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Estimating evacuation ratio in the Great Hanshin-Awaji Earthquake

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ABSTRACT

The purpose of this project is to clarify the relationship between the long-term evacuation ratio and the degree of building damage in the case of the Great Hanshin-Awaji Earthquake in 1995 by using ArcGIS. The specialty lies in proposing the geographical range of shelter to analyze the relationship quantitatively.
The process of analysis is as follows: (1) giving coordinates to each shelter in Kobe-city using geo-coding system, (2) calculating the number of refugees in each shelter and investigating the structure of damaged buildings within the range of each shelter, and (3) analyzing the behavior pattern of evacuation in accordance with degree of damage focusing on structure type and use of building. The outputs of this project would be useful in making the evacuation plan, such as the location of shelter and allocation of goods.

Introduction

On 17th of January in 1995 at 5:46 a.m., the Great Hanshin-Awaji Earthquake measuring 7.2 on Richter scale hit the southern part of Hyogo Prefecture in Japan. This earthquake caused a great deal of damage to the area. 6,433 people were died and 43,792 people were injured. Also, about 480 thousands of houses and buildings were damaged. In particular Kobe had suffered with the hardest damage. So preparedness in urban area against dreadful harm by striking big earthquake has been focused on more importantly. Damage was much larger than predicted, so the number of refugees was also more than estimated in pre-disaster planning of Hyogo. What if the number of shelters were set more than in evacuation plan, or if the number of refugees was precisely estimated, the damage would have been minimized. On this score, estimating evacuation ratio properly which is defined as the number of refugees in each shelter and from where in the range they have evacuated could be meaningful source to clarify. However, such data that where they come from and to which shelter they have evacuated was not investigated for every single refugee, only how many refugees were emerged in city or town and accommodated in each shelter were aggregated. There is only few researches have attempted to estimate evacuation ratio by considering on behavior pattern of refugees.

Recently, Geographic Information System (GIS) has developed as a strong tool for urban and spatial analysis and it has been used in various fields. In this perspective, the purpose of this project is to clarify

the relationship among the structure of buildings, the degree of building damage and evacuation ratio by range of each shelter in the case of the Great Hanshin-Awaji Earthquake. We also show the effectiveness of GIS, by calculating the distance from each building to each shelter, making the geographical point-data of shelters, and assuming the range of shelters using ArcGIS. The outputs of this project could be useful in making the evacuation plan, such as the location of shelter and allocation of goods.

Methodology

The procedure of this project is as follows. First, we build the spatial data of shelters using geo-coding system provided by Center for Spatial Information Science (CSIS) at the University of Tokyo. Address of each shelter is only information that we can gather for its location. So, by using geo-coding system, we seek for the geographical point of each shelter. Second, we estimate the range of shelter by adopting gravity model which is derived Newton's law of universal gravitation. Finally, we analyze the relations among the structure of buildings, the degree of building damage, and evacuation ratio by the range of shelter unit. For this analysis, we used spatial data of buildings and attribute data of damaged building which was compiled by Building Research Institute (BRI) at the same time of earthquake disaster.

We assume the range of each shelter is different. The shortest distance to the shelter would be the best way to be assigned for all refugees. It is simple if we do not consider about the capacity of shelter. However, in that situation, some shelters might be overflowed if the large number of refugees emerged. Sakata (2000) also showed that evacuation distance and capacity of shelter had influenced to choose shelters in the Great Hanshin-Awaji Earthquake [2]. Therefore, we adopt the gravity model to consider characteristic of behaviors. We calculate "gravitation" between buildings and shelters, and assign each building to shelters having the largest gravitation. In this project, the assignment focused on the building unit. In other words, we put the same weight on all buildings. Moreover, we assume that the number of refugees which was aggregated in the Great Hanshin-Awaji Earthquake is the capacity of each shelter, because of no certain data.

gravity model:

$$G_{ij} = \frac{p_i q_j}{d_{ij}^{\ 2}} \qquad (1)$$

G_{ij} : the gravitation between building i and shelter j
p_i : the number of refugees in building i ($p_i = 1$ all of i)
q_j : the capacity of shelter j
d_{ij} : Euclid distance between building i and shelter j

Murao et al. (1999) showed that the damaged building was correlated on the structure of buildings (wooden, reinforced concrete, etc) in *cho* and *aza* unit which is the smallest administrative unit in Japan [3]. However,

we analyze to the range of each shelter as the spatial unit.

