# Loss Estimation in Southeast Korea from a Scenario Earthquake using the Deterministic Method in HAZUS

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## Abstract

Strong ground motion attenuation relationship represents a comprehensive trend of ground shakings at sites with distances from the source, geology, local soil conditions, and others. It is necessary to develop an attenuation relationship with careful considerations of characteristics of the target area for reliable seismic hazard/risk assessments. In the study, observed ground motions from the January 2007 magnitude 4.9 Odaesan earthquake and the events occurring in the Gyeongsang provinces are compared with the previously proposed ground attenuation relationships in the Korean Peninsula to select most appropriate one. In the meantime, a few strong ground motion attenuation relationships are proposed and introduced in HAZUS, which have been designed for the Western United States and the Central and Eastern United States. The selected relationship from the ones for the Korean Peninsula has been compared with attenuation relationships available in HAZUS. Then, the attenuation relation for the Western United States proposed by Sadigh et al. (1997) for the Site Class B has been selected for this study. Reliability of the assessment will be improved by using an appropriate attenuation relation. It has been used for the earthquake loss estimation of the Gyeongju area located in southeast Korea using the deterministic method in HAZUS with a scenario earthquake (M=6.7). Our preliminary estimates show 15.6% damage of houses, shelter needs for about three thousands residents, and 75 life losses in the study area for the scenario events occurring at 2 A.M. Approximately 96% of hospitals will be in normal operation in 24 hours from the proposed event. Losses related to houses will be more than 114 million US dollars. Application of the improved methodology for loss estimation in Korea will help decision makers for planning disaster responses and hazard mitigation.

Keyword: HAZUS, earthquake loss estimation, deterministic method, attenuation relation

## 1. Introduction

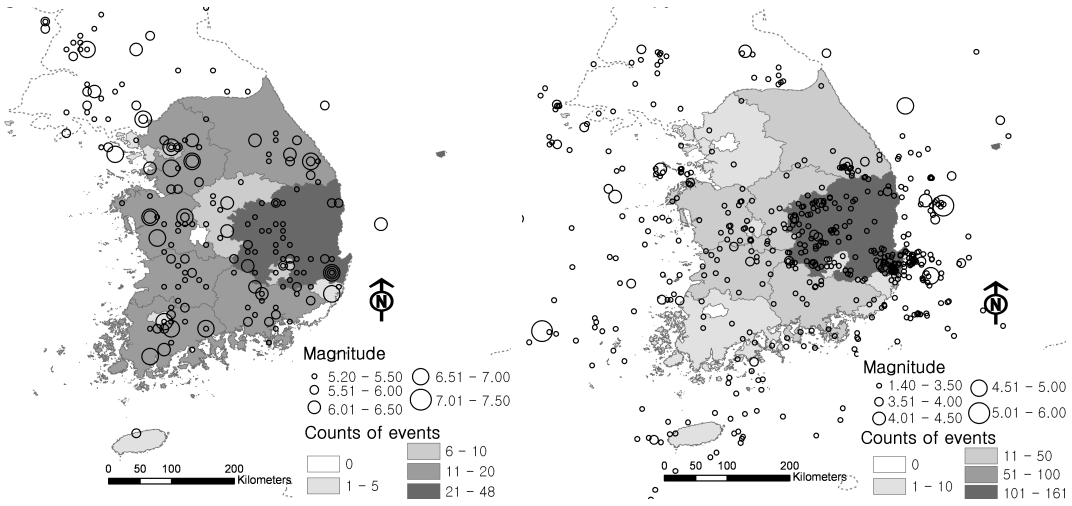
The unpredictability promotes efforts to mitigate hazards by taking efficient actions before and after the occurrence of disasters. Primary objectives of the system are to help communications among interested parties, analyses of hazardous elements before and after disasters, decision makings for emergency workers, and others. Due to the social interests, many public institutions have developed and managed systems for their own purpose. For instance, FEMA (Federal Emergency Management Agency) and NIBS (National Institute of Building Sciences) has developed and updated HAZUS Earthquake to estimate any losses due to a scenario earthquake or an observed earthquake with its source and inventory data (Schneider, 2006; FEMA, 2006). HAZUS is

a GIS-based system with a growing user community including both government and private sectors to estimate and to mitigate risks in the Unites States.

