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Study of quantitative evaluation methods and measures of stranded commuters at the time of large-scale disasters

Harumi YASHIRO[(1)] and Akihiro TSUKAMOTO[(2)]

[(1)] *Professor, Department of Civil and Environmental Engineering School of Engineering, National Defence Academy, hyashiro@nda.ac.jp*

[(2)] *Graduate student, Graduate school of Science and Engineering, National Defence Academy, em54008@nda.ac.jp*

In the Tokyo metropolitan area to a wide variety of capital function is concentrated, are many of the stranded commuters are expected to occur at the time of the capital directly under earthquake.This study reveals by simulation the distribution of each elapsed time of the number of people intended for the people to go home on foot from Tokyo the five central wards of Tokyo to Kanagawa Prefecture direction. Then, in the return home support object along the road, influence and a large amount of walk return home's due to building collapse, fire spread makes a discussion about the challenges that are considered to be caused.

Key Words : Capital Directly Under Earthquake, Stranded Commuters, GIS, Toilet shortage number

1. Introduction

By the Tohoku Pacific Ocean Earthquake that occurred on March 11, 2011, a number of stranded commuters has occurred in the Tokyo metropolitan area. In the metropolitan area a wide variety of capital function is concentrated, a large number of people every day, supported by large-scale transportation system for the railway as a representative has repeated the move. In other words, as soon as people who rely heavily on rail transport is moving means has been disrupted by the earthquake disaster, etc., it will return home forced the situation by walking.

This study reveals by simulation move distribution status of each elapsed time of coming home person and stranded commuters due to the concentration to walk from Tokyo the five central wards of Tokyo to Kanagawa Prefecture side of the daytime population. Then, in the return home support object along the road, buildings affected by the collapse, fire spread and a large amount of walk return home who has performed the analysis and discussion about the challenges caused.

2. Definition of stranded commuters

In the present study, the difficulty returning home and others were defined as shown in Fig. 1.

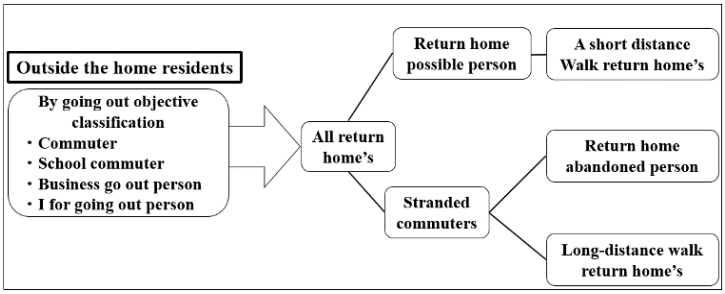

Fig. 1 – Outside the home stay's classification of

A home outside the residents from going out objective classification and all go home who, returning home can have a short-distance walk returning home who was stranded commuters include a long-distance walk returning home person and return home abandoned person.

3. Such direction by returning home's

Returning home have found, FY 2010 census [1], was calculated using the person trip survey results [2].Table 1 shows the return home's number, etc. to pass through the return home route from 5 central wards of Tokyo to Kanagawa direction for each direction. This was to pass through the center of the direction by the return home support target road.

Further, as a method of calculating the number of stranded commuters, until the calculation method A "return home distance 10km, which is used in the damage estimation is 100% return home possible person, since 10km is returning home can rate each time returning home distance increases 1km 10 % by reduction, all of the people and people having difficulty returning home in the 20km ", calculation method B" return home difficult rate (%) = organized method for calculating the two ways that (0.0218 × go out distance (km)) × 100) [3] did.

