Microsimulation of the Housing Policy following Urban Disaster

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Abstract

At present, the expected occurrence of a massive earthquake in the Tokyo Metropolitan Area is a matter of concern for the Japanese Cabinet Office. In the event of a large urban disaster, it is unclear whether the present policy of housing assistance will work effectively. Policy simulation is a useful research approach to design institutional arrangements as well as to make preliminary considerations. To carry out a reliable policy simulation, a household's behavior model was developed using an Internet-based questionnaire system. In addition, the micro data pertaining to rental housing and construction sites of prefabricated housings were generated using social statistics. Based on these foundational works, a microsimulation model that illustrates the housing situation following an urban disaster was developed. This paper discusses (1) the simulation outline, (2) the results of calculations, and (3) issues concerning and ways to enhance the developed model in order to solve the issues.

1. SIMULATION OUTLINE

1-1. Background

The anticipated Tokyo Metropolitan Earthquake is expected to be approximately eight times more destructive than the Kobe Earthquake (1995) in terms of damage to housing; it has already been termed the "Super Urban Earthquake Disaster." In the event of an earthquake of this magnitude, additional countermeasures will be required, in addition to further research as well as preliminary considerations.

In the event that the Tokyo Metropolitan Earthquake occurs, it is expected to cause the complete collapse of approximately 300,000 to 850,000 buildings (Cabinet Office 2004). In addition, approximately 500,000 to 1,500,000 families might lose their houses, and people will be faced with problems like evacuation, temporary housing, and housing reconstruction.

This paper focuses on the temporary housing problem and attempts to develop a new research approach to the Super Urban Earthquake Disaster. In Japan, prefabricated houses (prefabs) play the central role in developing countermeasures to the problem of temporary housing. However, the supply limit of prefabs is only approximately 120,000, which might prove to be insufficient if the Tokyo Metropolitan Earthquake occurs. However, there are approximately 1,000,000 vacant rental housing units in the Tokyo Metropolitan Area, which can be utilized as temporary housing for victims.

Merely acknowledging that the supply of prefabs is limited is not enough to solve the problem. Figure 1 illustrates the complexity of the temporary housing problem. There are many types of temporary housing, and each household has a different preference. In addition, the central and local governments also provide housing support. At present, in Japan, the development of countermeasures with respect to housing recovery needs more consideration in the event of a disaster such as the Tokyo Metropolitan Earthquake. For example, administrative support can be provided for temporary living in rental housing.

In order to further understand the abovementioned problem, it is essential to conduct concrete experimental research for the social simulation of the temporary housing situation following an

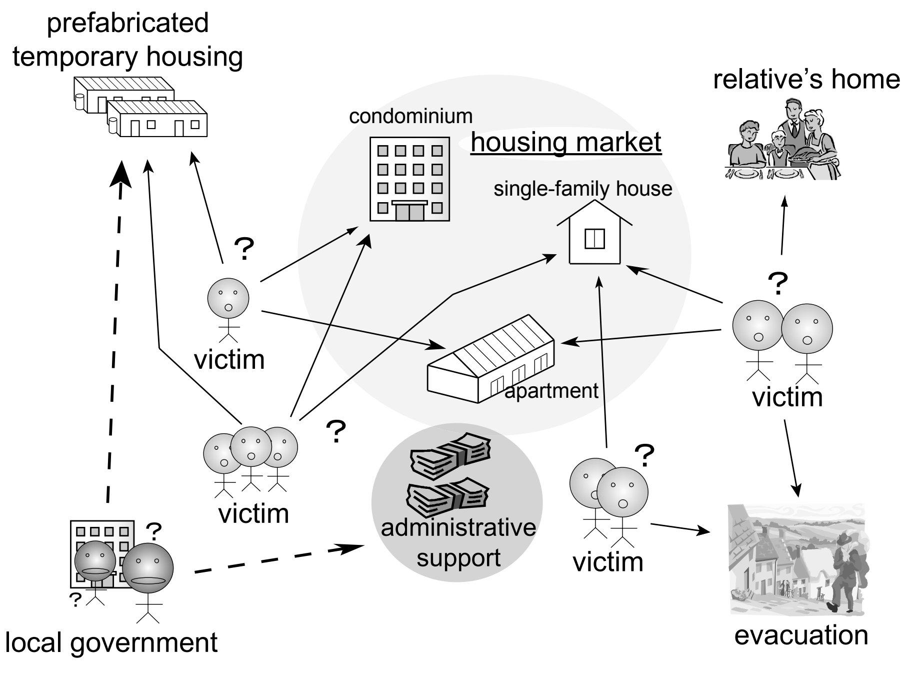

Figure 1 Complexity of the temporary housing problem

urban disaster. In this study, the following research steps are taken in order to understand the temporary housing problem.

1. Understand the mechanism of the preferences of disaster victims with respect to temporary housing following an urban disaster
2. Suggest measures to meet the housing requirements of disaster victims based on their preferences and real housing data
3. Evaluate the policy effect on disaster victims using constructed simulation.

1-2. Discrete Choice Modeling

The discrete choice analysis is useful in understanding victims' preference mechanisms, since it considers many variables, including policy variables. Additionally, the discrete choice analysis creates choice probabilities, and its results are suitable for prediction and simulation.

