Accessibility Assessment of Support Personnel to Hanul NPP during a Mw 7.0 Earthquake

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1. Introduction

When an earthquake causes an accident at a nuclear power plant, the prompt deployment of specialized support personnel is essential to prevent the escalation of the accident and to facilitate rapid recovery [1]. In particular, the surrounding road network is critical infrastructure that enables both the evacuation of residents and the timely deployment of emergency response teams, and thus its functionality must be maintained. During the 2011 Great East Japan Earthquake (Mw 9.0), more than 100 km of national highways and five bridges were destroyed, and road restoration required 13 days [2]. As seen in such past earthquake cases, road damage can delay rescue and support activities. This study quantitatively evaluated whether support personnel can reach the Hanul Nuclear Power Plant (NPP) within one hour following an earthquake.

2. Method for Assessing Road Network Safety during Earthquakes

The impact of road network damage on the accessibility of support personnel was quantitatively analyzed. To this end, the failure probability of road network components (roads, bridges, tunnels, etc.) near Hanul NPP was evaluated. Subsequently, the probability of access failure was estimated under the assumption that support personnel would travel on foot.

First, road and bridge information in the study area was constructed using the National Transport Database and OpenStreetMap (OSM), and the attributes and spatial positions of each road link were defined. The constructed road network is shown in Fig. 1. For road damage assessment, fragility curves for roads and bridges presented in reports by the Ministry of Public Safety and Security (MPSS) and the Ministry of the Interior and Safety (MOIS) were applied [3,4].

Fig. 1. Constructed road network near Hanul NPP

To quantitatively evaluate the probability that support personnel cannot reach the site within one hour, a network-based accessibility evaluation algorithm proposed by Eem et al. (2023) was used [5]. Origin and destination points were set, and all possible routes within the one-hour walking distance were extracted. Failure probabilities were assigned to road and bridge components, and Monte Carlo Simulation (MCS) was applied to repeatedly sample success or failure of each element. For each simulation run, whether access was possible along the routes was determined, and the proportion of failed access among all trials was used to estimate the probability of access failure.

3. Results and Discussion of Road Safety Assessment

3.1 Results of Road Safety Assessment

Assuming an earthquake occurs at the Hanul NPP site, road damage probabilities were evaluated. A maximum credible earthquake in the Korean Peninsula, Mw 7.0 (approximately PGA 0.5g), was considered [6].

For each road and bridge component, the damage probabilities were calculated using PGA (Jo et al.) and PGD (Youd & Perkins) values derived from attenuation equations, together with fragility curves provided by MPSS (2015) [3,7,8]. The damage status of each road was organized based on the definition provided by the Ministry of Public Safety and Security[4]. The constructed road network consisted of 19.613 km of auxiliary roads and three bridges (0.555 km in total). The results of road network damage assessment are shown in Fig. 2, and the road distances corresponding to each damage state are summarized in Table 1.

Fig. 2. Road network damage assessment results for Mw 7 (approx. PGA 0.5g)

Table I: Road and bridge damage distances and proportions based on damage state at Mw 7.0 (PGA ~0.5g)

Damage State	Road Damage Distance	Number of Bridges Damaged
Slight Damage (0-1%)	0 km	0
Moderate Damage (1-30%)	19.005 km (96.70%)	2
Extensive Damage (30-80%)	0.608 km (3.10%)	1
Complete Damage (80-100%)	0 km	0

MCS was performed until the variability of the results became 0.01%, and a total of 10^6 trials were performed. Using two entrances of KHNP staff housing as origins and the main gate of the NPP as the destination, the probability that support personnel could not reach the site on foot was evaluated. Based on an average walking speed of 6 km/h, the travel distance within one hour was limited to 6 km. A total of 22,151 possible paths were derived, and the probability of access failure due to the earthquake was calculated as 53.317%.

3.2 Discussion of Road Safety Assessment

This study assessed the probability that support personnel cannot reach Hanul NPP in the event of the maximum credible earthquake in Korea. Future research could apply various sensitivity indicators to identify the most critical road segments among the numerous paths, thereby supporting prioritization of resource allocation, selection of reinforcement targets, and formulation of road recovery strategies. These results provide essential evidence for disaster response and preparedness planning.

4. Conclusions

During an earthquake, nuclear power plant emergency procedures require sequential actions such as issuing alarms, automatic reactor shutdown, emergency call-up, and activation of radiation emergency plans depending on ground acceleration levels. However, in practice, whether support personnel can physically arrive at the plant within the required timeframe—particularly when large earthquakes damage the road network—has not been realistically assessed.

To ensure nuclear safety and effective accident response under large-scale disasters such as earthquakes, a realistic assessment of whether emergency support personnel can reach the plant within the limited timeframe is indispensable. This study quantitatively evaluated the probability of successful access of emergency personnel to Hanul NPP under such conditions, contributing to the enhancement of disaster preparedness and safety assurance.

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