Behavior analysis of the people having difficulty in going home in Tokyo metropolitan area -the 2011 off the Pacific coast of Tohoku Earthquake-

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SUMMARY
Right after the 2011 off the Pacific coast of Tohoku Earthquake, railway system in Tokyo metropolitan area completely shut down so that a large number of people had difficulty in moving. However, it was observed after the earthquake that many people tried to return their home on foot even though the trip distance was quite long. Thereafter, in this study, we have conducted a web-based questionnaire survey to collect the data regarding the behaviour of the people who experienced inconvenience on returning home. We have developed two kinds of models. One model can explain the choice behaviour whether affected people stayed in damaged area or not. The other model can explain the result of the attempt to return home. As the results of this study, the dominant factors of people's choice and the reasons of success/failure in returning home are identified.

Keywords: Earthquake, Shutdown of transport system, difficulties returning home, discrete choice model,

1. BACKGROUND AND RESEARCH OBJECTIVE

Massive destruction was brought to the north-eastern region of Japan when the 2011 off the Pacific coast of Tohoku Earthquake occurred at 14:46 (JST) on March 11th, 2011. In Tokyo metropolitan area where maximum of 5-upper seismic intensity (JMA) was recorded, the earthquake suspended the transport system such as bus and train services. As the result, many people tried to return home on foot. However not all were successful and many of them ended up going to emergency shelters put into place or waited the recovery of public transportation for a long time.

According to the 10th census on transportation in Tokyo metropolitan area, approximately 9,500,000 commuters use public transportation system per day and the average travel time was 68 minutes long. It is evident that once the public transportation system fails, a great number of people will face difficulty in returning home.

Nakabayashi (1992) researched the relation between the distance to home and the success rate of returning home. He mentioned that all the people could return their home if the distance is less than 10km and the rate decreases by 10% per additional kilometer. Furthermore, people face difficulty in returning home if the distance is more than 20km. However, on March 11th, 2011, there were those who could not return home even though the distance was less than 10km and those who succeeded in returning home even though the distance was more than 20km. Shimohara et al. (2010) and Osaragi (2008) examined disaster prevention plans by estimating a behaviour model of the commuters in case of devastating earthquake. However, these studies may not fully reflect the actual behaviors as mentioned above.

Transportation system will be completely shut down if the Tokyo Metropolitan Inland Earthquake

with magnitude-7 level occurs. Tokyo Metropolitan Government has worked on establishing new ordinance which asks companies to stock emergency supply in the office buildings. This countermeasure would contribute to keep employees staying in the building until the transportation system recovers.

In order to study the effective disaster prevention countermeasures regarding the evacuation of affected people after the great earthquake, we analyzed the behaviors of the affected commuters by the 2011 off the Pacific coast of Tohoku Earthquake on March 11th, 2011.

Hiroi (2011) conducts similar study and estimated choice behaviour model of the affected commuters with using questionnaire survey data. However it is not verify whether they succeeded in returning their home.

In this study, we have analyzed the behavioural characteristics of the affected commuters using a web-based questionnaire survey. The respondents of the survey were the affected commuters who faced difficulty in returning home. We have developed two kinds of models. One demonstrates the choice behaviour whether they stayed in damaged area or not and the other demonstrates the results whether the attempt to return home succeeded of not. The estimated models demonstrate the dominant factors of the people's choice to stay/return home as well as the several causes which influence the result of the attempt to return home.

2. DATA

A web-based questionnaire survey was conducted in this study to collect the data regarding the behaviors of the people who experienced inconvenience in moving on the day of the earthquake. The number of samples collected was sufficient enough to analyze the characteristics of the affected commuters.

Summary of the survey is described in Table 2.1. Pre-survey for screening the monitors was conducted during 7-13 April, 2011. Three questions as follows were prepared to screen the appropriate monitors: frequency of daily use of train services, behaviors taken on March 11th, 2011, and location for stay on March 11th, 2011. Out of 850,000 total monitors, 32,683 were selected as appropriate monitors. Afterwards, the main survey was conducted during 13-18 April, 2011 and 5,052 respondents were answered.

As shown in Figure 2.1, 62.7% of those who attempted to return home accomplished its purpose, however many of them had some kind of difficulties. Furthermore, 20.5% of the people gave up going a home.