Considering the shifting of houses after the Great Hanshin-Awaji Earthquake, we created a fundamental model of temporary housing options, as shown in Figure 2. The options were divided into three categories: (1) prefabricated temporary housing, (2) rental housing, and (3) others such as relative's home.

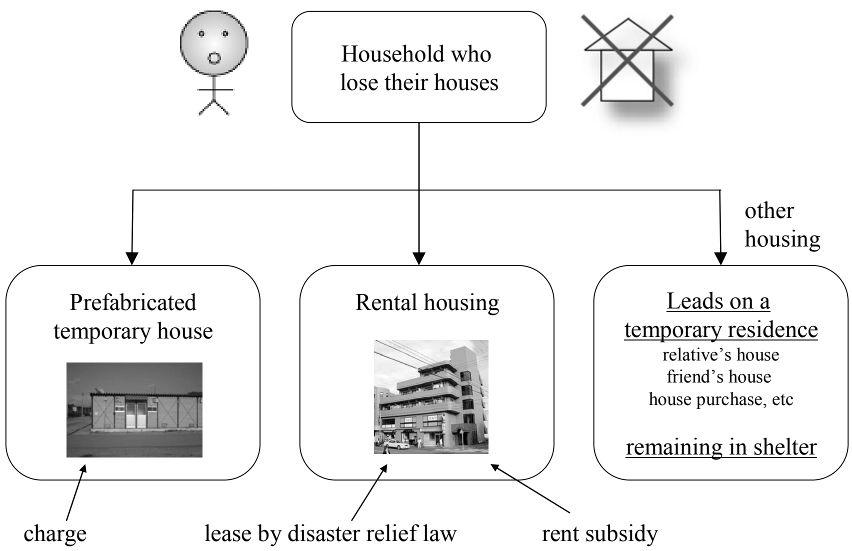

Figure 2 Fundamental model of temporary housing options

Based on the fundamental model, an Internet-based questionnaire system was designed, as shown in Figure 3. In this system, a common gateway interface (CGI) program, which develops the conditions for temporary housing (such as location and rent) based on the respondent's conditions and database of rental housing, was created. This system manages extensive combinations of choice problems following household's attributes. The mechanism of the preferences can be expressed using the data in a variety of ways.

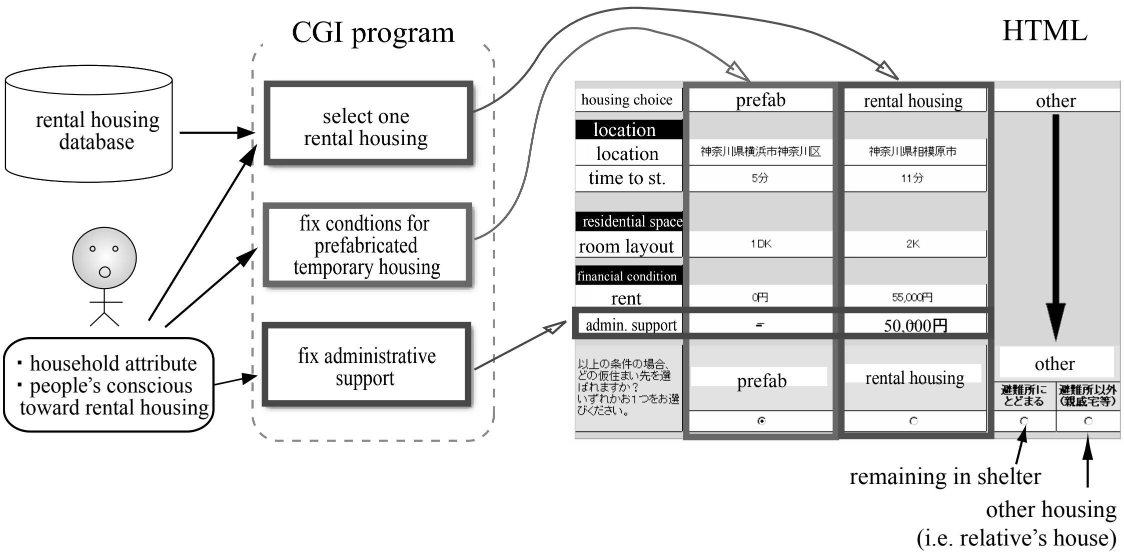

Figure 3 Outline of the Internet-based questionnaire survey

The Internet-based questionnaire was conducted from January 2007, and a total of 2,869 households responded. The parameter estimation of the discrete choice model was calculated using all the replies to the questionnaires (Sato et al 2007a).

Table 1 shows the numerical examples of the constructed discrete choice model. The choice probabilities can be calculated using the households' attributes and the conditions for temporary housing. In case 1, the choice probability of prefabs is high and that of rental housing is low. However, the relation of choice probabilities changes in case 2, in which governmental support is provided for rental housing. In this approach, as shown in table 1, several choice probabilities can be calculated under all the settings (concerning housing conditions, household's attributes, and policy variables).