Table 1 – Return home's such as the number passing through each return home route

Classification / Return home route	All return Home's	Calculation method A		Calculation method B	
		Stranded commuters	Return home Possible person	Stranded commuters	Return home Possible person
Route 1 (Yokohama , Kawasaki station direction)	208000	200000	8000	154000	50000
Route 15 (Yokohama , Kawasaki ,Yokosuka station direction)	457000	257000	200000	185000	270000
Meguro street (Meguro , Todoroki station direction)	75000	0	75000	10000	65000
Nakahara Kaido (Musashi Nakahara , Sakuragaoka station direction)	107000	80000	27000	53000	54000
Route 246 (Futakotamagawa , Yamato station direction)	300000	175000	125000	100000	200000
Setagaya street (Komae , Machida station direction)	400000	183000	217000	180000	220000

All go home who are expected to pass along the each return home route, stranded commuters, the number of returning home possible person shown in the 250m mesh. Fig. 2 shows the distance by passing situation of all return home who headed to Kanagawa Prefecture area from 5 central wards of Tokyo. Also showed distance-passage number of each stranded commuters and return home allowed person according to the method of calculating the two types in Fig. 3-6.

Along with the large number of stranded commuters to move along the return home support target road, 200,000 people close to the people alone return home possible person has become clear that the move.

Walk returning home's problem at the time of a large-scale disaster is believed to have to consider measures to expand until all of the walk returning home who also including return home possible's not stranded commuters only. Chapter 4 and later, using both the calculation method A and B, returning home who were subjected to analysis and evaluation for all return home possible person, difficult person.

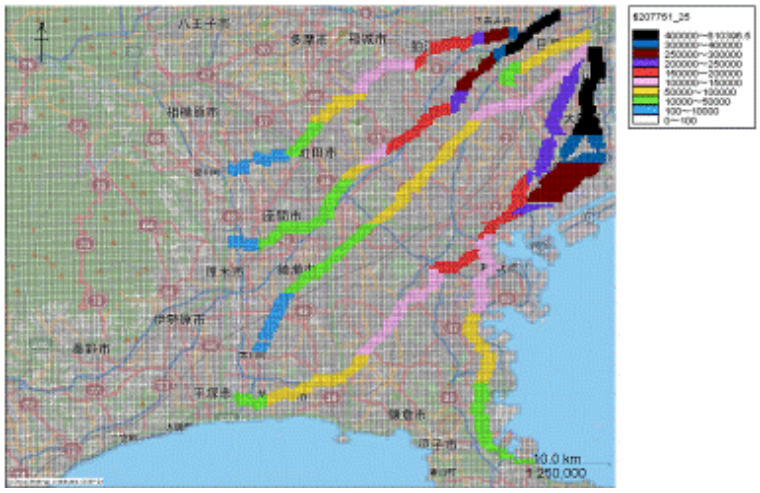

Fig. 2 – Walking-distance another distribution of all return home's

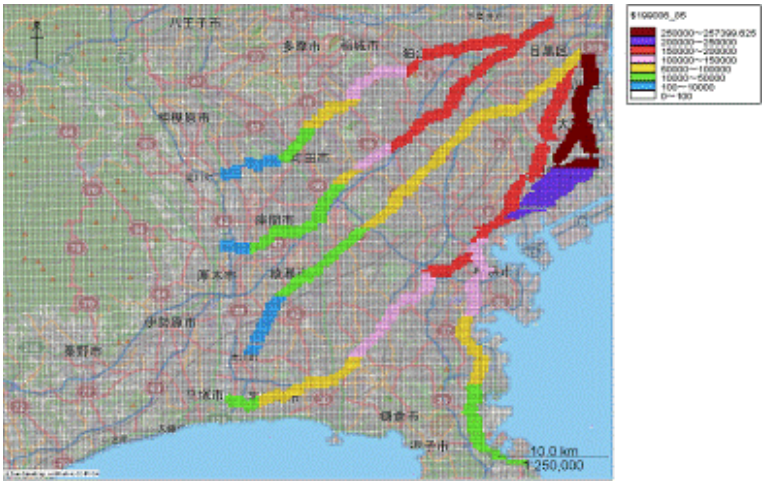

Fig. 3 – Stranded commuters (Method A)