The place where the affected people wanted to stay on the day of the earthquake was examined. As shown in Table 2.2, 64.4% of the affected people stayed in their own home, 25.0% stayed in a work place, 4.6% stayed in a home of parents/friends, 1.8% stayed in a hotel, and 1.6% stay in a building. Only 1.3% utilized the emergency evacuation space.

As the results of the screening survey, it founds that a small percentage of the affected people stayed in a home of friend, some kinds of building, and an emergency evacuation center. Then, we applied stratification sampling based on the last stay place as sampling method in order to examine the difference, which was caused by the last stay place, in the characteristics of the behavior and the individual attributes.

Meanwhile, the respondents of the survey were limited to the people are as follows:

- People living in Tokyo, Chiba, Saitama or Kanagawa prefecture

- People using railway service more than once a week
- People having inconvenience for moving on the day of the earthquake

The sampling results are shown in table 2.2. Scaling coefficient for each segment was calculated by the location of stay in order to satisfy the share of last stay place. Scaling coefficients are mentioned in most right column.

The data used for analysis were of those people who stayed within Tokyo or other three prefectures mentioned above. Distance in a straight line between starting point and home was measured. In case the detailed information regarding the address of starting point/ home was unknown, the address of the nearest railway station was used for the calculation of distance between starting point and home.

Table 2.1. Summary of survey

investigation day		pre survey : 7 - 13 April, 2011 main survey : 13 - 18 April, 2011
investigation method		web-based questionnaire survey
question items	behavior	-place where I was when the earthquake occurred -place where I stay on the day -movement path
	consciousness	-place for the stay -difficulties/problems
	personal attribute	-sex, gender, place of residence, occupation, having marriage or not, having children or not
number of samples		pre survey : 32,683 main survey : 5,052

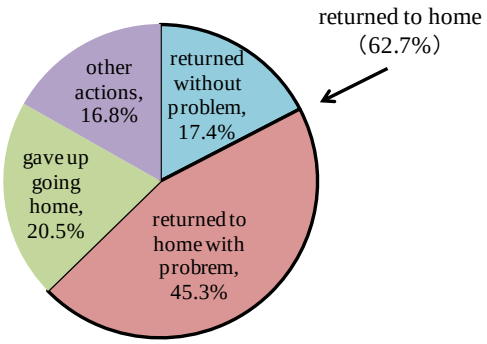

Figure 2.1. Behaviors of the affected people (N=60,000)

Table 2.2. Results of sampling

Place to stay	the number of random sampling (N)	share	the number of sample stratification (S)	Stratification extraction rate (S/N)	Scale coefficient (N/S)
Own home	21,049	64.4%	1,246	5.9%	16.9
Work place	8,158	25.0%	1,320	16.2%	6.2
Home of parents/ friends	1,511	4.6%	1,117	73.9%	1.4
Hotel	592	1.8%	406	68.6%	1.5
Emergency evacuation space	435	1.3%	358	82.3%	1.2
Eating house, store	412	1.3%	302	73.3%	1.4
Building	526	1.6%	303	57.6%	1.7
Total	32,683	100%	5,052		

3. BEHAVIOR OF THE AFFECTED PEOPLE

3.1. Basic analysis

Figure 3.1 shows the share of behavior after the earthquake. 29.5% of the people did not move at the time, while 70.5% of the people tried to move. Figure 3.2 shows the amount of time spent for returning home. Most people spend about 2-3 hours and about 30% of the people spent more than 5 hours. Figure 3.3 shows the relation between the linear distance to home and desired location of stay. The result indicated that less people wished to return home as the distance to home increased and more people wished to remain where they were. It also shows that 27% of the affected people wished to return home even though their homes were far more than 40km.

3.2. Estimation of stay choice model

To the reason why people stayed/moved after the earthquake would contribute to examine the countermeasure preparing for coming large scale earthquake. In this study, we built logit model with two alternatives such as “stayed within the damaged area” and “attempted to return home”. Based on the results, the following variables are used as the explanatory variables of the model, “personal attributes such as the gender and generation”, “linear distance to a home”, and “difficulties one faced while returning home”. Weighted Exogenous Sampling Maximum Likelihood (WESML) was applied to estimate the parameter because the data were collected through the stratification sampling.