Table 1 Numerical examples of the constructed choice model

household's attributes

householder's age	34
household number	3
housing ownership	rental
household income	4 million JPY
months passed	1month
leads on temporary housing	no
residential area	saitama2

case1

	prefabs	**rental housing**	remaining shelter	other
time from neaby station	21minutes	12minutes	-	-
room layout	2DK	2DK	-	-
rent	0 JPY	100,000 JPY	-	-
location	saitama 4	saitama3	-	-
governmental support	-	-	-	-
A systematic component of utility	-0.31	-1.377	-2.204	-1.175
choice probability	**57.5%**	**19.8%**	8.6%	14.1%

case2

	prefabs	**rental housing**	remaining shelter	other
time from neaby station	21minutes	12minutes	-	-
room layout	2DK	2DK	-	-
rent	0 JPY	100,000 JPY	-	-
location	saitama 4	**saitama 2**	-	-
governmental support	-	**rent subsidy 50,000 JPY per one month**	-	-
A systematic component of utility	-0.31	-0.132	-2.204	-1.175
choice probability	**38.6%**	**46.1%**	5.8%	9.5%

1-3. Micro Simulation Model

After we conduct a discrete choice analysis of the victim's preferences, the microsimulation that explains the situation of temporary housing can be carried out because discrete choice model can calculate several choice probabilities under all the settings. Next, the prototype of a microsimulation model was developed, as shown in Figure 4. The simulation flow is summarized below.

1. Secure individual data of the families who have lost their houses. Gather housing data on prefabs and rental housing.
2. Randomly extract a household that is looking for temporary housing.
3. Extract the rental housing based on the victim's preference and rental housing data. Extract the prefabs that can be supplied. In a complex situation, there is a possibility that rental housing and

the prefab will not exist.

4. Compute the choice probability of the generated choice problem using the constructed discrete choice model and assign a result using a random number.
5. Delete the selected supply data.
6. Randomly extract the next household that is looking for temporary housing and compute steps 3 to 5 again. The same calculation is to be repeated for all the households.

