datasets should contain data sources and precautionary statement. In response to requests from Proponent Experts or Technical Integrators in the following workshops, some additional datasets will need to be prepared.

3.6. Understand the Refine Technical Issues(Workshop#1)

The purpose of this workshop is to discuss the technical problems and datasets. The technical problems have been already identified in 3.1., however there might be unidentified problems or the solved problems so the technical problems should be discussed in the workshop. Through the workshop, the technical problems will be identified. The technical problems have uncertainties, so that the uncertainties will be expressed as a branch in a logic tree.
Also experts will confirm the prepared datasets by Resource Experts to confirm whether it is enough to evaluate the branch weights in the developed logic tree. When Proponent Experts or Technical Integrators request additional datasets, Resource Experts will prepare an additional data.
After the first workshop, the project team should provide worksheets to Proponent Experts. Each sample of the logic tree and the worksheet will be shown in figure 2 and table 2. The Proponent Experts should confirm the logic tree developed through the workshop in the worksheet and modify the logic tree based on the datasets. Also the Proponent Experts should fill the weights of each branch in the logic tree. The experts should also answer the confidence level to be utilized in the integration phase.
The prepared datasets are not direct evidence for the discussed branch because experts judgement is not necessary if the direct datasets are prepared, so knowledge of the Proponent Experts which have been gained through their experiences is utilized in the expert judgement. For example, for discussing weighs of compornent' falling, the proponent experts may utilize the result of seismic safety analysis. This is not a direct data for the branch, but the experts can utilize to identify which part in the component is damaged.
In the pilot study, experts were required to fill the confidence level from level 1 to level 4 based on their confidence.

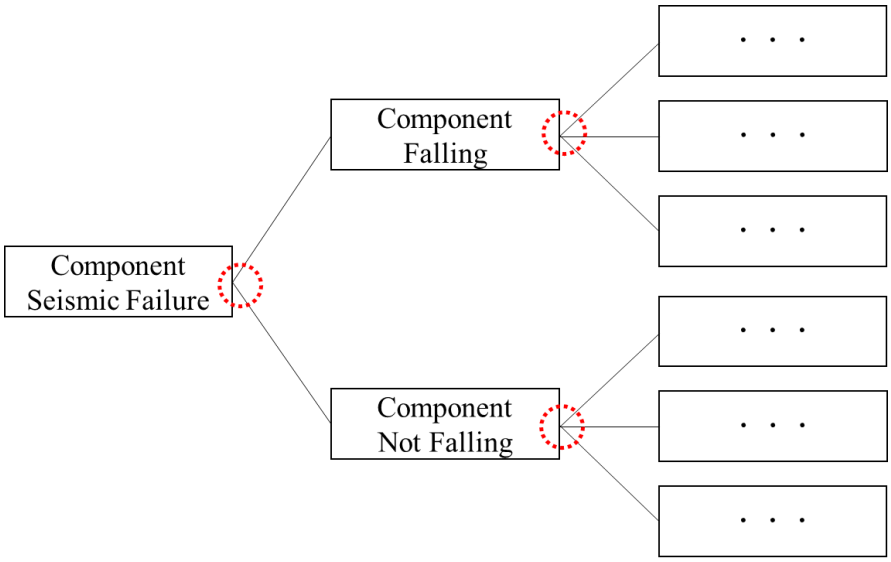

Figure 2. An example of logic tree for accident scenario

Table 2. An example of a worksheet

	Branch	Accerelation								
		…	0.8 G	0.9 G	1.0 G	…	…	…	…	3.0 G
Weights	① Component Not Falling	…	0.80	0.80	0.70	…	…	…	…	0
	② Component Falling	…	0.20	0.20	0.30	…	…	…	…	1
Basis	. . .									

3.7. Conduct Evaluation and Elicitation (Workshop#2)

In the workshop#2, the experts will explain their evaluation results in the provided worksheet and have discussion about their results. Technical integrators also confirm the experts' results. This confirmation is largely helpful in the following integration phase. Technical integrators sometimes ask the Proponent Experts to add the basis for the evaluation after this workshop. The Proponent Experts will be allowed to improve their own results based on the discussion. These improvements are originated from the misunderstanding or new datasets provided in this workshop and are not intended to unite the results by the experts.