Table-3.1 shows the results of parameter estimation. The likelihood ratio and hit ratio were 0.157 and 70.4% respectively. This model can explain the reasons why people stayed or not. If the sign of the estimators are positive, it indicates that the probability to stay will increase as the correspondent variable increases. The statistical significance of each parameter is examined by t-value as shown in the most right column of the table. The t-value indicates the level of statistical significance. If the t-value exceeds 1.96 in absolute value, the estimated parameter is statistically significant with 95% confidence interval.

Subsequently, the influence of each variable on the choice behaviour is examined. Sing of the parameter of “distance to home” is positive so that the probability to stay becomes higher as the distance to home becomes longer.

The inconvenience that was faced when the people attempted to return home is examined. The sign of parameter of “Availability of the information about the means of transit” is positive so that the probability to stay becomes higher when people faces difficulty in obtaining traffic information.

Figure 3.4 shows the estimated parameter of “Availability of communication with others”. Different colour indicates same attributes regarding the gender and with/without children. Moreover, the horizontal axis indicates the age of the sample. The sign of almost parameter is negative so that the probability to stay becomes higher when people faces difficulty in communicating with others. Especially, Since the estimated parameters of female having children are large negative value, female having children is most affected by the unavailability of communication with others. Meanwhile, there is a large difference between male and female even though the other attributes are same. These facts indicate that a disaster prevention plan should consider the individual attributes.

Figure 3.5 shows the result of sensitive analysis regarding the distance to a home. It shows the change of the probability to stay in damaged area in accordance with the distance. Male having children has a tendency to stay in damaged area, and female having children does not prefer to stay in damaged area.

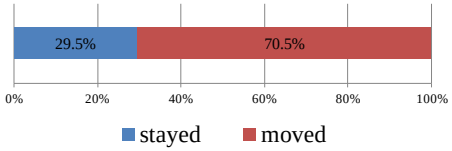

Figure 3.1. Share of behaviors (stayed/ moved)

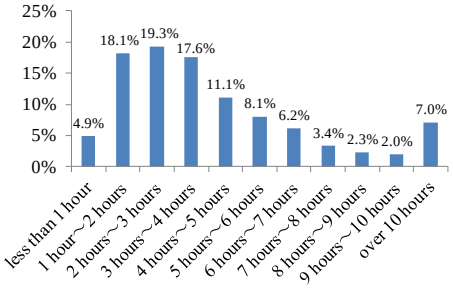

Figure 3.2. Rrequired time for returning home

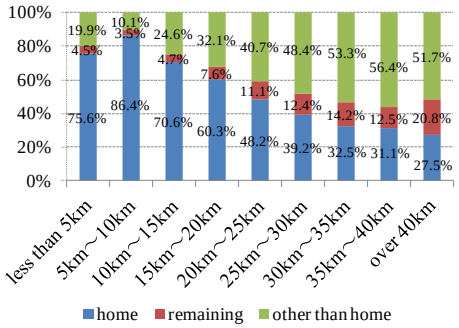

Figure 3.3. Relation between the linear distance to home and desired location of stay

Table 3.1. Estimation result of stay choice model

Variable		Parameter	t-value
Distance to home (natural logarithm) [km]		0.463	12.72
Availability of the information about the means of transit (available: 0, unavailable: 1)		0.191	2.78
Availability of communication with others (available: 0, unavailable: 1)	male not having children and less than thirties	-0.342	-3.00
	male not having children and forties	-0.431	-3.08
	male not having children and over fifties	-0.182	-0.72
	female not having children and less than thirties	-0.208	-2.02
	female not having children and forties	-0.241	-1.31
	female not having children and over fifties	0.173	0.46
	male having children and less than thirties	-0.218	-1.55
	male having children and forties	-0.078	-0.68
	male having children and over fifties	0.102	0.79
	female having children and less than thirties	-0.280	-0.89
	female having children and forties	-0.629	-2.06
	female having children and over fifties	-0.578	-1.47
Constant term		-1.979	-17.06
ρ^2 value		0.157	
hitting ratio		70.4%	