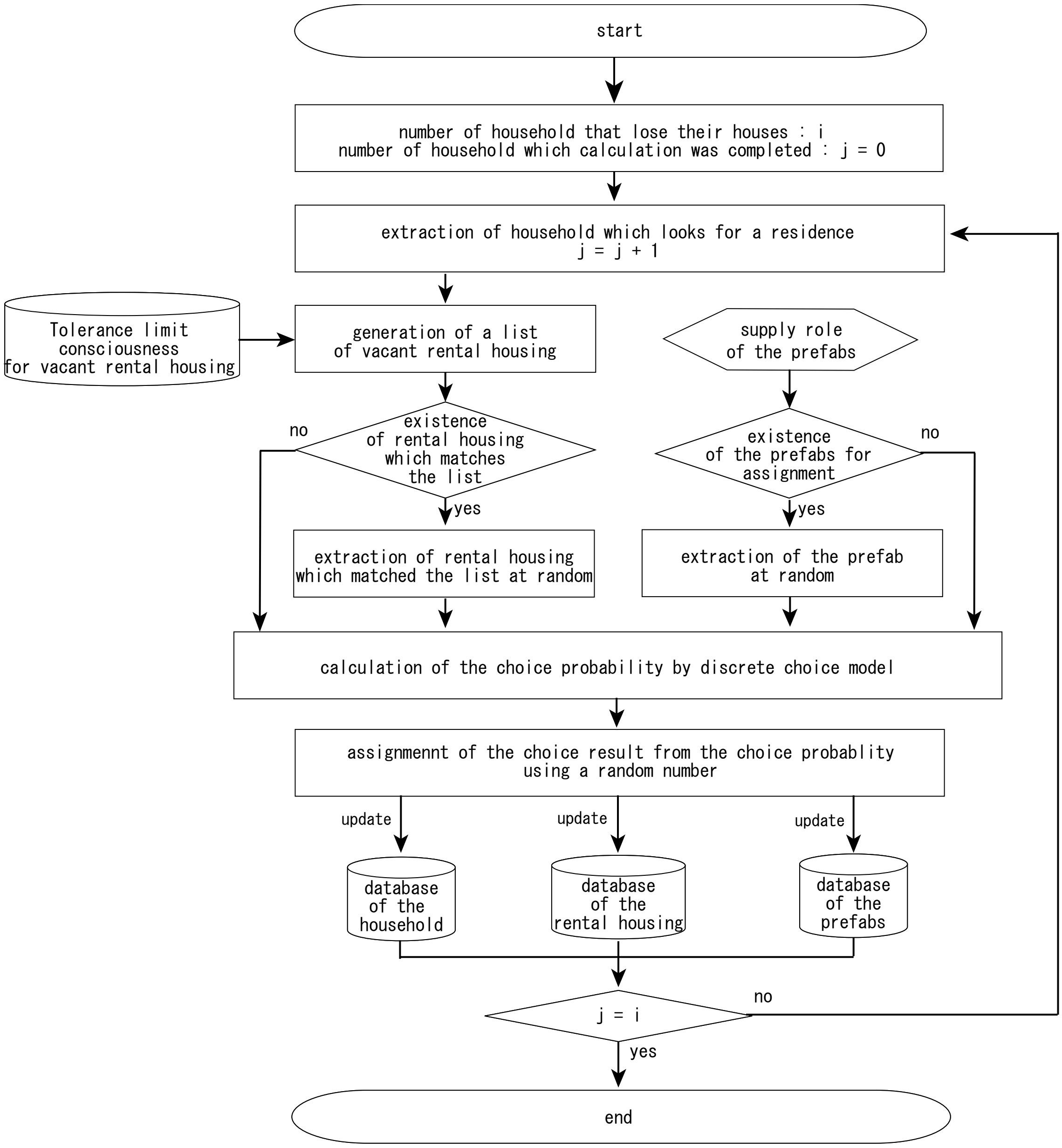

Figure 4 Prototype of the microsimulation model

One calculation is completed in the abovementioned flow. Since the result concerning the choices is assigned by random numbers, the calculation has to be performed repeatedly. By summing up the results of the repetitive calculation, we can understand the temporary housing situation.

1-4. Data Set and Micro Data

In order to implement the constructed simulation model, it is necessary to set the micro data. Generally, it is necessary to generate micro data from aggregate values in case the individual data cannot be obtained. In this research, the aggregate values of households, rental housing, and temporary housing are required. The supply limit of prefabs is obtained from the temporary housing sites of prefectural governments. The families that lose their houses, and the rental housings that can be used following disaster, are acquired from our past survey (Sato et al 2007b). Figure 5 illustrates the total values of all the 24 areas of the Tokyo Metropolitan Area. In the central area, the number of households who might lose their houses is significant, and temporary housing is not adequate.

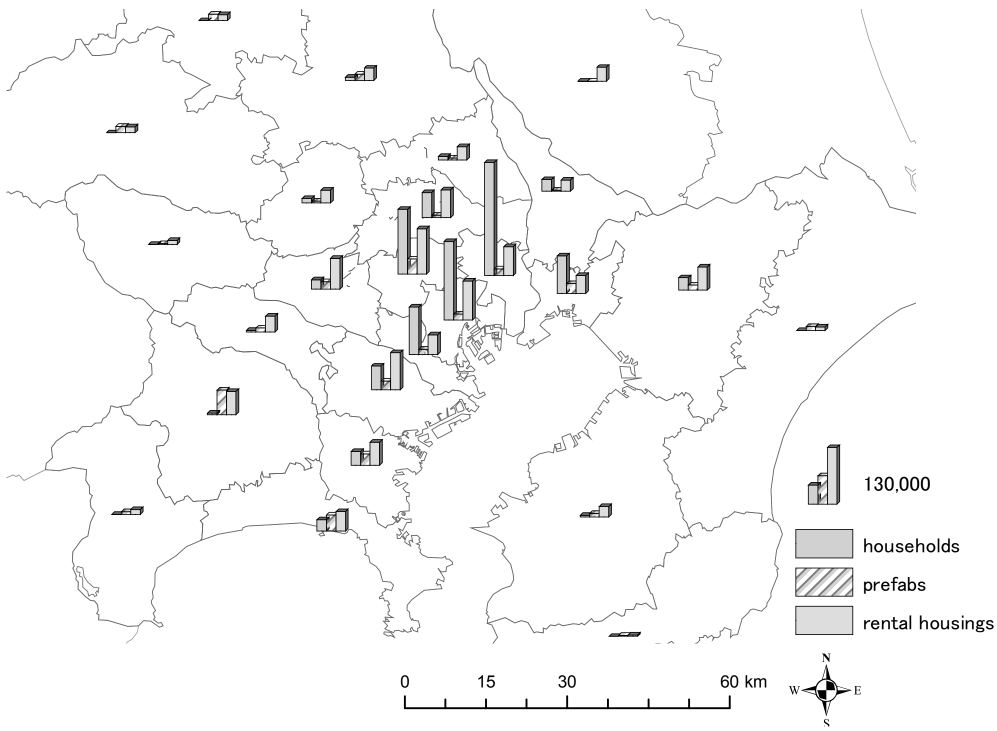

Figure 5 Temporary housing amount of TME M7.3

Next, the micro data were generated from the aggregate values. The prefab sites were used to directly obtain the micro data pertaining to the prefab supply. The micro data of rental housing were generated using online information on rental housing. Figure 6 lists the details of the generation of micro data. The total estimated vacant rental housing is approximately one million. The amount of online micro data pertaining to rental housing is approximately 0.2 million. Thus, the online data was used several times for applying to the estimated number of rental housings by room layout in each area. The micro data concerning households that lose their houses were generated using the national statistical data on housing and land. Figure 7 illustrates the details of the micro data generation. The attribute of each piece of micro data was generated using random numbers and the ratio of the statistical data.