We use three indices: wooden building ratio, building damage ratio, and evacuation ratio. First, we focused on the wooden building ratio because wooden building is broken easily by fire and impulse compared to other structures. At the Great Hanshin-Awaji Earthquake, 90 percent of all damaged buildings were the wooden building. The wooden building ratio, *W*, is defined as follows:

$$W = \frac{n_W}{N_B} \qquad (2)$$

n_W : the number of wooden buildings
N_B : total number of buildings

Second, damaged building ratio represents the ratio of damaged building including all the case of totally destroyed, half destroyed, partially damaged or fire on building. In the report published by BRI (1996), they did not consider the case of fire on building to investigate the relationship between the damaged building and fire [4]. However, we include it because people will consider to evacuating even if there is fire on their building. The damaged building ratio (D) is defined as follows:

$$D = \frac{n_d}{N_B} \qquad (3)$$

n_d : the number of damaged buildings which are classified into four :
totally destroyed, half destroyed, partially damaged, fired

Third, evacuation ratio represents what the percentage of total population in the range of shelter takes the number of refugees. Population was distributed proportionally by the number of buildings in the range. The evacuation ratio (E) is defined as follows:

$$E = \frac{p}{N_P} \qquad (4)$$

p : the number of refugees
N_P : population in the range of shelter

Case Study

Kobe was particularly suffered with serious damage in this earthquake. Kobe has been a local heartland in Japan, and about 1.5 million inhabitants lived in area 545 km^2. Particularly in urbanized area, buildings stood with high-density and there were many wooden detached houses before the earthquake. In that area,