In spite of the increasing needs for improved disaster planning and response, no seismic risk assessment tool has been implemented in Korea yet. This short note begins with a brief review of historical and modern seismicity in the Korean peninsula. Then, a study region and a scenario earthquake with magnitude 6.7 in the southeastern Korea are proposed. Inventory data for the study region are arranged by assembling data from various sources. Finally, the deterministic method in HAZUS has been applied to estimate any losses in the study region due to the proposed scenario earthquake. Although the short note presents preliminary results, it demonstrates the effectiveness of risk assessment tool in Korea.

## 2. Seismicity in the Study Area

Distributions of earthquake epicenters recorded in historic literatures and by modern seismic instruments are shown in Figure 1. Interpretation of historic seismicity pattern needs additional attention, since its distribution tends to proportional to the population density. Locations of epicenter clusters with large magnitude in Figure 1 (a) are indeed consistent to those of ancient capitals. On the other hand, it is also clear that southeastern part of the Korean peninsula has experienced more earthquakes during the modern seismicity recording period since 1994 (Figure 1 (b)). Although there are disagreements in the estimation of magnitudes and epicenters for historic events, seismicity in the southeastern Korea near Gyeongju is relatively high in both historic and instrumental seismic recordings. By the general consent, the observed higher seismicity is related to the active faults in the area, the Yangsan fault. It is worthwhile to note two historic earthquakes occurred in 779 and in 1643. The earlier one caused the largest casualties and the later one is estimated to be the largest magnitude in the Korean history. Both events were located in the southeastern part of Korea. Thus, the area is selected for the pilot study. The study area has a population of about 1.5 million in the year 2005 and includes one highly populated metropolitans(Ulsan) and two cities(Gyeongju and Pohang), and many industrial facilities and infrastructures (Figure 2).




(a) Historic Earthquakes in Korea (b) Earthquakes in Korea between 1994-2006

Figure 1. Distributions of earthquake epicenters in Korea

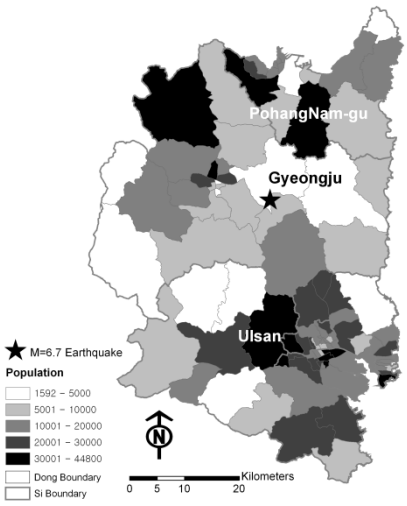



Figure 2. Population of the study area in 2005.

## 3. Application of HAZUS

### 3.1 Selection of Attenuation Relations for HAZUS

In this study, observed event data from January 2007 magnitude 4.9 Odaesan earthquake and from magnitude 3.0 in the Gyeongsang provinces are compared with the previously proposed ground attenuation relationships in the Korean Peninsula to select the most appropriate one (Figure 3). HAZUS proposes a few strong ground motion attenuation relationships designed for the Western and the Central & Eastern United States. The selected attenuation relationship from the ones for the Korea Peninsula can be compared with attenuation relationships available in HAZUS. Then, the attenuation relation for the Western United States proposed by Sadigh et al.(1997) for the Site Class B and D has been selected for this study (Figure 4). Application of this attenuation relationship to the study area will increase the reliability of seismic loss estimation using HAZUS in the Korean Peninsula.

