THE INFLUENCE OF TSUNAMI WAVE RELATED & EVACUATION RELATED FACOTRS ON THE FATALITY RATIO IN 2011 GREAT EAST JAPAN EARTHQUAKE AND TSUNAMI

Waseda University Student Member ○Nam-Yi Yun
Waseda University Regular Member Masanori Hamada

1. INTRODUCTION

The authors investigated various influential factors on the fatality ratio in the 2011 disaster, such as the tsunami wave related and evacuation related factors. The tsunami wave related factors were the maximum tsunami wave height and the maximum tsunami arrival time, and the evacuation related factors were evacuation starting time and the distance to evacuation areas (i.e. evacuation shelter and higher ground such as a hill).

2. PREVIOUS RESEARCH AND RESEARCH QUESTION

The fatality ratio due to earthquake and tsunami is affected by various factors (Kawata, 1997). Several studies analyzed the relationship between fatality ratio and influential factors, however, these studies found that there is not clear result between a tsunami related factors and fatality ratio and discussed the general tendency, and they mentioned the influence of evacuated related factors on fatality ratio as well. Therefore, the aim of this study is how can be investigated and developed formula with various influential factors on fatality ratio in the 2011 Great East Japan earthquake and tsunami.

3. DATA AND PROCEDURE

This study testes not only the tsunami wave related factors but also evacuation related one. Since evacuation actions taken by residents are fundamental to human damage mitigation measures against disasters, therefore, this research pays attention to two more factors: first, time interval between evacuation starting time and earthquake occurrence time using survey data; second, evacuation distance defined by the nearest evacuation area from residential area using aerial photo from the Geospatial Information Authority of Japan (GSI). Considering gathered data sample number, we focus on the inundated area at Iwate Prefecture (i.e. Miyako city, Yamada town, Otsuchi town, Kamaishi city, Ofunato city, and Rikuzentakata city) and Miyagi Prefecture (i.e. Kesennuma city, Onagawa town, Ishinomaki city, Higashimatsushima city, Tagajo city, Natori city, and Iwanuma city) in Japan were selected as the study areas. For the fatality ratio in the inundated areas, the published data from the Fire and Disaster Management Agency (FDMA), for time interval data, surveyed data from the Weathernews, and for tsunami wave information, surveyed data from the 2011 Tohoku Earthquake Tsunami Joint Survey Group is used. Especially, for the evacuation distance in this study, we used photo and area data from the Geospatial Information Authority of Japan (GSI), the higher ground (i.e., hilly area) location information from the Google earth, and information of the evacuation shelter from the Cabinet Secretarial Civil Protection Portal Site. Fig. 1 shows an example of Otsuchi town in Iwate Prefecture. There are 16 evacuation shelters and 7 higher grounds nearby the 10 resident areas.

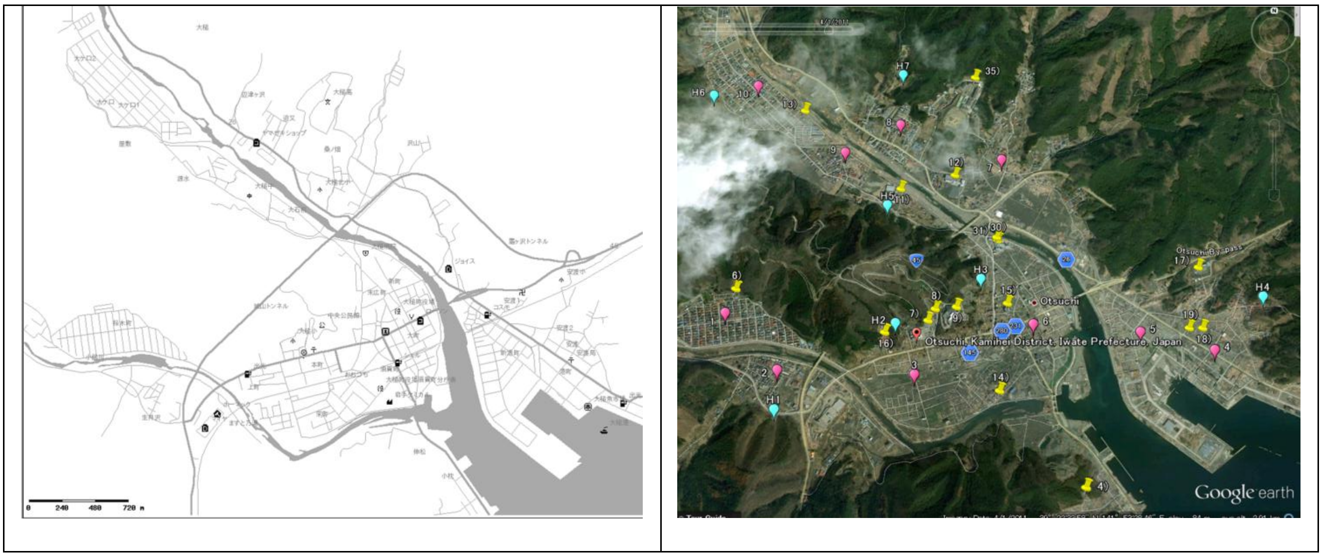


Fig. 1. Otsuchi town (1:12,500 map)

4. RESULTS OF ANALYSIS

The empirical relationship between fatality rate and the tsunami wave related factors from observed data in the 2011 Great East Japan earthquake and tsunami using the least square method is evaluated. Eq. (1) describes this function

$$\text{Fatality Ratio (\%)} = 0.501H_t - 0.007T_A \quad (1)$$

where H_t = the maximum tsunami wave height (m); T_A = the maximum tsunami wave arrival time (minute).