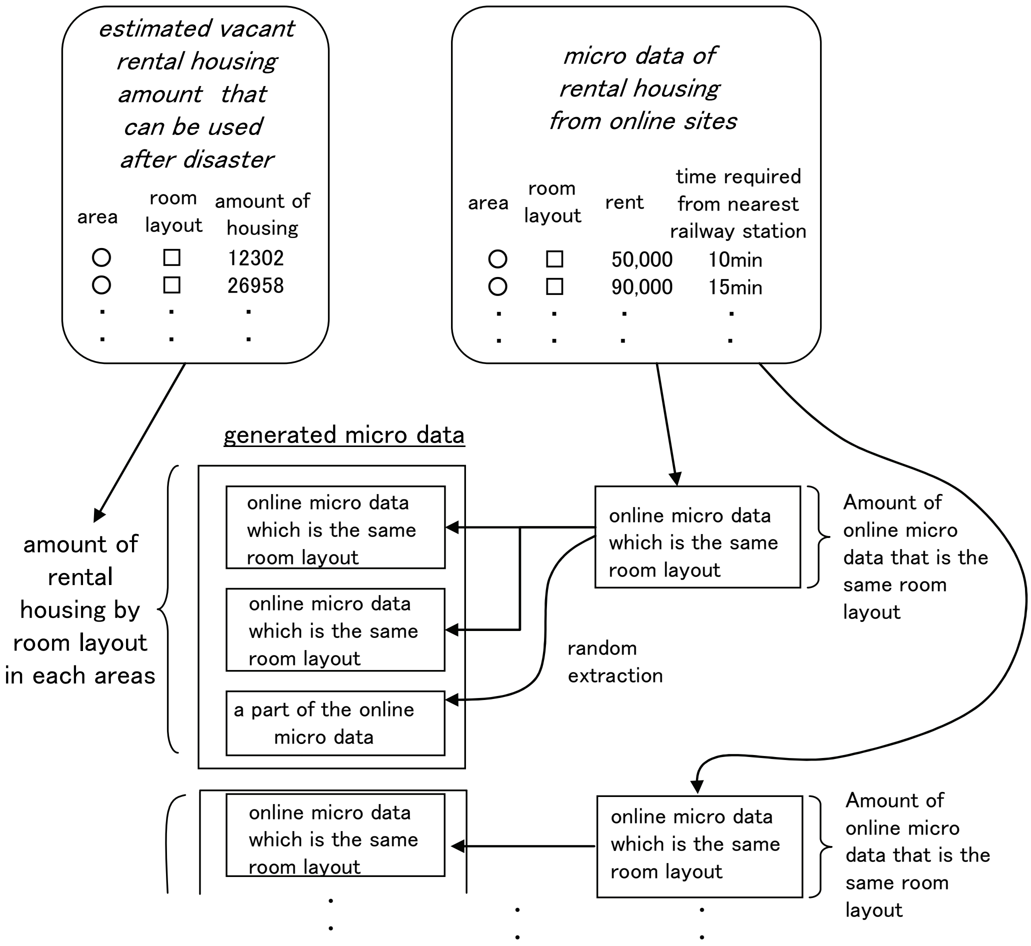

Figure 6 Micro data generation (rental housing)

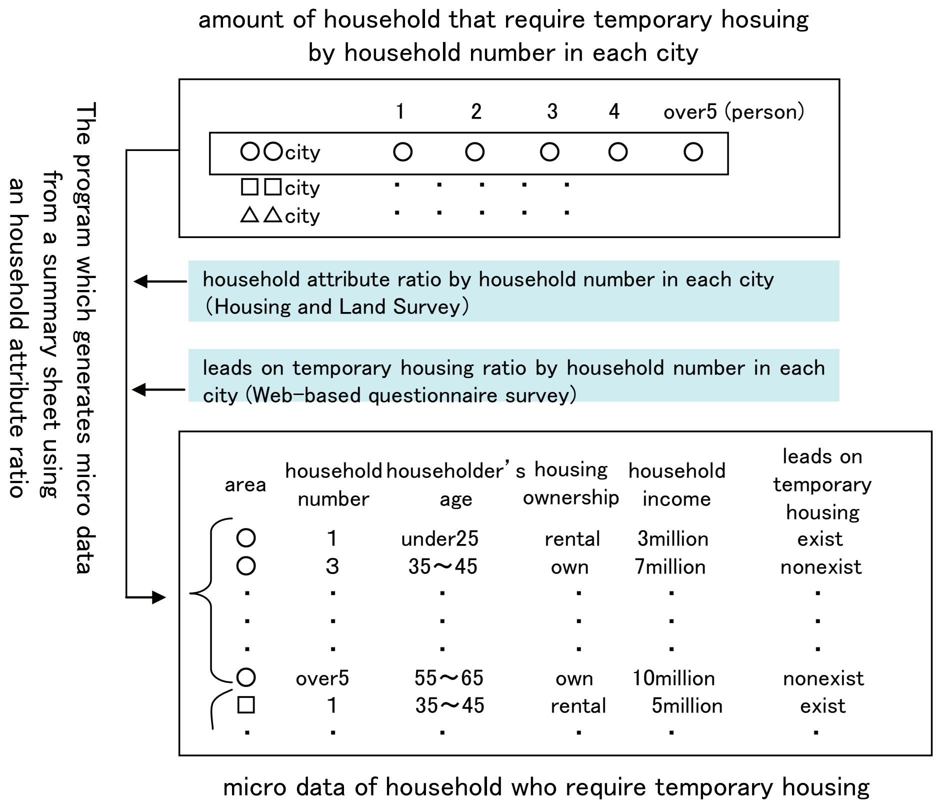

Figure 7 Micro data generation (households that require temporary housing)

2. RESULTS OF CALCULATIONS

2-1. Calculation Process

A simulation was carried out using the constructed model and the generated micro data. First, we have to set the supply rule for the prefabs. In this paper, a simple rule that assigned prefabs according to the order of search was adopted. As other examples, the supply rule that enables households with elderly people to shift preferentially can be considered. However, since the development of the microsimulation is the purpose of this research, we do not treat various supply rules in this paper. The simulation case is the Tokyo Metropolitan Earthquake M7.3 (winter, 18 o'clock). A calculation of one million households was required in approximately an hour, using the general workstation.