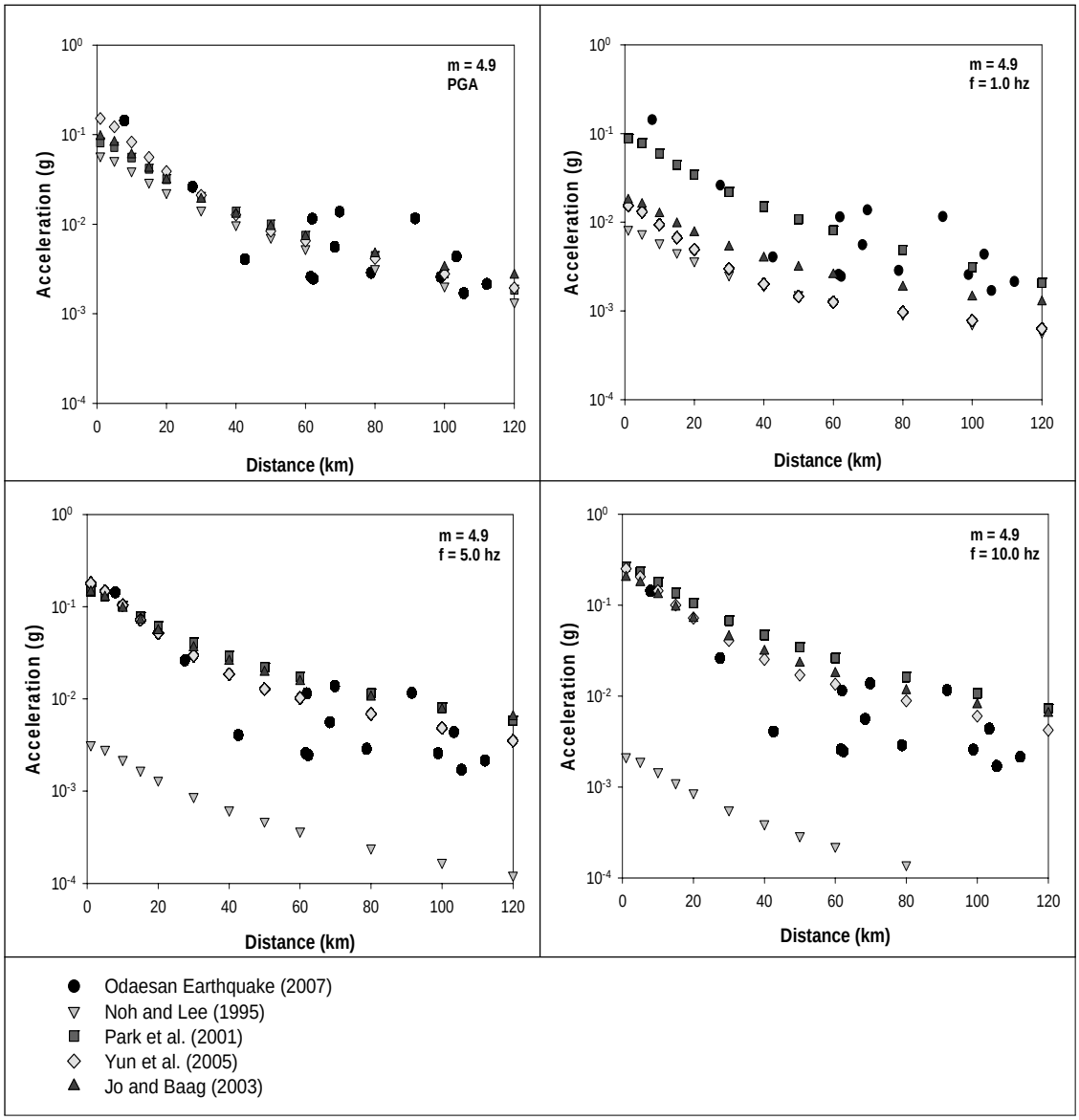



Figure 3. Comparisons of observed strong motions due to the Odaesan earthquake with different attenuation fucntions for M 4.9.