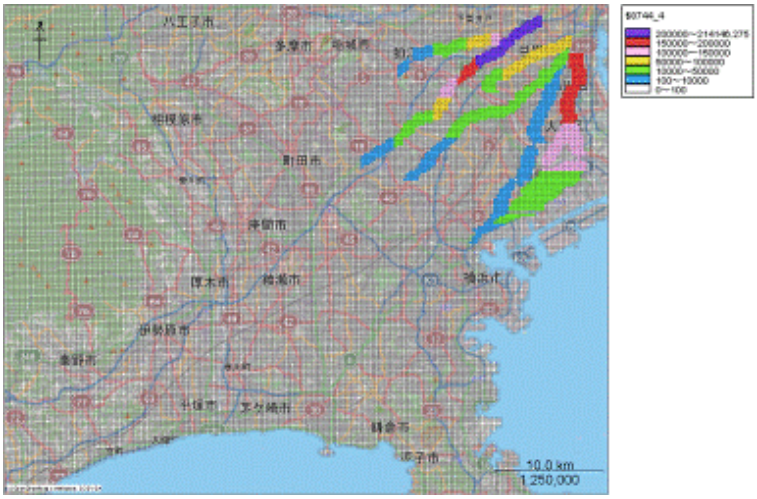

Fig. 4 – Return home possible person (Method A)

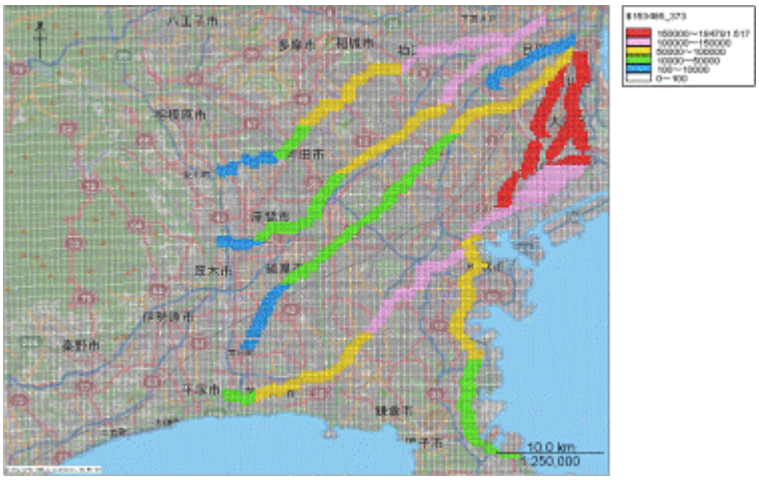

Fig. 5 – Stranded commuters (Method B)

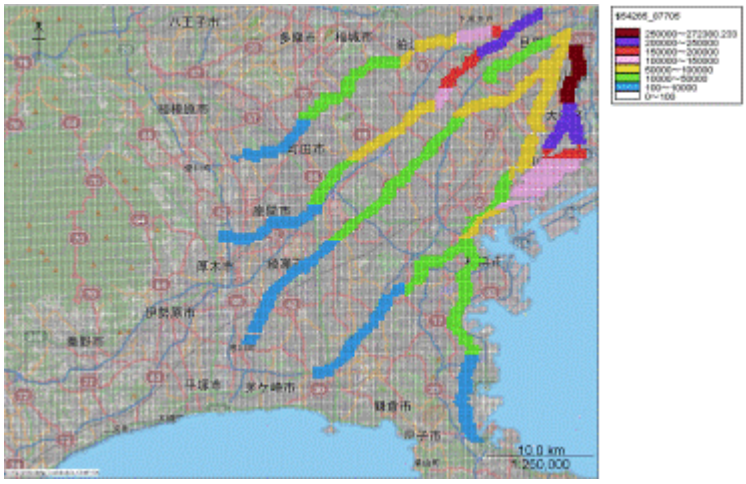

Fig. 6 – Return home possible person (Method B)

4. Distribution of subscribers such as the number of time each series

To evaluate and analyze the distribution of returning home and others due to the time elapsed after the disaster. Target area was in Tokyo in the range of up to the Tama River is about 10km to the Kanagawa Prefecture area from 5 central wards of Tokyo. Returning home user in Fig. 7-8, Fig. 9-10 the method A, Fig. 11-12 shows the distribution of the number of returning home's after 5 and 20 hours of stranded commuters calculated by the method B .