Figure 8 shows the calculation process of all the households. The vertical axis indicates the number of households that shifted, and the horizontal axis indicates the number of households seeking housing. To 200 thousands in seek no., there is a marked increase in the prefabs. After the prefabs are exhausted, the number of rental housing increases rapidly. Further, there is a gradual increase in the number of other types of housings and shelters. As a result, approximately 120,000 households shifted to prefabs, and approximately 500,000 households shifted to rental housing.

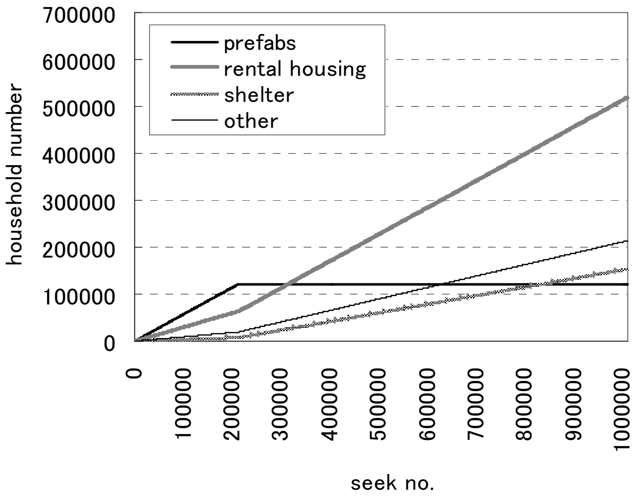

Figure 8 Calculation process

2-2. Stability of the Simulation

It is essential to examine the stability of the constructed simulation because many random numbers were used in the simulation, such as choice making, by calculating the probability of the discrete choice model. In order to examine the stability, numerous simulation results are required. However, there exists a limitation to the computational effort. Figure 9 indicates the variation of ten simulation results. This figure indicates that the number of prefabs and other types of housing are stable. Otherwise, the number of rental housing and shelters has a range of about ±50,000.

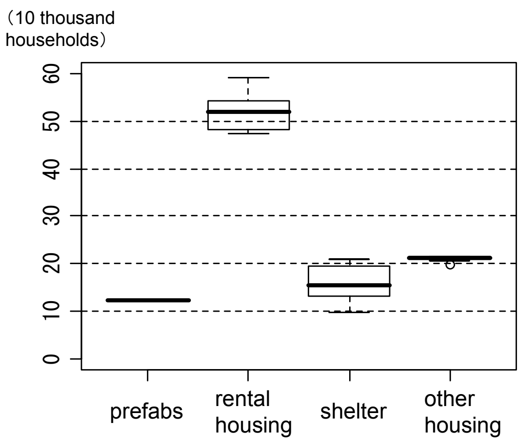

Figure 9 Stability of the simulation

2-3. Results of the Simulation

The micro simulation yielded various micro data. Thus, we have to sum up some variables in order to summarize the results. In this paper, we only indicate the choice results by residential area, as shown in Figure 10. It is observed that choice trends differ according to area. In the tokyo1, tokyo2, and chiba1 areas, many households live in shelters. Therefore, it can be said that the provisions of more prefabs in these three areas will lead to the gradual decrease in the number of households living in shelters.

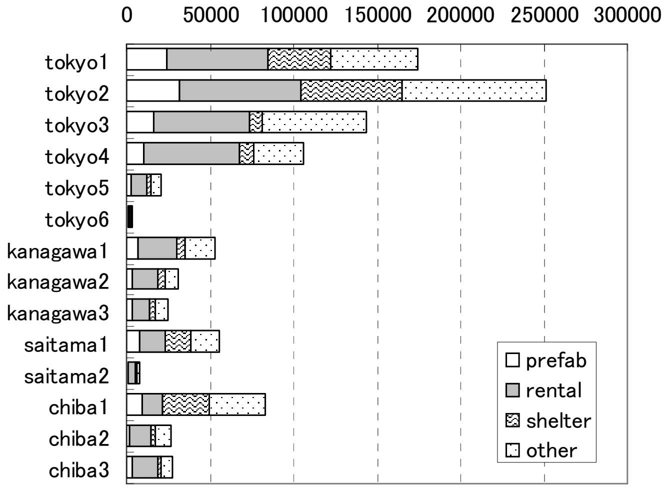

Figure 10 Simulation results by residential area

2-4. Trial of Policy Simulation

As shown in Figure 3, the Internet-based questionnaire survey took into consideration administrative support for rental housing. We ascertain five policy cases mentioned below for the trial of the policy simulation.

