Fragility Curves for Economic Losses in Industrial Sectors after Strong Wind Disaster: A case of 2018 Typhoon Jebi

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This study proposes strong wind disaster fragility curves for economic losses of industrial sectors, which represent conditional probabilities of reduction of economic losses given a strong wind. This is an extension of the method of fragility curves for structural vulnerability. The present paper conducts a questionnaires survey regarding economic impacts on business activities of firms after the 2018 Typhoon Jebi and estimates the fragility curves by using the data. The estimation is conducted for different industrial sectors and the result imply that fragility curves are different between sectors. The information of functional fragility curves in this paper are helpful for conducting quick estimation of economic impacts on business sectors in case of large-scale strong wind disaster. In addition, the functional fragility curves can be used by individual firms for understanding the potential impacts of future disaster on their businesses and preparing countermeasures for the risk such as business continuity plan (BCP).

1. Introduction

Typhoon Jebi (2018), which struck Japan on the 4 September 2018, damaging many coastal cities of Kinki area. JMA achieved the maximum instantaneous wind speed more than 50 m/s on the Kinki area, the strongest to hit mainland Japan for 27 years. Essentially, strong winds tore down some constructions, and more than 22,000 houses were reported to have been damaged to some extent during the event. It caused 14 deaths and injure 1011 people; total economic losses were estimated at 68.5 billion yen. In order to capture the economic impact to the industry caused by the Typhoon Jebi. This study proposes strong wind disaster fragility curves for economic losses of industrial sectors, which represent conditional probabilities of reduction of economic losses given a strong wind. The present paper conducts a questionnaires survey regarding economic impacts on business activities of firms after the 2018 Typhoon Jebi and estimates the fragility curves by using the data.

2. Data and Methodology

(1) Wind speed data

Maximum wind speed is considered as a measurement of hazard information to individual firms. And the maximum wind speed data of Typhoon JEBI is provided by Prof.Takemi. The data investigate the influences of densely built urban environments on the occurrence of wind gusts in an urban district during Typhoon Jebi by merging mesoscale meteorological and building-resolving large-eddy simulations (LES).

(2) Questionnaire data

To capture the economic impact to the industry caused by the Typhoon Jebi, especially at Osaka. About 4000 firms are listed as a candidate of the survey based on the survey of distribution of strong winds. A total of 548 businesses (219 manufacturing and 329 non-manufacturing) were responded.

(3) Fragility Curves

The fragility curves are used to reflect the relation between hazard value and losses. It represents the probability distribution of the losses that are likely to occur following the given hazard intensity. Firms are assumed to exceed a certain damage state k if the wind speed exceeds a threshold x. it is assumed that the threshold has uncertainty and follows a probability distribution $\boldsymbol{f_k}$ $(\boldsymbol{x}, \boldsymbol{\mu_k}, \boldsymbol{\sigma})$. Under the condition of wind speed as z, the conditional probability that a firm's damage state will exceed k can be formulated as follows:

$$F_k(z) = \int_0^z f_k(x)dx$$

$$f_k(x, \mu_k, \sigma) = \frac{1}{\sqrt{2\pi}\sigma x} exp\left(-\frac{(ln\,x - \mu)^2}{2\sigma^2}\right)$$

Parameters $\boldsymbol{\mu_k}$ and $\boldsymbol{\sigma}$ are simultaneously estimated by maximizing a likelihood function:

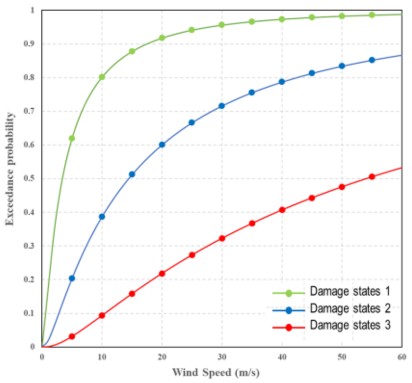
$$L = L(\mu_1, \mu_2, \mu_3, \sigma) = \prod_{i=1}^{N}\prod_{k=0}^{3} P_k(Z_i)^{\delta_{ki}}$$

δ_{ki} = 1 (when it exceeds a certain damage mode)

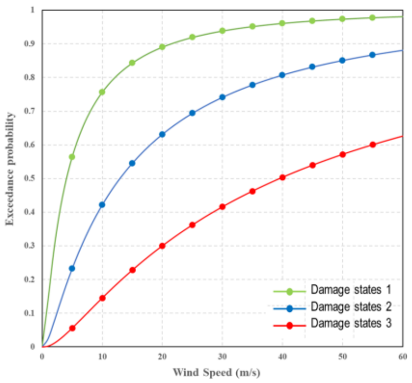
= 0 (Otherwise)

3. Result

(a) Manufacturing industry



(b) Non-manufacturing industry



Comparing the fragility curve of the manufacturing (Fig.a) and non-manufacturing (Fig. b), at the same level of wind speed, the probability of damage states 1 (green-bule range), the manufacturing industry is high. The probability of becoming damage state 2 (from blue to red range) is a little higher in the manufacturing industry, and the probability of exceeding damage state 3 (red range) is higher in the non-manufacturing industry.

In non-manufacturing industries, the percentage of damage to restoration costs for buildings and equipment is greater than in manufacturing industries, and these are considered to contribute to the increase in the damage rate. According to the questionnaire data, The percentage of taking Inundation measures and earthquake reinforcement of buildings and equipment fixation, Nonmanufacturing industry is less than manufacturing industry. Therefore, take disaster prevention measures or not may have affected the direct damage to buildings and equipment. From the questionnaire used for estimation in this paper, it can be said that the non-manufacturing industry is more vulnerable than the manufacturing industry.

4. Conclusion

(1) Wind speed can be regarded as a representative variable for predicting economic losses from wind disasters.

(2) Fragility curves also could be applicable in strong wind disaster.

(3) The information of fragility curves in this study are helpful for conducting quick estimation of economic impacts on industrial sectors in case of large scale strong wind disaster.

(4) Different vulnerable level could be obtained for different industrial sectors right after disaster