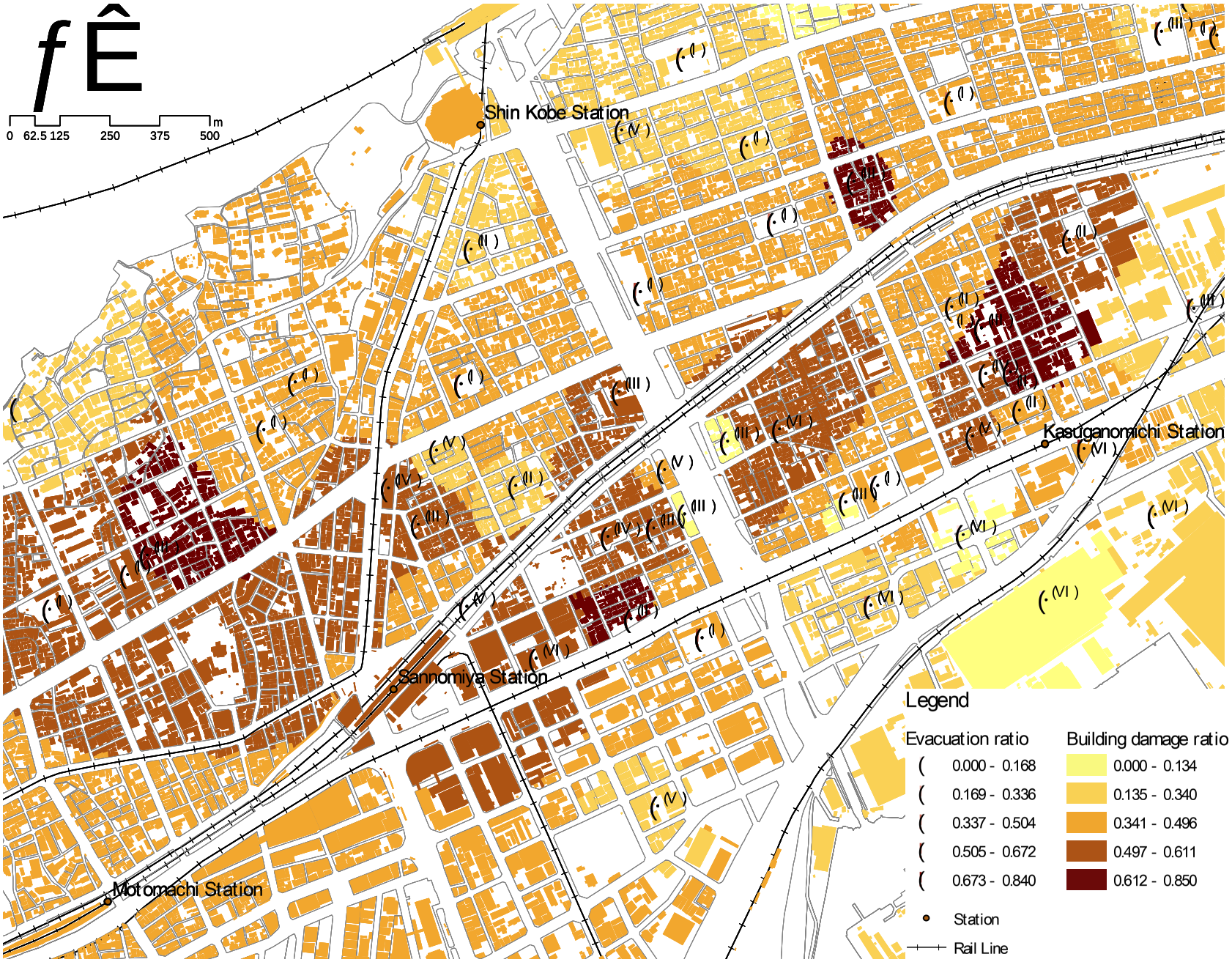

Figure1 : The classification of shelters, evacuation ratio and damaged building ratio

Table 1: Classification of facility and the number of refugees

No.	classification of facility	number of facility	total number of refugee	average number of refugee
(I)	education or culture	27	23078	855
(II)	public open space	11	4395	400
(III)	medical care or welfare	14	2457	176
(IV)	collective housing	7	1090	156
(V)	private company	6	245	41
(VI)	others	18	6857	381

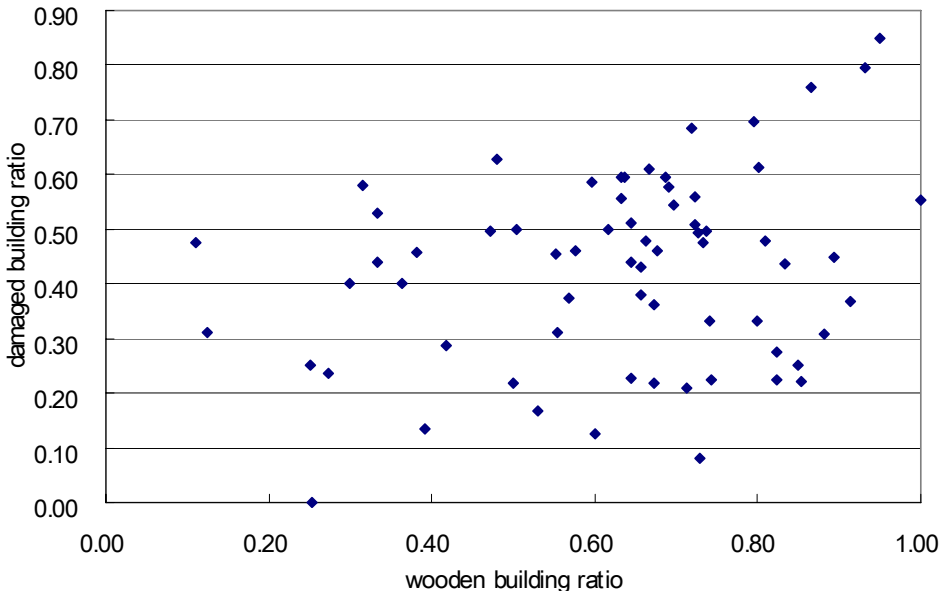

Figure 2: The relationship between wooden building ratio and damaged building ratio