- Case 1: No administrative support
- Case 2: Disaster Victims Relief Law, which was revised in 2004
- Case 3: Rent subsidy of 50,000 JPY per month (fictive)
- Case 4: Rent subsidy of 100,000 JPY per month (fictive)
- Case 5: Governments hire all the rental housings, and the victims are not charged rent (fictive)

Each microsimulation of the five policy cases was calculated ten times, and the average values of the results are shown in Figure 11. The number of households who shifted to rental housing changes from 484,000 to 761,000 by policy cases. These figures clearly prove that administrative support has a significant impact on the number of households that shift to rental housing. However, the households that live in shelters stay the same. It can be said that other options such as more prefabs or evacuation for households who live in shelters are required.

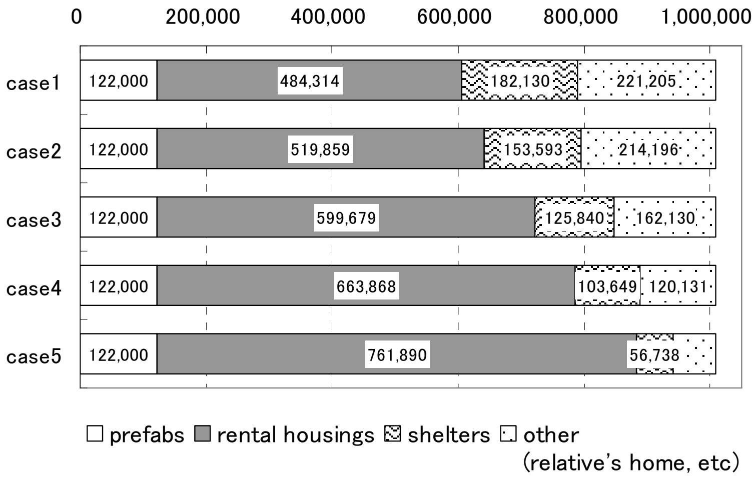

Figure 11 Results of the policy simulation

2-5. Dynamic Relation Between Demand and Supply

Table 2 shows a case set of the simulations to check dynamic relations between demand and supply. The case sets have nine patterns in the combination of three sets of demand and three sets of supply. The codes of each case are described in Table 2.

Table 2 Case set of the microsimulation

		supply amount of prefabs		
		0.1million	0.2million	0.3million
number of household who require temoary housing	1.3million	case130-10	case130-20	case130-30
	1.0million	case100-10	case100-20	case100-30
	0.7million	case70-10	case70-20	case70-30

First, we examined the effect of fluctuations in the number of prefabs. In this section, the total demand was set to only 1.3 million, and the number of prefabs ranged from 0.1 million to 0.3 million. The average values of the ten simulations are summarized in Figure 12.

Even when the number of prefabs increased, there was no significant change in the number of households who lived in shelters. This suggests that if many prefabs are constructed, even those households that can reside somewhere else may shift to these prefabs. In order to address this problem, it is important to acknowledge that it is inadequate to simply supply numerous prefabs; rather, it is important to employ a distribution method of prefabs. This can be suggested from the results of this research.

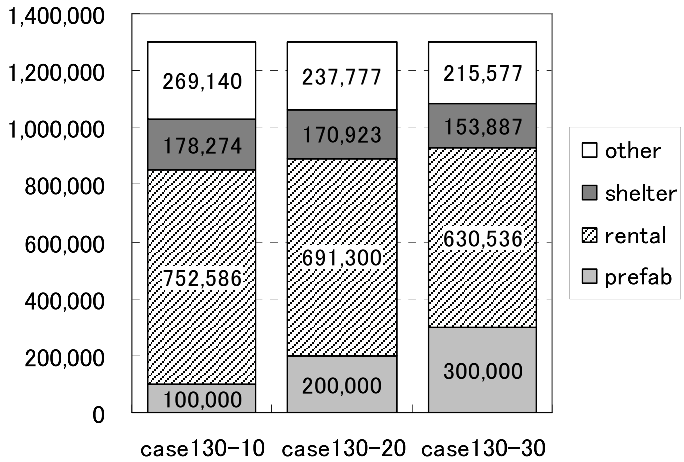

Figure 12 Effect of the fluctuations in the number of prefabs

Next, we examined the effect of fluctuations in the number of households. In this section, the number of prefabs was set to only 0.1 million, and the number of households that required temporary housing ranged from 1.3 million to 0.7 million. The average values of the ten simulations are summarized in Figure 13.

When the housing damage is less than the assessed value, the number of households who live in shelters can also be reduced. Although 0.9 million rental housings exist, all of them are not used in the three cases. It is difficult to move into the rental housing that has preferable conditions. Considering the conditions for temporary housing, merely reducing the housing damage will be inadequate, and the importance of the countermeasures with respect to the problem of increasing the shelters can be pointed out.