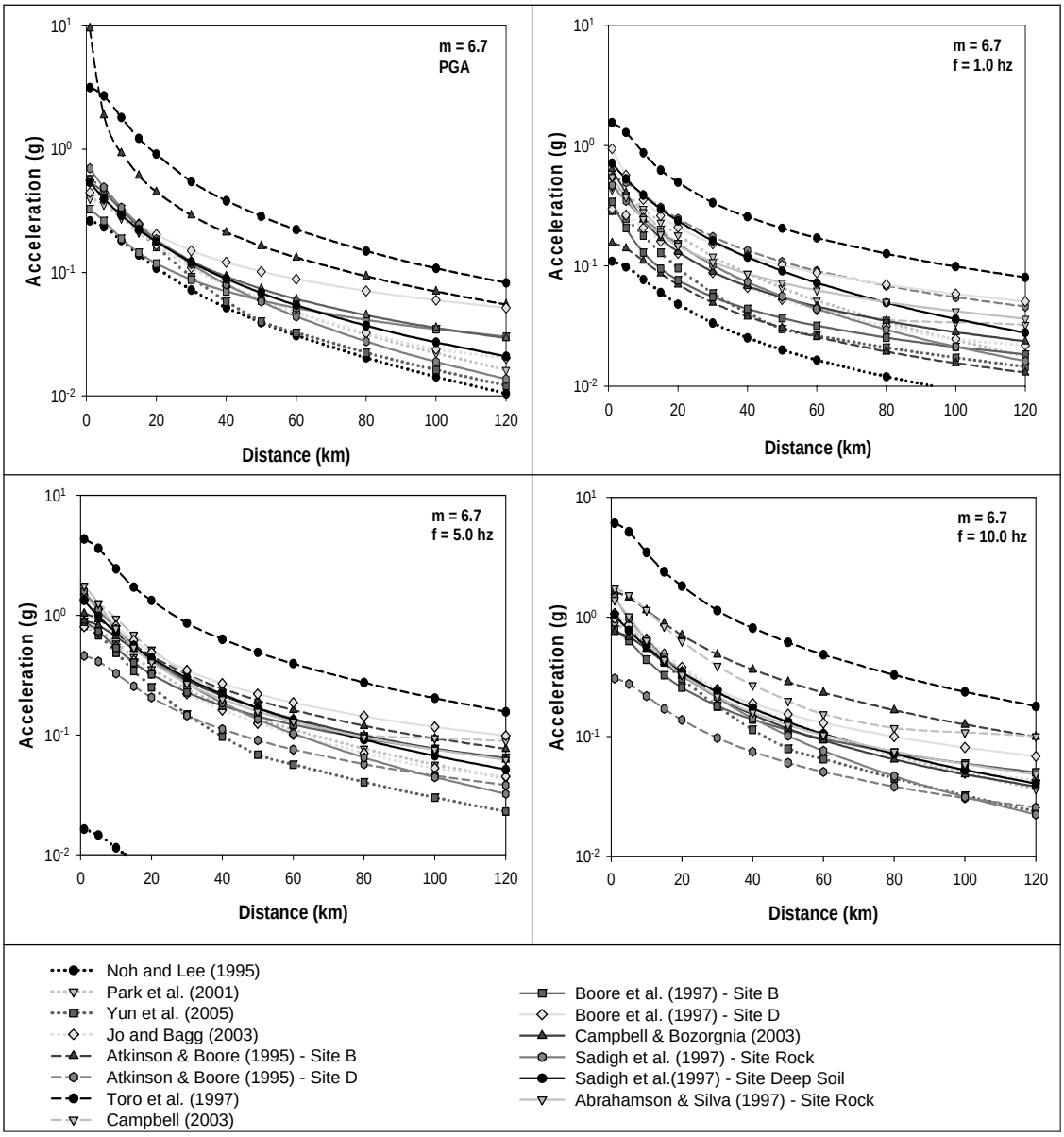



Figure 4. Ground shaking with different attenuation functions at magnitude 6.7.

### 3.2 Application of HAZUS

In this study, losses due to a magnitude 6.7 scenario earthquake in the Gyeongju area have been estimated using the deterministic method in HAZUS. The attenuation relation proposed by Sadigh et al.(1997) for site classes B, C, and D, which are assumed to represent the characteristics of the strong-motion attenuation in the Korean Peninsula, has been applied. Losses due to the hypothetical earthquake have been also calculated using other attenuation relationships to examine their roles in the loss estimation. The findings indicate differences among the estimates based on various attenuation relationships.

## 4. Results

### 4.1 House Damage

Our preliminary estimates show 15.6 % damage of house when we apply magnitude 6.7 earthquake in Gyeongju area using attenuation relation proposed by Sadigh et al.(1997) for site class B. On the other hand, the house damage should be increased when we apply attenuation relations proposed by Sadigh et al.(1997) for site class C or D.

