Modeling the cooperative behaviors for the evacuations between the residents. –With the case study of the heavy rain disaster.

Junji Urata *

Pacific Consultants CO., LTD., Tokyo, Japan

Eiji Hato

Department of Urban Enginnering,

The University of Tokyo, Tokyo, Japan

***** Email: mailto: junji.urata@tk.pacific.co.jp

1 Introduction

Generally, people judge their behaviors by the information of the dangers and the possibility to evacuate under the disasters. Not all people can get enough the information for the evacuations by only the mass medias and the disaster radios. There is also variation in the criteria to evacuate in residents by the living places. The residents often need the local cooperative behaviors, for example the mutual assistances and exchange of the information between the residents. The cooperation behaviors can help individuals with low mobility and low recognition of the risk.

In this study, we focus on the cooperative behaviors for the evacuation in the disaster areas and introduce the choice model of the residents' pairs of the cooperative behaviors. The model brings in the other-regarding preferences because this preference shows that people rescue others and evacuate with the people who are in need despite the growing their dangers. The model is formulated by the cross-nested logit (CNL) model [1] for representing the correlations and the cross-elasticities between all the residents' pairs. And we estimate the parameter of the choice model from the behavior data under the heavy rain disaster.

2 The choice model of the pairs of the cooperative behaviors

2.1 The relationships of the pairs

This paper classifies the type of the relationships of the pairs according to decision-making rule about the cooperative behaviors under the disasters. The first type of the relationships is 'the basic relationships' that has priority of cooperating with each other under the disasters,

for example family, intimate and so on. The second type of the relationships is 'the reasonable relationships' that is made if the cooperative behaviors are mutually beneficial, for example the neighborhoods, the chairman of block association and so on. The choice model targets at 'the reasonable relationships'.

2.2 Other-regarding preferences

We introduce the other-regarding preferences [2] into the model. The preferences are influenced by the difference between their payoffs. They feel inequity if their payoffs are worse than the others, and they also feel inequity if they are better. The cooperative behaviors of helping others are reasonable by the preferences.

This paper evaluates the differences of the behavioral constraints under the disasters as the factors of the other-regarding preferences. For instance, people suffering directly, aged people and people with children have the strong behavioral constraints. They are recognized as under the constraints by others and they are helped in the states of emergency by the preferences.

In the two player (*i* and *j*) case, the utility function of player *i* is given by

$$u_i(x) = x_i - \alpha_i \cdot \max\{x_j - x_i, 0\} - \beta_i \cdot \max\{x_i - x_j, 0\} \tag{1}$$

In this formula, x_i and x_j denote simply payoffs. Additionally, α_i shows player-*i*'s degree of inequality which is useful when the player-*i*'s payoff is lower than the player-*j*'s and β_i is otherwise.

2.3 The framework of the model

This paper introduces the choice model of the residents' pairs of the cooperative behaviors in local area. The formulation of the choice model is consistent with the CNL model. The utilities of the pairs are defined by two residents' payoffs by the other-regarding preferences. The distributions of the random error terms have the correlations between the residents' pairs if they have the same resident.

The probability of the residents' pair *n* is

$$P_n = \sum_m P_m P_{n|m} \tag{2}$$

where P_m, the probability of resident *m*, is

$$P_m = \frac{\left(\sum_{n' \in N_m} \left(\alpha_{n'm} e^{V_{n'}} \right)^{\mu_m} \right)^{1/\mu_m}}{\sum_m \left(\sum_{n' \in N_m} \left(\alpha_{n'm} e^{V_{n'}} \right)^{\mu_m} \right)^{1/\mu_m}} \tag{3}$$

where $P_{n|m}$, the probability of residents' pair n if resident m is selected, is

$$P_{n|m} = \frac{\left(\alpha_{nm} e^{V_n} \right)^{\mu_m}}{\sum_{n' \in N_m} \left(\alpha_{n'm} e^{V_{n'}} \right)^{\mu_m}} \tag{4}$$

and the allocation parameter $\alpha_{nm} = 1/2\delta_{nm} \quad \forall n$, μ_m is the logsum parameter for resident m ($0 < \mu_m < 1$). If μ_m is small, P_m is high and the difference of $P_{n|m}$ in some n is relatively small.

3 The case study of the 2004 heavy rain and mudslide disaster

3.1 The outline of the disaster survey

We applied the choice model to residents' cooperative behaviors in real disaster's situations in Japan. The evacuation behavior data which is used in this case study was gathered in Niihama city after the heavy rain and debris flow disasters in 2004 [3]. The behaviors data was assembled by the interviews at Nishikusuzaki area and the interviews were carried out to target some households. The purposes of the interviews are to know the risk management behaviors and the cooperative behaviors along the time series. Nishikusuzaki area is situated in foot of a mountain and has about 60 houses. The area has a creek and the debris flow occurs from the creek. Deaths have come by the debris flow.

3.2 The estimation results

In this section, we estimate the parameter of the choice model from the behavior data at Nishikusuzaki area. The data of the households have 30 cooperative behaviors, for example rescuing, talking, evacuating with others and so on. There are three types of the utilities of the residents' pairs. One is spatial utilities, for example the distances of the residents. The second is action record, for example having rescued before that time, and the third is the differences of the behavioral constraints which is showed by degree of the damage by the disaster, the number of aged people and being only woman in the households. And the logsum parameters μ_m is defined by the dangerous extents. Specifically, we classify

Nishikusuzaki area into 4 areas according to the distance of the debris flow point and set four logsum parameters μ_m.

The estimation result shows that three variables which is the distance of the residents, having rescued before that time and the difference of the degree of the damage is significant (significant level at 5%). The four logsum parameters is significant and their estimated parameters is smaller if there area is nearer by the debris flow point. It shows that the cooperative pair formations are more independent closer to the danger point.

4 Conclusions

This paper focuses on the cooperative behaviors for the evacuation in the disaster areas and introduces the choice model of the residents' pairs of the cooperative behaviors. The model brings in the other-regarding preferences and the model is formulated by the cross-nested logit (CNL). This formulation can explain that the distributions of the random error terms have the correlations between the residents' pairs if they have the same resident. And we estimate the parameter of the choice model from the real behavior data under the heavy rain disaster and clear up that the cooperative pair formations are more independent closer to the danger point.

References

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