Fig. 7 – Return home's number distribution (5 hours after)

Fig. 8 – Return home's number distribution (20 hours after)

Fig. 9 – Returning home difficult number distribution (5 hours after : Method A)

Fig. 10 – Returning home difficult number distribution (20 hours after : Method A)

Fig. 11 – Returning home difficult number distribution (5 hours after : Method B)

Fig. 12 – Returning home difficult number distribution (20 hours after : Method B)

5. Impact on the walk returning home by the building collapse and fire spread

It showed the building collapse, burned down percentage in along the main return home path of the walk returning home's in Fig. 13. Range of mesh that shows a high percentage building collapse, fire spread in along the route return home is considered to be a difficult passage.

Fig. 14 shows a case where the return home's, percentage collapse, fire spread is assumed to be diverted to Nakahara Kaido from large Route 1 and Meguro street and 30% to 50%.

Fig. 15, showed the before and after the return home's number of distribution to bypass to Nakahara Kaido. From Fig. 13, after the bypass is made to about 400,000 returning home who is about 3.7 times that passes through the Central Plains Road, is considered as a new risk, such as crowd avalanche occurs due to severe congestion.

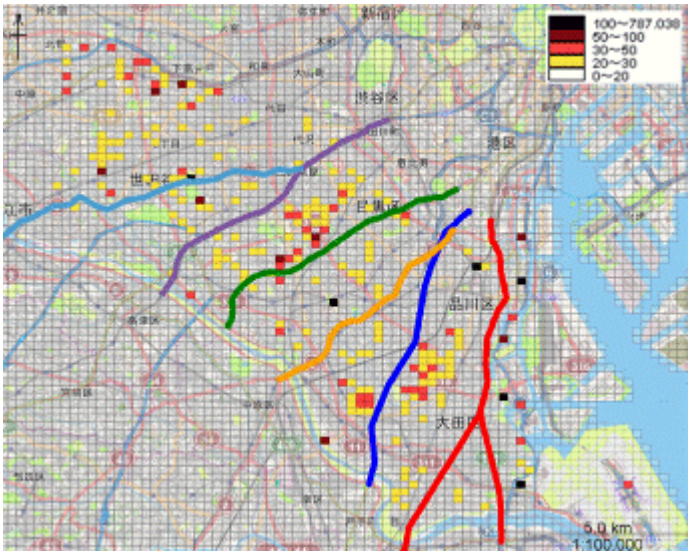

Fig. 13 – Buildings collapsed, burned percentage along the route return home

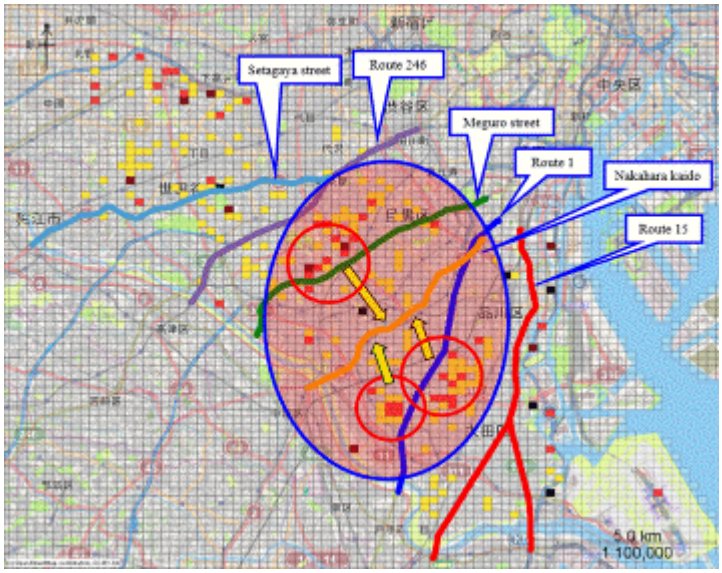

Fig. 14 – Assumed situation to detour to Nakahara Kaido

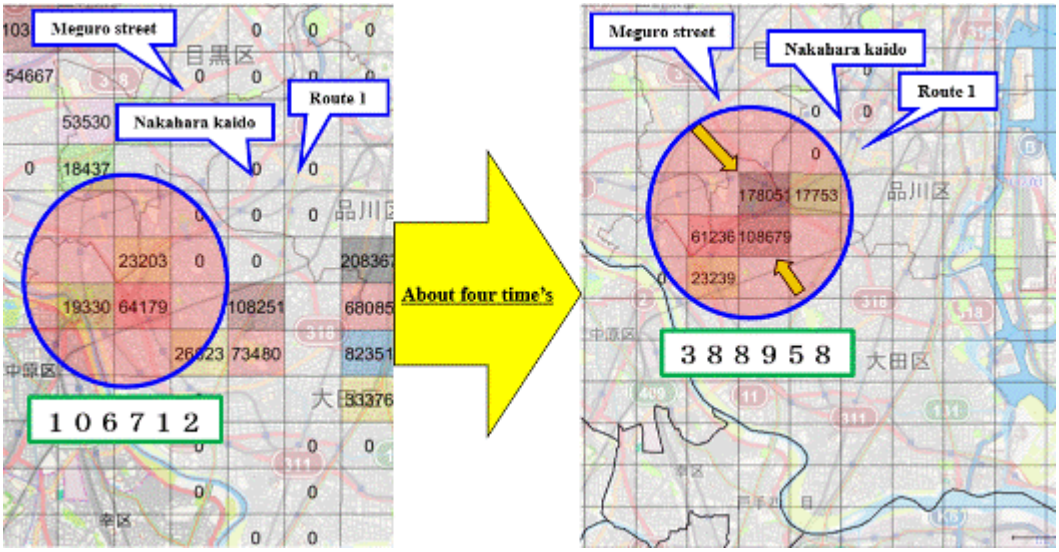

Fig. 15 – Return home toll distribution in the case of detour (after 10 hours)

6. Impact on the bridge passing time by walking return home's