3.8. Perform integration (Workshop#3)

Based on the worksheet by the experts, the technical integrators will conduct a pre-integration before the workshop#3. One of the methods to integrate the weights is just to average the values, however backgrounds of the experts will be different from expert to expert because the technical problems are often originated from many technical fields (e.g. system analysis, fragility, seismic safety evaluation). Accordingly the confidence level filled in the worksheet is utilized to conduct the weighted average in the integration. Also technical integrators classifies the experts' confidence levels of the evaluation results based on their basis. Some expert might answer the low confidence level, others might answer the high confidence level even though the same basis, So it is necessary for technical integrators to classify the confidence level by themselves. Then the weights of each branch by each expert are integrated at weighted average method based on the confidence level evaluated by the technical integrators.
In the pilot study, the matrix shown in table 3 was utilized in this integration phase.
Assume that there are two experts and the experts' outputs of a weight in a logic tree are 0.3 and 0.4 and technical integrators judge that the level of one expert is level2 and the other is level3. Then the weight is integrated and the result would be 0.32(=0.3*0.8+0.4*0.2).

This matrix may need to be modified based on the subject of expert elicitations.

Table 3 Matrix for integration phase

			Expert Y			
			Level 1	Level 2	Level 3	Level 4
			Experts' outputs are based on direct evidences	Experts' outputs are based on indirect evidences	Experts' outputs are based on qualitative evidences	Experts' outputs are based on only subjective evidences
Expert X	Level 1	Experts' outputs are based on direct evidences	0.3～0.7 / 0.7～0.3	0.2 / 0.8	0.1 / 0.9	0.01 / 0.99
	Level 2	Experts' outputs are based on indirect evidences	0.8 / 0.2	0.7～0.3 / 0.3～0.7	0.2 / 0.8	0.01 / 0.99
	Level 3	Experts' outputs are based on qualitative evidences	0.9 / 0.1	0.8 / 0.2	0.7～0.3 / 0.3～0.7	0.01 / 0.99
	Level	Experts' outputs are based on only subjective evidences	0.99 / 0.01	0.99 / 0.01	0.99 / 0.01	0.5 / 0.5

Also Importance analysis should be conducted to identify the important branch. The identified branch will be prioritized in the workshop#3. There are some uncertainties in this integration phase, so sensitive analysis should be also conducted to identify the important parameters.
Based on the pre-integration result, the workshop will be held. Through the workshop, the integrated result will be reached an agreement among the experts

3.9. Documentation

Process, results and technical basis should be documented to ensure the transparency. the contents which should be documented are basically the same recommended by NRC white paper [1].

3.10. Participatory Peer Review

Participatory peer review should be conducted throughout expert elicitation process. The peer reviewers are expected to have comments on discussions or processes in the workshops.
In the pilot project, experts of SSHAC process, seismic safety analysis and system analysis were selected as the peer reviewers. The reviewers had some comments on the process, output in the workshops.

4. Insights from the Pilot Study

This paper doesn't describe the detail of the pilot study. Only insights gained through the pilot study are summarized.

1) A logic tree was discussed in the workshop#2, and the result shows that the developed logic tree has hundreds of scenarios. In the pilot study, the complete logic tree was expected so the complete discussion was conducted, but to identify the important branch will be effective to group some sequences so that experts will be able to focus on the discussion of an important branch.

2) In the pre-integration phase, technical integrators found that the experts had a different definition on a branch in the logic tree. Technical integrators should encourage Proponent Experts to ask each experts' output and to have discussion in the workshop#2 to correct differences in experts' recognitions.
3) The output does not contain the uncertainties of each weights in the logic tree. The peer reviewers had a comment that the uncertainties should be considered in the integration phase because each output of experts has uncertainties based on the confidence level. Uncertainty analysis is expected in the following application.

5. Conclusion

In this paper, the developed process of expert elicitation for accident scenario was discussed. Some of the scenarios induced by an earthquake are assumed the worst scenario in the current seismic PRA, but the developed process is expected to allow detailing accident scenarios. The output from the process is the weights of each branch in the logic tree, then the conditional probability of each scenario can be calculated based on the output. By modeling the probabilities in seismic PRA, the conservative originated from the assumptions will be improved.

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