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Identification of Factors Affecting Evacuation Time Estimates in Seismic Events

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1. Introduction

After Fukushima accident, the concept regarding “both all modes and all scopes” was recommended to be implemented within the scope of Probabilistic Safety Assessment (PSA). Especially in Level 3 PSA, it was performed partially for Shin-kori 3, 4 and it is important to secure its basic technology for performing Level 3 PSA. In order to performing full scope Level 3 PSA by considering domestic characteristics, the development of emergency response model and ingestion model are needed. The emergency response model is an important factor for Level 3 PSA on seismic events and furthermore needed for establishing a realistic and effective emergency preparedness plan.

Evacuation Time Estimates (ETE), which is a way to evaluate early public protective measure, has to be performed to assess the emergency response. However, in Korea, no proper ETE study was done because of the lack of experts with experience in ETE analysis. For this purpose, this study is conducted to identify important factors considered on ETE analysis for the seismic event emergency response model as well as to evaluate the evacuation speeds during emergency periods.

2. Evacuation Time Estimates Factors

Evacuation is used as a protective action to remove people from areas potentially affected by wind-borne radioactive materials released form nuclear power plants.

ETE is a calculation of the time to evacuate the plume exposure pathway Emergency Planning Zone (EPZ) [1], which consists of Precautionary Action Zone (PAZ) with a radius from 3km to 5km, and Urgent Protective action planning Zone (UPZ) with a radius from 20km to 30km [2]. Such subdivision of EPZ actually makes ETE analysis more complicated than the past.

Evacuation time in the normal situation is simply the time required by evacuees before beginning to evacuate, plus the time required to drive out of the EPZ [3]. Commonly, the time before beginning to evacuate, which is called as Trip Generation Time (TGT), is obtained by questionnaire survey and the time to drive out of EPZ is obtained from traffic simulation code output.

Performing seismic ETE analysis is based on the same methodology for normal ETE analysis, but there are some additional considerations.

The following sections discuss the key factors affecting evacuation time estimates in seismic events. The simplistic example in Fig. 1 illustrates the process of seismic ETE.

2.1 Analysis of Earthquake Impact

In order to perform seismic ETE analysis, seismic Level 1, 2 PSA should be preceded. Moreover, seismic hazard analysis must be carried out for the seismic Level 1, 2 PSA.

The seismic hazard gives the frequency of occurrence of earthquake motions at various levels of intensity at the site. The final output of the seismic hazard study should be a hazard curve. It is convenient for the calculation to discretize the seismic hazard into a number of intervals; for example, subintervals are 0.1-0.25g, 0.26-0.5g, 0.51-0.75g, and 0.76-1.0g [4].

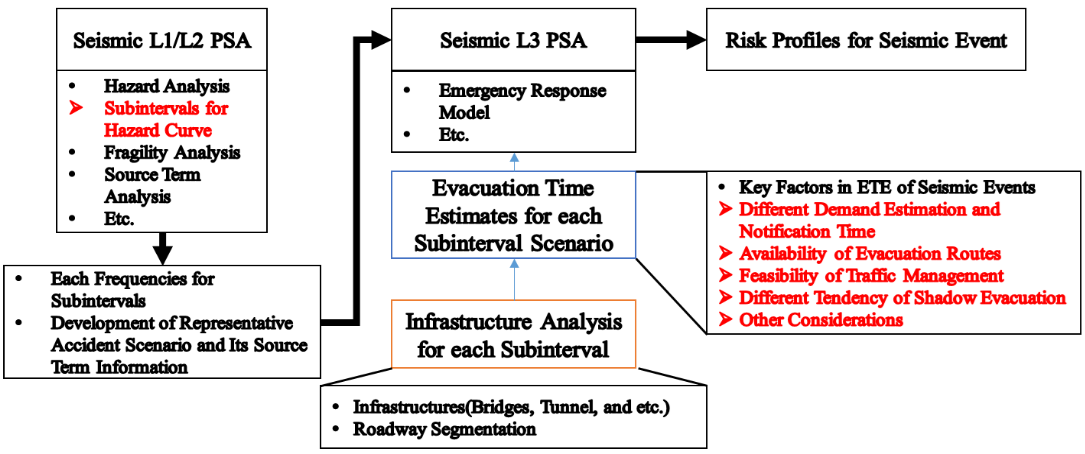

Fig. 1. Simplistic Example for the Process of Seismic ETE

A seismic analysis for each subinterval should be developed to assess the potential effects on local infrastructure, communications, and emergency response in the event of a large-scale earthquake. The potential effects of the earthquake are largely identified by the occurrence of previous earthquakes in the region [5].

Through a geological survey, the location of faults around the site should be identified; whether the faults are damaged by the representative ground acceleration for each subinterval should be analyzed; finally, the availability of the evacuation routes, which can be roadway segments in an infrastructure analysis, on the damaged faults should be analyzed.

2.2 Infrastructure Analysis

Infrastructure is composed of public-private physical improvements such as roads, bridges, tunnels, water supply, electrical grids, and so on.

A purpose of infrastructure analysis in seismic ETE is to identify and list infrastructures that are damaged by an earthquake. Another purpose of the infrastructure analysis is to check the point where the bottleneck occurs intensively in the evacuation situation due to damage to the infrastructure.

In SOARCA project, only roadways and bridges were selected as the roadway networks that are potentially affected by an earthquake. The example of the Peach Bottom site is shown in Fig. 2[5].