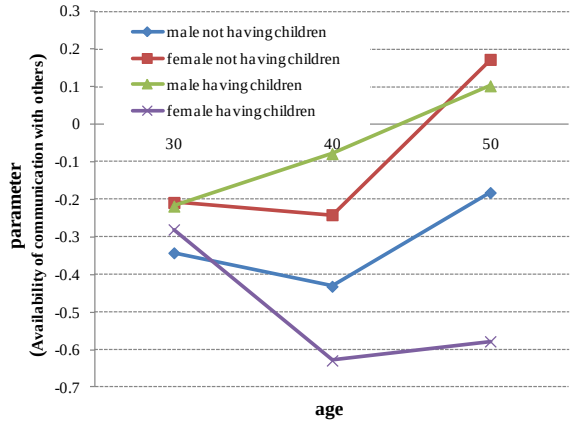

Figure 3.4. Comparison of the parameter regarding age

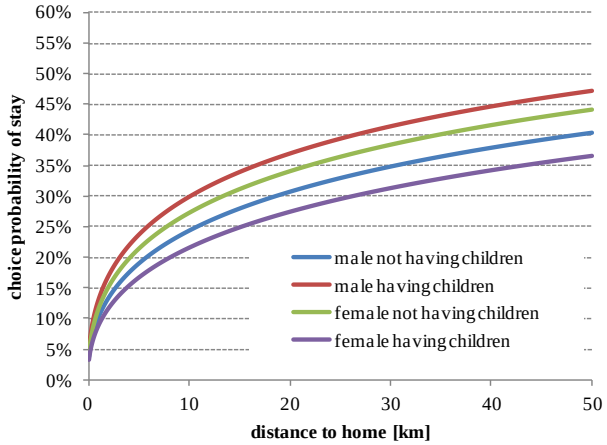

Figure 3.5. Relation between distance to home and choice probability for forties

4. RESULT OF THE ATTEMPT TO RETURN HOME

4.1. Characteristics of the result

In this section, the result of the attempt to return home is examined. Figure 4.1 shows the success/failure rate of the attempt by walking. In either case, as the distance increases, the success rate decreases. Moreover, as a whole success rate of those who tried to return home on foot is low.
In the previous studies as mentioned, it was assumed that all the people will be able to return their home if the distance is less than 10km and that people will not be able to return home if the distance exceed 20km. However, as seen in figure 4.1, it is demonstrated that many people succeeded in returning home even though the distance exceed 20km.

Figure 4.2 shows the success rate by gender. It shows that the success rate of male is higher than that of female and that the difference by gender expands according to increase of the distance to home. Meanwhile, figure 4.3 shows the success rate by the generations. The success rate of twenties is lower than those of other segments since young generation has more alternatives to stay such as friend's houses and commercial facilities (bar, comic cafe, etc.). This fact forced young generation to halt the attempt to return home. Furthermore, figure 4.4 shows the success rate by family structure such as with/without children. The success rate of the people having children is relatively higher than that of the people not having children and that the high success rate with children was maintained even though the distance to home is longer than 20km. It is certain that many people could not contact with family members due to the failure of telecommunication system. It is thought that this fact evoked the

feelings of the people having children to have to return home. From the result, it is necessary to construct an effective method of safety confirmation of family members from the perspective of ensuring safety of affected people.

Successively, relation between the condition at the time and the success rate are examined. Figure 4.5 shows the relation between the success rate and the availability of the information about places to stay. The success rate of the people without information was lower than that of the people with information. Especially there is a large difference in the success rate for the people whose home was far more than 15km. When the distance to home was far more than 25km and the information was not available, people failed to return to a home. Meanwhile, figure 4.6 shows the relation between the success rate and the availability of routing information. As shown in the figure, the availability of routing information obviously contributed to increase the success rate.

As the result of analysis regarding the success rate of the attempt to return home, several factors related to the rate are identified. These factors are used as explanatory variables of success/failure model which is built in the following section.

4.2. Estimation of success/failure model

It is worthwhile to clarify the factors of success in returning home in order to examine effective countermeasures to ensure the safety of the people. Based on the results of the analysis in former section, individual attributes such as gender, the generation and family structure are utilized to explain the result of attempt to return home. To verify the difference in influence of these attributes on the result, the dummy variables were prepared for each segment divided by these attributes. Moreover, linear distance to home and inconvenient matters on returning home are also adopted as the explanatory variables of the model.