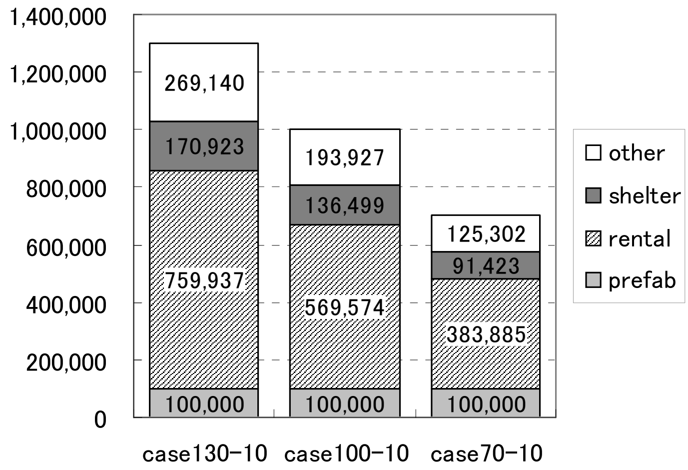

Figure 13 Effect of the fluctuations in demand

Finally, we examined the relationship between demand and supply. The microsimulations of the nine cases mentioned in Table 4 were calculated ten times each, and the average value of the households who lived in shelters was described in Table 3 (see above).

The number of households who live in shelters is mitigated by increasing the supply of prefabs from 0.10 million to 0.3 million. The rate of mitigation changes with the number of households that require temporary housing. In the case of 1.3 million households, the rate is 86%. In the case of 0.7 million households, the rate becomes 47%. Therefore, it can be said that if the mitigation of housing damage progresses, it will increase the effect of prefabs in solving the problem of increasing the shelters.

Table 3 Number of households that live in shelters in the nine cases

		supply amount of prefabs			reduction rate from 0.1 million of the supply to 0.3 million
		0.1million	0.2million	0.3million	
number of households who require temorary housing	1.3 million	178,274	170,923	153,887	86.3%
	1.0 million	136,499	119,200	90,163	66.1%
	0.7million	91,984	64,808	43,407	47.2%

3. ISSUES AND REMARKS FOR FUTURE STUDY

By way of a conclusion of this paper, we wish to consider the issues concerning the constructed microsimulation. The following three points appear to be helpful in attempting to ascertain the issues: (1) limitations in problem setting, (2) the reliability of the stated preference data, and (3) the difficulty in describing the interdependence between individuals and social relationships.

First, the aim of the microsimulation is limited to describing the temporary housing situation. There is a housing reconstruction problem after the temporary housing problem. Even if it optimizes only the temporary housing countermeasures, it is meaningless if it does not smoothly coordinate with the problem of housing reconstruction. According to Deming (1994), "optimization is a process of orchestrating the efforts of all components toward the achievement of the stated aim. Any group should have as its aim optimization over time of the larger system that the group operates in." This description is suitable for business management; however, the indication that partial optimization does not lead to complete optimization is a serious problem with respect to constructed simulation.

Second, the reliability of stated preference data on which the victim's behavior model is based is not perfect. The stated preference data were collected by an online survey, as fictive consciousness. In the event of an urban disaster, there is no guarantee to which people act as a whole. This problem occurs frequently when we develop social simulations for the future.

Third, it is difficult to describe the interdependence between individuals and social relationships. When a disaster victim considers shifting to a temporary housing at a distant location, the social trends (such as neighborhood trend, relative's move, and media reports) highly affect the victims' choice. The constructed microsimulation is not sufficient with respect to the expression of interdependence between individuals and social relationships.

Next, I would like to describe the consideration to the problem mentioned before. In order to solve the target limitation problem, in March 2009, we conducted a new questionnaire survey to collect preference data on housing reconstruction. An anticipated disaster is a phenomenon of the future, and it is difficult to collect actual behavioral data. Although the Kobe Earthquake (1995) is a preceding example, the local characteristics and the scale of damage differ in Kobe and Tokyo; thus, there is no guarantee that the housing situation also remains the same. Although actual data has restrictions and the necessity to use stated preference data is significant, it is difficult to verify the reliability of the data. This can be considered as the problem of uncertainty arising from the modeling of people's consciousness. To solve this problem, it is necessary to implement the following: (1) prepare a questionnaire which is not facilitate, (2) indicate the uncertainty of simulation results such as the confidence interval, and (3) use simulation results as background information, and not directly for policy design.

With respect to the housing reconstruction problem, it is believed that social trends influence individual choice. Thus, many social trend variables (such as the possibility of donation from a relative, the possibility of living with a relative, and the migration rate in the present residential area) were treated in the newly conducted investigation. The victim's behavior model incorporating interdependence will be developed in the new investigation; however, it might be restrictive. Therefore, it is necessary to consider how to complement the inductive approach such as understanding by means of investigation. There exists a deductive approach to express interdependence by exploring the definition of relationships from reproducing a result. For example, some research techniques (multi-agent systems, artificial neural networks, etc.) have already been indicated as approaches (Nigel Gilbert & Klaus G. Troitzsch 2005). However, if the purpose of simulation is to anticipate a situation, there is also a limitation to the deductive approach. This is because verification is difficult owing to the lack of correct answers. It is possible that a combination of both the approaches is the one of the drawbacks of the abovementioned fundamental problem. With respect to research on the realistic issues of society in the future, the reliability of simulation results is required, and the consideration of this problem is our next difficult step.

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