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Flood/Typhoon Vulnerability Indicators of Nuclear Power Plant in South Korea Considering Climate Change Impacts

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1. Introduction

The Republic of Korea lies in the principal course of the typhoon that is occurred to the Pacific Northwest. It has distinct monsoon wind, a rainy period from the East-Asian Monsoon locally called "Changma", typhoon, and while often heavy snowfalls in winter. It belongs to a relatively wet region due to much more precipitation than that of the world average. In the last 10 years, there frequently was a lot of damage due to flooding with typhoon. In particular, the damage was estimated at up to 5,000 billion KRW by the Rusa in 2002. Lately, after the 9.0 magnitude earthquake and resultant tsunami hit Japan on March 11, 2011, consecutively approached Typhoon Roke made a larger threat. Although it fortunately passed without significant impact. That is, not only typhoon and flood are one of a threat to nuclear power plant but also it could lead to overwhelming damage when it overlapped the other accident. Therefore, flood/typhoon vulnerability assessment could provide important information for the safety management of nuclear power plants.

This study derived all the feasible indicators and their corresponding weights for a Flood/Typhoon Vulnerability Index (FTVI) to nuclear power plant considering climate change. In addition selection of the candidates and determination of their weights were estimated using a Delphi process, which is an advanced method for opinion measurement.

2. Methodology and Results

This study consisted of four activities. First, the organizing group had to select all the feasible indicators for an FTVI based on the historic records of severe floods/typhoon and devise a questionnaire. This required a very creative brainstorming process as well as rational and logical thinking. In particular, all the criteria had to be selected based on the conceptualized vulnerability by IPCC (2001). Second, the organizing group also had to identify a group of experts. It was suggested that the respondents should have a high level of responsibility. Third, the expert group had to respond to the questionnaire. Interaction with the group members was handled in a completely anonymous fashion. This avoided the possibility of identifying a specific opinion with a particular person. Fourth, the organizing group determined the consensus of the expert group.

2.1 Delphi procedure

The Delphi technique is 'a method for structuring a group communication process so that the process is effective in allowing a group of individuals, as a whole, to deal with a complex problem' [1]. The Delphi Method is based on a structured process for collecting and distilling knowledge from a group of experts by means of a series of questionnaires interspersed with controlled opinion feedback [2]. The Delphi technique uses a series of iterative questionnaires that are sent to a group of purposively selected experts who remain anonymous to one another [3]. The results of the previous questionnaires are returned to the respondents, who are then able to modify their responses. By the second or third round of this process, it is hoped that the experts will be able to arrive at a consensus on the estimation problem.

In this paper, the organizer selected all the feasible draft indicators. Then, the respondents had to decide whether the given indicators were necessary for flood risk assessment. After this first round, the indicators that might be needed were adopted. The following rounds were used to estimate the weights of the adopted indicators, which were performed in two steps. In the first step, the respondents determined subjective weights. After the organizer analyzed these weights, the feedback was distributed to the panelists. The next step provided a final opportunity for the participants to revise their judgments after referring to the previous information.

2.2 Climate exposure-Sensitivity-Adaptive Capacity

IPCC (2001) conceptualized vulnerability within a systems perspective [4]. It judges a system to be vulnerable if it is exposed to climate change impacts, if it is sensitive to those impacts, and if it has a low capacity to cope with those impacts. A general conceptual model vulnerability has emerged in the climate change scholarship, similar to the use of concept more widely [5]. Consistent throughout the literature is the notion that the vulnerability of any system (at any scale) is reflective of the exposure and sensitivity of that system to hazardous conditions and the ability or capacity or resilience of the system to cope, adapt or recover from the effects of those conditions. Exposure is the nature and degree to which a system experiences environmental or socio-political stress. The characteristics of these stresses include their magnitude, frequency, duration and areal extent of the hazard [6]. Climate exposure then referes to a vast variety of climate-related stimuli such as sea level rise, temperature change, precipitation change, heat wave, heavy rainstorm, drought, etc. Sensitivity is the degree to which a system is modified or affected by perturbations.1 Adaptive capacity is the ability of a system to evolve in order to accommodate environmental hazards or policy change and to expand the range of variability with which it can cope [7].

2.3 Weighting value analysis using Fuzzy sets

A fuzzy set is a powerful mathematical tool for handling uncertainty in decision-making. A fuzzy set is general form of a crisp set. A fuzzy number belongs to the closed interval 0 and 1, in which 1 represents full membership and 0 represents non-membership. In contrast, crisp sets only allow values of 0 or 1. There are different types of fuzzy numbers that can be utilized, depending on the situation. It is often convenient to work with triangular fuzzy numbers (TFNs) because they are relatively simple to compute and are useful in representing and processing information in a fuzzy environment [8]. The priority among the many available indicators is derived by the corresponding fuzzy weight vectors; the final results become a problem of ranking fuzzy numbers.

2.4 Indicator selection and weights determination using Delphi technique

The success of the Delphi study clearly rested on the combined expertise of the participants who made up the expert panel. There were two key aspects, (1) the panel size and (2) qualifications of the experts. In total, 12 flood/typhoon and 10 nuclear power plant management specialists participated in the panel for this research. Thus, it was expected that various opinions with diverse perspectives would arise. The interviewees were surveyed individually. All the selected indicators and their values are shown in Table 1.

3. Conclusions

This study aimed to select all the feasible indicators and quantify their importance (weights) in a flood/typhoon vulnerability assessment of nuclear power plant in Korea considering Climate Change Impacts. The indicators and their weights were determined by a survey using the Delphi technique. This research will be used to help quantify the specific FTVI for the nuclear power plant.

Table I: Nominated proxy variables and weighting values

Component	Indicators	TFNs		
		Min	Mode	Max
Sensitivity	C1.Nuclear power plant operation rate(%)	0.42	0.66	0.74
	C2. Nuclear Power Generation rate(%)	0.53	0.71	0.79
Adaptive Capacity	C3. Number of tidal/wave height warning system	0.31	0.50	0.58
	C4. Number of flood /typhoon forecast systems	0.29	0.44	0.51
	C5. Number of civil servants and power plant staffs related to hazard	0.37	0.49	0.62
Exposure	C6. Annual number of floods/typhoons	0.45	0.69	0.75
	C7. Daily maximum precipitation(mm)	0.41	0.68	0.77
	C8. Daily maximum wind speed(m/sec)	0.43	0.62	0.70
	C9. Surface Runoff(mm/day)	0.31	0.43	0.56
	C10. Maximum tidal/wave heights(m)	0.52	0.72	0.80

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