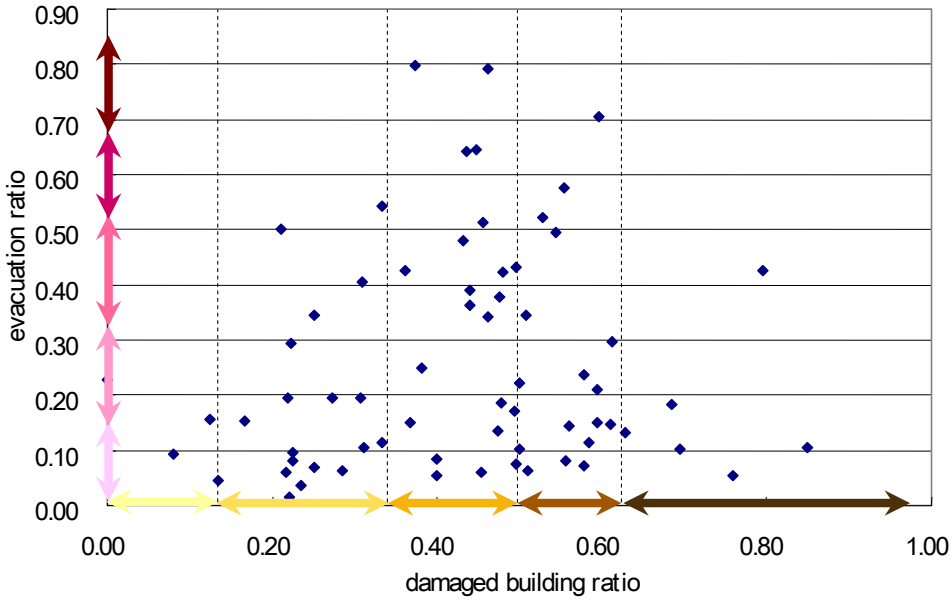

Figure 3: The relationship between damaged building ratio and evacuation ratio

fire and the building damage accompanied mostly, and many casualties and refugees emerged due to the earthquake. That is why we choose Chuo Ward where many commercial establishment and wooden houses concentrated in this region. We use the building data and the degree of building damage data to analyze. The building data of Chuo Ward and the degree of building damage data are in concert with City Planning Institute of Japan (CPIJ) Kansai branch office, Architectural Institute of Japan (AIJ) Kinki branch office, Hyogo Prefecture, and BRI. Moreover, the data of the number of refugees was investigated by Kobe City Health and Welfare Station. Regarding population data, we use Basic Resident Register, as of 4th of January in 1995.

Results

Figure 1 shows geographical distribution and pattern of evacuation ratio and degree of building damage by using ArcGIS. From this map, we reveal that the area where represents with high evacuation ratio is not always shown with high damaged building ratio. Consequently, we need to consider how to improve the areas where densely wooden buildings are located. Moreover, more shelters are needed to be equipped because the number of refugees possibly increases in these areas even after improvement.

Figure 2 describes the relationship between the wooden building ratio and the damaged building ratio. The damaged building ratio rises as wooden building ratio rises together. In other words, densely areas with a lot of wooden buildings are apt to be damaged by earthquake. Figure 3 describes the relationship between the evacuation ratio and the damaged building ratio. High ratio of evacuation appeared as the damaged building ratio is between 0.4-0.6. In lightly damaged circumstances, people are not fluttered to evacuate. On the other hand, in heavily damaged circumstances, people can not evacuate due to fire or debris after the earthquake. However, in intermediately damaged circumstances, the most of people have more chance to evacuate than people who are in heavily damaged circumstances. Thus, we can see that the evacuation ratio is the most high as the damaged building ratio is between 0.4-0.6 in Figure 2.

Conclusion

In this project, we analyzed the relationship among the wooden building ratio, the damaged building ratio, and the evacuation ratio in the case of the Great Hanshin-Awaji Earthquake, by assuming the range of shelter using gravity model. We showed that the damaged building ratio rises as wooden building ratio rises together, and high ratio of evacuation appeared as the damaged building ratio is between 0.4-0.6. In conclusion, it is important to improve the structure of buildings for big earthquake, but in that case the number of refugees is apt to increase. So we need to consider how to improve the areas where densely wooden buildings are located, and more shelters are needed to be equipped because the number of refugees possibly increases in these areas even after improvement.

In Japan, there are many high-density areas. In such areas, in the case of huge earthquake a great number of refugees emerge, and the number of shelter may not be enough. Pre-disaster planning, particularly the

evacuation planning, is very important in Japan. GIS as a powerful analyzing tool offers a helpful information in the planning process, and it is necessary to stock detailed data on the behavior just after the earthquake.

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