Tokyo walk returning home's from the city center to the Kanagawa Prefecture direction is, after moving along the return home support roads in Tokyo, will pass through eight of the bridges of the Tama River to enter the Kanagawa Prefecture. A large amount of walk return home's from moving concentrate on the eight bridges, serious congestion and retention is a concern. Table 2 for the eight bridges that were included in the analysis, showed the transit time in accordance with the walk returning home's classification think the previous section as well as the passing speed and sidewalk width, the sidewalk number. In the case of all return home person, take up to about 7 hours to up to 24 hours to pass through the bridge. In addition, it was found that the big difference by returning home direction and the number of returning home who may occur.

Table 2 – Pass the number and time of each of the bridges across the Tama River

Classification / Bridge name (Passing persons , Time passing)	All return home's	Calculation method A		Calculation method B	
		Stranded commuters	Return home possible person	Stranded commuters	Return home possible person
Daishi Bridge	111000	101000	9000	6000	48000
	6.9	6.3	0.6	0.4	3.0
Rokugou Bridge	111000	101000	9000	6000	48000
	9.2	8.4	0.8	0.5	4.0
Tama River Bridge	104000	100000	4000	77000	27000
	13.0	12.4	0.5	9.6	3.4
Gas Bridge	104000	100000	4000	77000	27000
	13.0	12.4	0.5	9.6	3.4
Maruko Bridge	107000	80000	26000	53000	54000
	6.7	5.0	1.7	3.3	3.4
Futago Bridge	96000	61000	71000	36000	60000
	24.1	15.2	17.8	9.0	15.0
Shin Futago Bridge	193000	122000	143000	72000	120000
	24.1	15.2	17.8	9.0	15.0
Tama Suidou Bridge	164000	156000	8000	106000	59000
	20.6	19.5	1.0	13.2	7.3

7. Impact of returning home person to evacuees

7.1 Refugee status

The 246 Route that is specified in the return home support target road through the Setagaya Ward, is that the large number of returning home's that about 30 million people pass through is expected by the analysis. The ones that the evacuees were guess mesh shown in Fig. 16. From the relationship between the two of returning home and others with the evacuees using it, to analyze and evaluate the problems and issues.