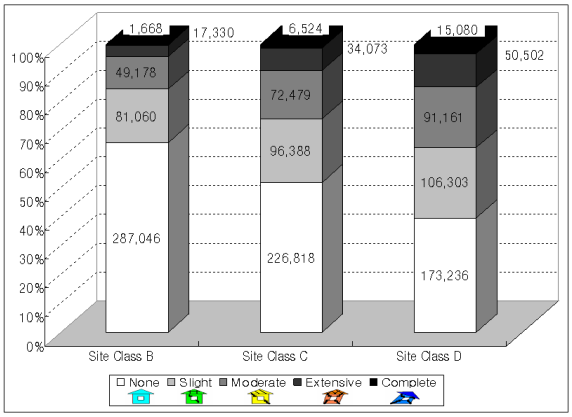
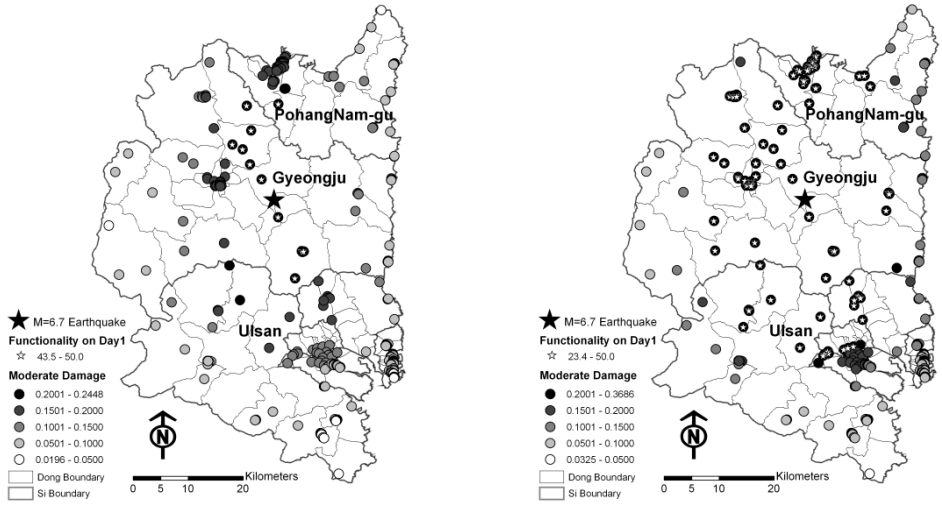



Figure 5. Potential house damage in the Gyeongju area by M 6.7 earthquake with the attenuation relation proposed by Sadigh et al.(1997) for site class B, C, and D.

### 4.2 Essential Facilities Damage

Essential facilities include medical care facilities, emergency response facilities and schools. They are vital to emergency response and recovery following a disaster (FEMA, 2006). Figure 6 shows the hospital damage by the event. About 95% of the total hospital may restore the status of normal operation within 24 hours from the proposed event under the site class B. Other essential facilities may not be affected seriously under the same condition.

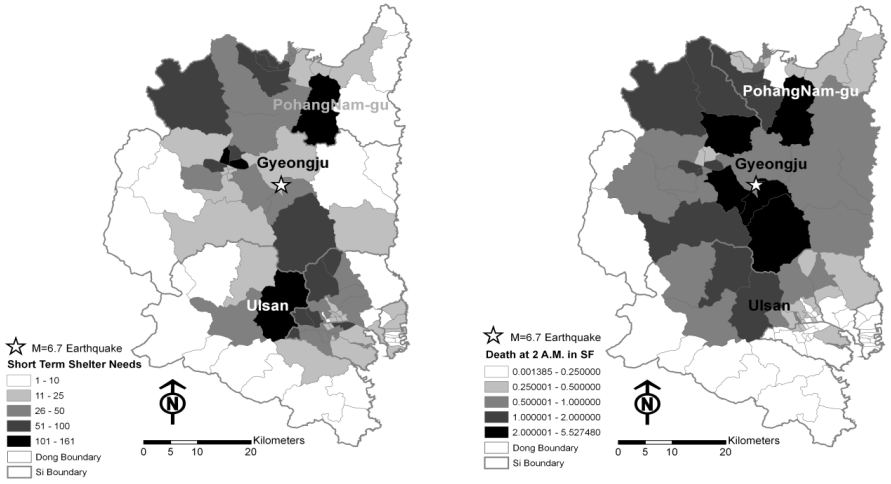



(a) Site Class B (b) Site Class C

Figure 6. Estimated damage of hospitals in Gyeonju area by M 6.7 earthquake with the attenuation relation proposed by Sadigh et al.(1997) for site classes B and C.