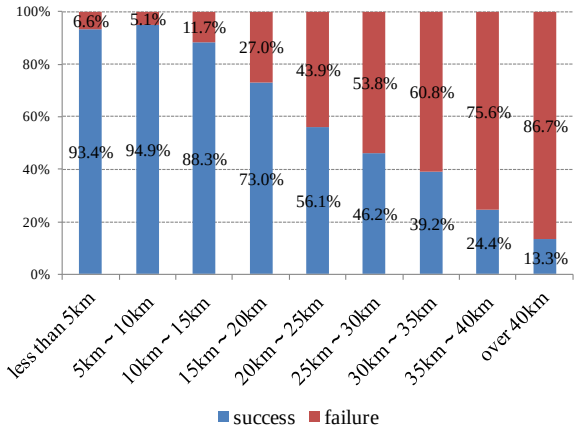

Figure 4.1. Success/failure rate of returning home by walking distance

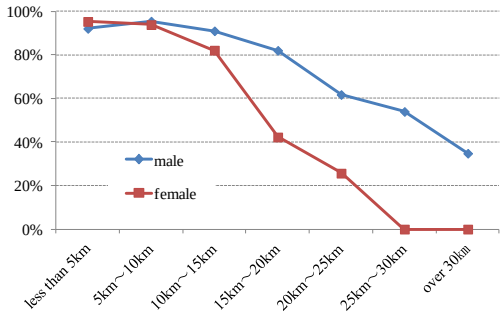

Figure 4.2. Success rate of returning home by gender

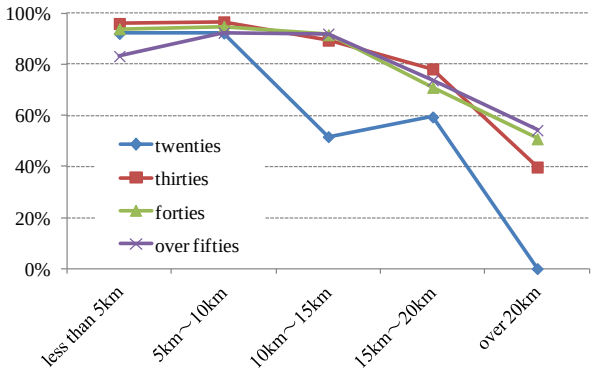

Figure 4.3. Success rate of returning home by the generation

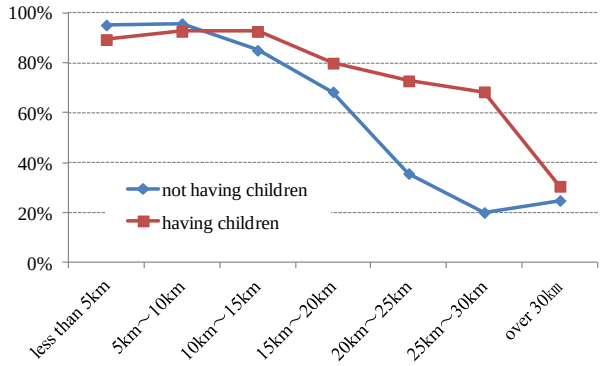

Figure 4.4. Success rate of returning home by family structure

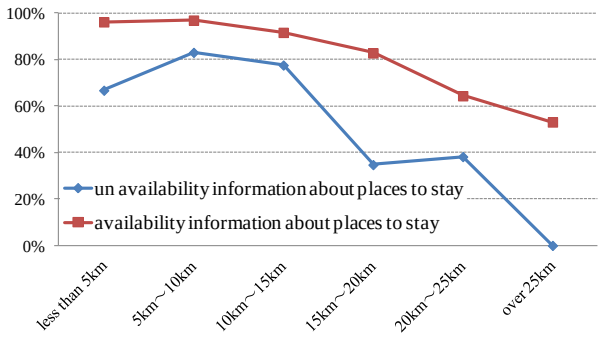

Figure 4.5. Success rate of returning home by available information about place to stay

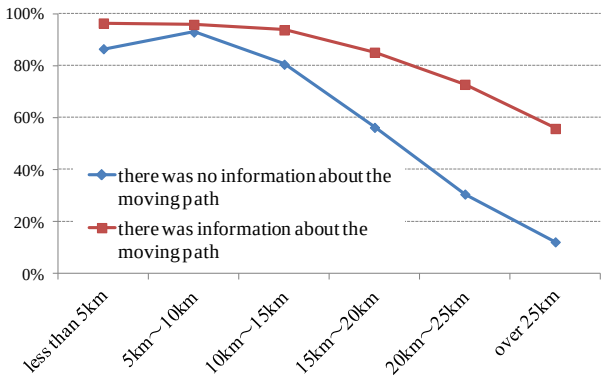

Figure 4.6. Success rate of returning home by available information about moving path to home