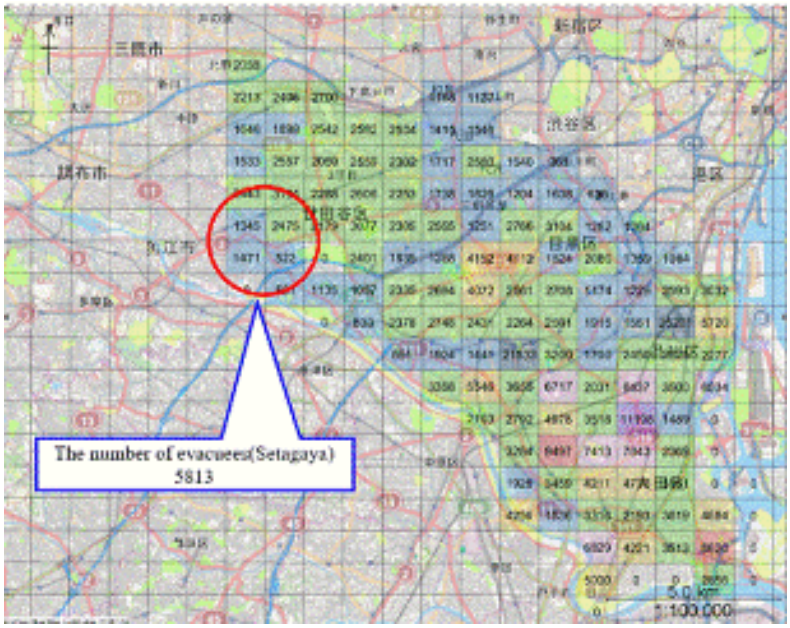

Fig. 16 – Situation of refugees in the target area

In the Setagaya Ward shelter there is 95 place. In addition, stockpiles on the basis of the food number [4], and about 1,700 people acceptable to the one place shelter. Thus, evacuees acceptable capacity of Setagaya Ward is about 16 million people, but about 100,000 near the evacuees occurrence at the time of the capital directly under earthquake is expected, can be accommodated if the number of acceptance of evacuees It is that there is.

The area of ○ mark of Fig. 17 was the analysis region. This area is located shelter is five places, evacuees are expected to occur about 6000 people. And is expected to be about 1,200 evacuees per shelter one place to come, it is believed that the evacuation acceptance is possible. Fig. 17, there is shown a return home's distribution of 10 hours after the disaster, from the fact that such as about 22 million people return home who is on the road, if you stop by the shelter, evacuate stranded commuters, etc. it is considered as the corresponding thing is very difficult in place.

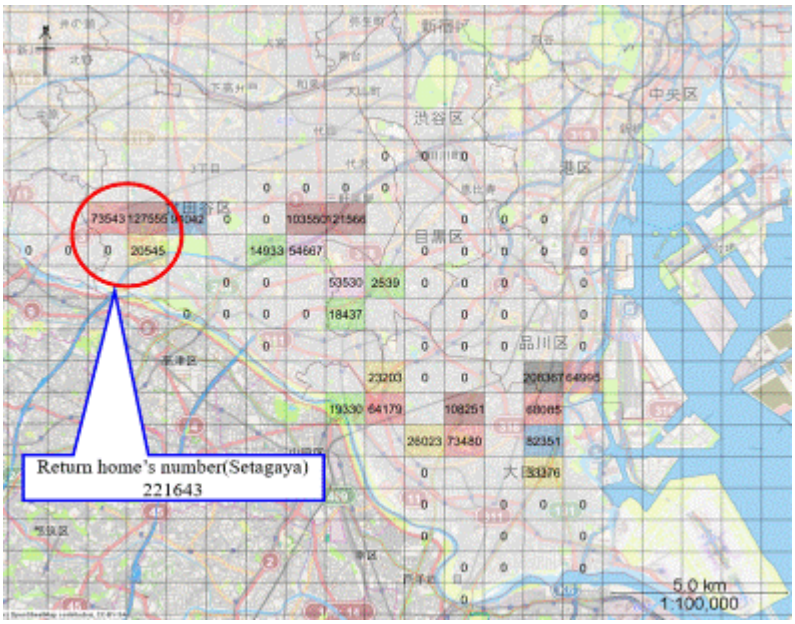

Fig. 17 – Return home's number distribution situation in the target area

7.2 Toilet situation

Unable to return home's toilet can be cited as one of the reasons why the drop in shelter and returning home support station, or the like. A major challenge in coming home route a large number of returning home and others to pass through.