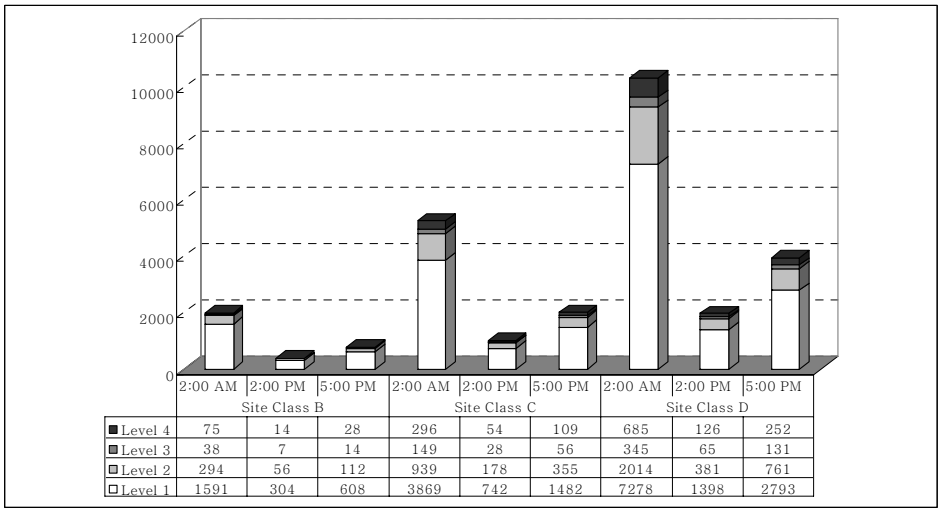
### 4.3 Other Losses

Preliminary estimates show shelter needs for approximately three thousands residents, and 75 life losses in the residential area of the study region for the scenario events occurring at 2 A.M. under site class B. Losses related to houses will be more than 114 million US dollars.




(a) Short term shelter needs (b) Death probability at 2 A.M. in single family houses(SF)

**Figure 7. Short term shelter needs and causality probability occurring M 6.7 earthquake at 2 A.M. with the attenuation relation proposed by Sadigh et al.(1997) for site class B.**




| | 2:00 AM | 2:00 PM | 5:00 PM | 2:00 AM | 2:00 PM | 5:00 PM | 2:00 AM | 2:00 PM | 5:00 PM |
|---|---|---|---|---|---|---|---|---|---|
| | Site Class B | | | Site Class C | | | Site Class D | | |
| Level 4 | 75 | 14 | 28 | 296 | 54 | 109 | 685 | 126 | 252 |
| Level 3 | 38 | 7 | 14 | 149 | 28 | 56 | 345 | 65 | 131 |
| Level 2 | 294 | 56 | 112 | 939 | 178 | 355 | 2014 | 381 | 761 |
| Level 1 | 1591 | 304 | 608 | 3869 | 742 | 1482 | 7278 | 1398 | 2793 |

**Figure 8. Causalities occurring M 6.7 earthquake with Sadigh et al.(1997) attenuation relation.**

## 5. Conclusion

Due to the fast growing civilization and recent development in economics, societies vulnerable to natural hazards are increasing on the globe. Current expectation based on scientific results indicates such a trend will continue in the future. It is also our understanding that we may neither control natural hazards nor predict exact time and magnitude in the near future. Hazard mitigation becomes a serious issue under such circumstances. As an effort to mitigate natural hazards, HAZUS-MH has been successfully applied beyond its original applicable region.

In this study, the attenuation relation for the Western United States proposed by Sadigh et al.(1997) has been selected to estimate damages by an earthquake after careful considerations of earthquake occurrence information. The study area may experience serious physical, economic and social damages by a proposed M 6.7 earthquakes. The loss estimation can provide essential information to the decision makers and emergency workers to expedite post-seismic management and rescue missions. It helps us to be better prepared for any potential hazards in the future.

## 6. References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