Table 4.1. Estimation result of success/failure model

Variable		Parameter	t-value
Availability of the information about the place to stay (available: 1, unavailable: 0)		-1.468	-6.14
Availability of the information about moving path (available: 1, unavailable: 0)		0.760	3.38
Distance to a home (natural logarithm) [km]		-1.246	-8.14
Availability of safety confirmation of family member (available: 1, unavailable: 0)	male not having children and less than thirties	-0.079	-0.24
	male not having children and forties	-0.352	-0.75
	male not having children and over fifties	-1.912	-2.06
	female not having children and less than thirties	-0.862	-2.76
	female not having children and forties	0.193	0.36
	female not having children and over fifties	-2.286	-2.17
	male having children and less than thirties	0.111	0.26
	male having children and forties	-0.513	-1.42
	male having children , over fifties	-0.043	-0.10
	female having children and less than thirties	-0.149	-0.17
	female having children and forties	-0.692	-0.71
	female having children and over fifties	0.025	0.02
constant term		5.549	12.19
ρ^2 value		0.492	
hitting ratio		85.8%	

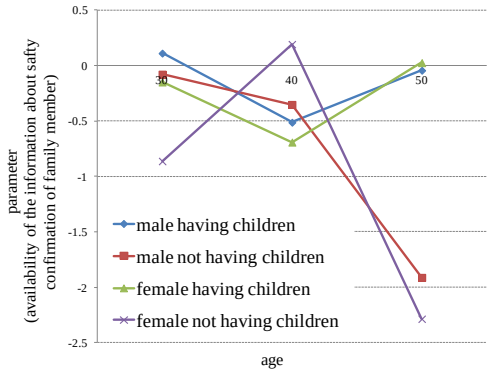

Figure 4.7. Comparison of estimated parameters for each age

Table 4.1 shows the result of parameter estimation. The likelihood ratio and hitting ratio are 0.492 and 85.8% respectively. The t-value in the most right column indicates level of statistical significance. If the t-value exceeds 1.96 in absolute value, the estimated parameter is statistically significant with 95% confidence interval. Meanwhile, the value of estimated parameter expresses the scale of influence on success/failure of the attempt to return home. Plus/minus sign of each parameter indicates positive/negative impact on the success of returning home. Therefore, it becomes clear that increase in the distance makes the success rate lower. Also, having children makes the success rate higher. Moreover, unavailability of the information about the places to stay and the route make the success rate decrease.

Figure 4.7 shows the difference of the value of estimated parameter regarding the availability of safety confirmation of the family member. Horizontal axis indicates the segment regarding the age of affected people. It shows that the parameter is influenced by the gender and the age. The negative large value concerning the people not having children and being over 50s indicates that the people in this segment has tendency to give up returning home.

5. CONCLUSION AND FUTURE PROSPECTS

This study investigates the behaviour of the people having difficulties in going home after the 2011 off the Pacific coast of Tohoku Earthquake occurred.

As the result of this study, it becomes clear that approximately 70% of the affected people attempted to move and approximately 92% of those who attempted to return home managed to do it.

Meanwhile, we have developed two kinds of choice models. One is the stay choice model which can explain whether affected people stayed in damaged area or not. The other model is success/failure model which can explain the result of the attempt to return home.

Stay choice model can extract the dominant factors of people's choice. As previously described, people has a willingness to move when "the distance to a home is short", "the safety confirmation of family member is not available", and "the information about moving path is not available".

Meanwhile, success/failure model can also extract the dominant factors which influenced the result of the attempt to return home. As previously described, success rate of returning home become increase when "the distance to home is close", "people have children", "availability of the information about the place to stay", and "unavailability of the information about moving path".

We clarified that many affected people had attempted to move and many of them succeeded in doing it. However, it is estimated that Tokyo Metropolitan Inland Earthquake would bring more severe condition such as shut down of transportation services, massive fire, building collapse, road congestions and so on.

Thus, in order to be prepared for the coming large scale earthquake in Tokyo metropolitan area, it is necessary to prepare an effective countermeasure such as storing of necessary items and securing of safe places to stay, announcing the employees to remain until the transit system recovers, and establishing a procedure of safety confirmation of family members and friends.

On the other hand, it is desirable to prepare safe environment to return home for those who attempt to return home. In order to accomplish it, development of a method of safe evacuation is required, considering the disaster level, distance to a home, and personal attributes.

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