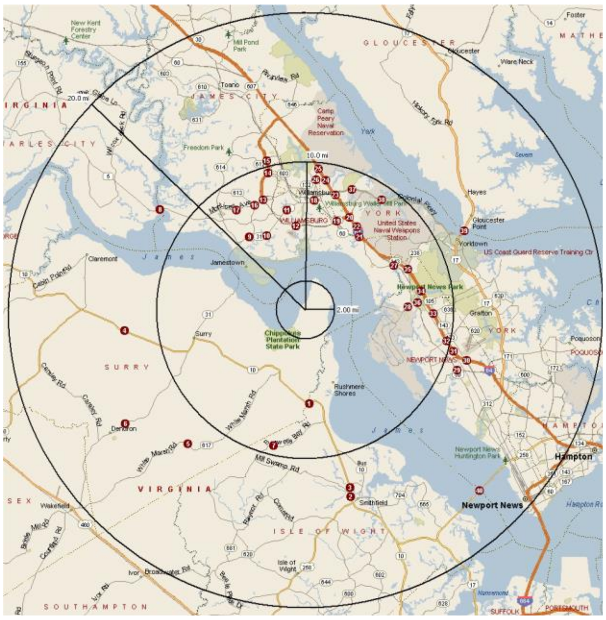

Fig. 2. Roadway Network Identifying Potentially Affected Roadways and Bridges in Peach Bottom Site [5]

In addition, unlike the normal ETE analysis, the effect of the potentially affected infrastructure by the earthquake to increase evacuation time must be analyzed. In addition, it should be identified whether the evacuees can move to the inner direction due to the destruction of the infrastructure.

2.3 Electrical Power and Communications

The seismic event causes the loss of all onsite and offsite power, which can affect the response timing and actions of the public. Where sirens are inoperable, the initial alert and notification of the public may take longer. The loss of power affects the number of residents receiving instructions via the Emergency Alert System(EAS) messaging [5].

And, the loss of power will cause a traffic signal to default to an all-way stop mode(four-way stop mode in the United States), which is less efficient than normal signalization [6]. If this situation occurs in Korea, it may not be a problem in the countryside of the PAZ, but there can be huge traffic congestion in the UPZ adjacent to the city.

On the other hand, the SOARCA project concluded that these factors had little impact on the ETE results because of the low traffic volume and the low number of intersections with traffic signals. However, in the case of Korea, it is the opposite situation; hence, it must be considered in the seismic ETE analysis.

2.4 Emergency Response

After the earthquake, there will be an initial need to assess plant damage and responds to life-threatening needs. Then, a licensee has to declare an emergency. The emergency types can be Facility Emergency (White), Site Area Emergency (Blue), and General Emergency (Red) depending on the severity of an accident. The declared emergency type can be changed by the progress of the accident and mitigation. In Korea, public protection measures are carried out differently depending on the emergency type and weather condition.

In the case of seismic ETE analysis, a delay of emergency declaration to the public must be considered. However, unfortunately, a methodology for determining the notification time even in normal condition has not been established yet in Korea. Therefore, it would not be easy to consider the notification delay time at the current level.

2.5 Other Considerations

One of the key aspects of ETE analysis is to define the number of evacuees. Although the object of evacuation is to remove people from the EPZ, it is the number of evacuating vehicles that determine if any transportation-related delay is likely. Occasionally, it is more appropriate to estimate the number of evacuating vehicles directly [3]. If a strong earthquake occurs, there will be so many casualties and a population that cannot be evacuated. In this situation, it is needed to exclude those people from the number of existing evacuees. Of course, if the evacuation method for the injured people is already set up, they must be included.

Secondly, it is how to consider a shadow evacuation. The shadow evacuation occurs when people outside of any officially declared evacuation zone evacuate without having been instructed to do so. It is very important because it can increase the total traffic volume. People living around nuclear power plants may be more aware of earthquake risks than ordinary people. This difference in perception can have a significant impact on the ratio of shadow evacuation.

Thirdly, driver behaviors after an earthquake should be considered in the traffic simulation model. The driver behavior is not homogeneous, and thus different drivers may behave differently given the traffic conditions. Most of the microscopic models, including CORSIM and VISSIM code which were used to analyze ETE in Korea, represent stochastic or random driver behavior(from passive to aggressive drivers) by taking statistical distributions of behavior-related parameters.

3. Conclusions

The emergency response model is an important factor for Level 3 PSA on seismic events and furthermore needed for establishing a realistic and effective emergency preparedness plan. Evacuation Time Estimates, which is a way to evaluate early public protective measure, has to be performed to build the emergency response model. In this study, it is identified that differences between 'Normal' and 'Seismic' conditions. In the ETE analysis on seismic events, firstly, it is needed to analyze earthquake impact for each subinterval. From the result, the availability of the evacuation routes, which can be roadway segments in an infrastructure analysis, on the damaged faults should be analyzed. Secondly, infrastructure analysis should be performed in order to check the point where the bottleneck occurs intensively in the evacuation situation due to damage to the infrastructure. Thirdly, the loss of on-site and off-site power, which can affect the response timing and actions of the public, should be considered. In addition to these three things, there are many additional considerations.

Finally, it is obvious that the ETE study in normal condition should be performed proactively. However, it is considered that the methodology developed in this study will contribute to analyzing ETE during a seismic event.

Acknowledgements

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