Fig. 2 (a) shows evaluated values for the loss of lives and the actual fatality ratio in the 2011 disaster. When the combination of the tsunami height (H_t) is higher and its arrival time (T_A) is faster, the fatality rate will be larger.
The following Eq. (2) explains an effect of evacuation distance with tsunami wave related factors on fatality ratio for the 2011 disaster considering tsunami height, its arrival time, and evacuation distance.

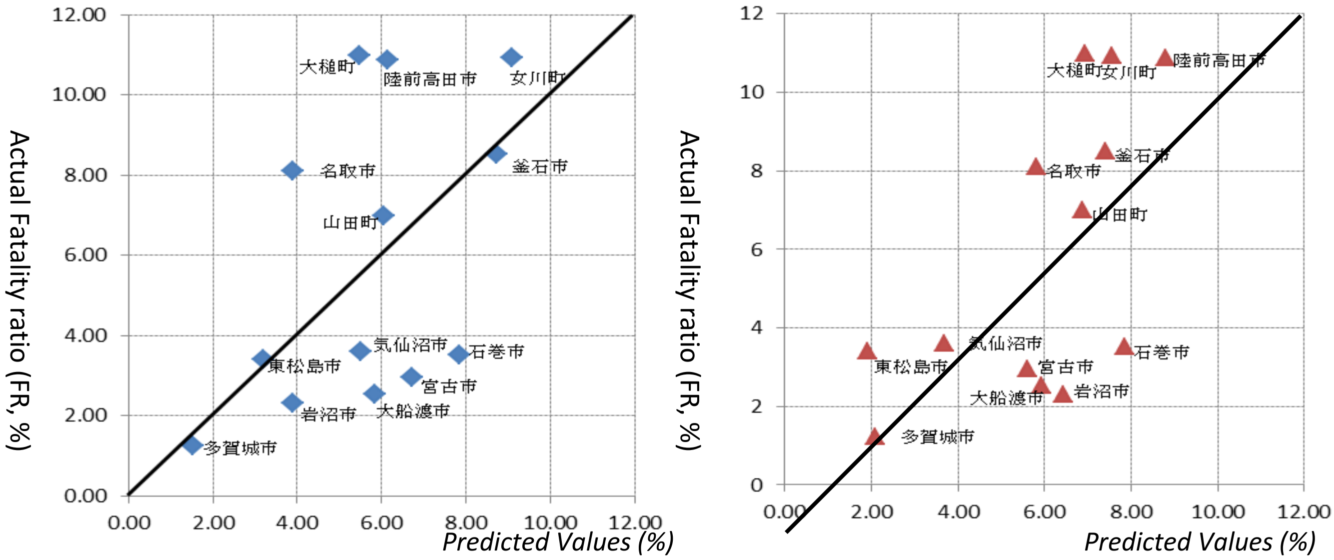
$$\text{Fatality Ratio (\%)} = 0.409H_t – 0.103T_A + 0.018D_{istance} \quad (2)$$

where H_t = the maximum tsunami wave height (m); T_A = the maximum tsunami wave arrival time (minute); $D_{istance}$= evacuation distance (m).

Fig. 2 (b) illustrates the estimated results using Eq. (2); this suggests that some scatter points are nearer the black line with 1:1 slope. It means observed results with Eq. (2) are closer that estimated results with Eq. (1); especially, the high fatality ratio could be explained by Eq. (2).
Eq. (3) show the results for the time interval between the evacuation starting time and earthquake occurrence and three other factors on fatality ratio, but a little different from Eq. (2).

$$\text{Fatality Ratio (\%)} = 0.382H_t – 0.108T_A + 0.017\text{Distance} + 0.013T_1 \quad (3)$$

where H_t = the maximum tsunami wave height (m); T_A = the maximum tsunami wave arrival time (minute); $D_{istance}$= evacuation distance (m); T_1 = time interval between evacuation starting time and the earthquake occurrence (minute).



(a) Fatality Ratio (%) = $0.501H_t – 0.007T_A$ (b) FR=$0.409H_t – 0.103T_A + 0.018_{Distance}$

Fig. 2. Evaluated fatality ratio with influential factors and actual fatality ratio

Results with Eq. (3) indicate that fatality ratio increase in the areas with higher tsunami wave, faster tsunami arrival time, longer evacuation distance, and longer time interval; the tsunami height is the most important characteristic marking the potential danger of massive loss of human lives. As a result of multivariable method, the three influential factors related with the fatality ratio is the optimization model.

5. CONCLUSIONS

This study investigates that the four influential factors on the fatality ratio in the 2011 Great East Japan earthquake and tsunami. The results demonstrated that the fatality ratio in inundated areas increases when the tsunami height is higher and the tsunami arrival time is faster and when the distance to evacuation area is longer and the time interval is longer. These results contribute to more integrated analysis for prediction of loss of human lives and mitigation the risks due to catastrophic earthquake and tsunami disaster in future disasters.

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