The toilet installation situation in the target area is shown in Fig. 18.

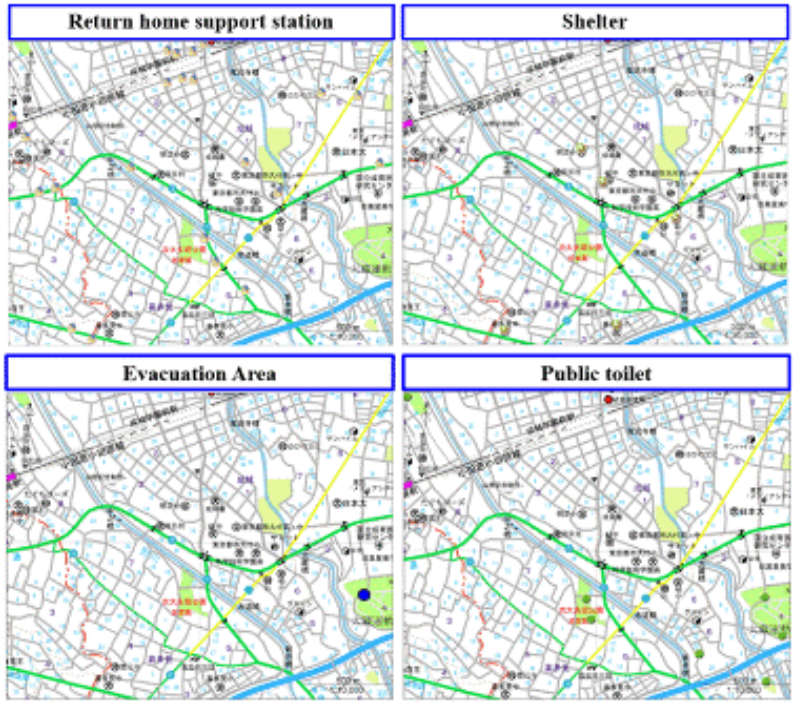

Fig. 18 – Toilet installation situation in the target area

The toilet base per toilet installation facility one place assumed as shown in Table 3, Table 4 shows the toilet sufficiency rate. From Fig. 18 and Table 3, in the target area of 2km square, tray installation number is 33, it was a toilet, including 202 groups of shelter. When considering a return home pattern as a countermeasure of the city returning home who, unable to return home who even sent home (the calculation method A and B) only, fill rate of the toilet is as much as about 23% at the maximum, return home support target road toilet shortage problem faced by the beach is considered to be a serious became clear.

Table 3 – Toilet base of each facility

①Toilet installation number			②Toilet per location	Number of toilet ①×②
Return home support station	Gas station	2	1	2
	Convenience store	18	1	18
	Restaurant	2	4	8
Shelter	Public elementary school	3	42	126
	Public junior high school	2	24	48
Other	Public toilet	5	6	30
	Evacuation Area	1	30	30
Total		33	—	202

Table 4 – Toilet sufficiency rate

Toilet sufficiency rate[5]=Toilet supply number of times/Toilet demand number of times

Classification	Toilet conditions of use of the shelter			Use only return home support station	Water outage rate
	No use	Half of use	All use		
Return home's	4.2%	8.4%	12.5%	4.3%	24.7%
Return home possible person (Calculation method A)	4.5%	8.9%	13.3%	4.6%	
Stranded commuters (Calculation method A)	8.5%	17.0%	25.3%	9.0%	
Return home possible person (Calculation method B)	5.2%	10.4%	15.5%	5.4%	
Stranded commuters (Calculation method B)	7.8%	15.6%	23.2%	8.2%	

The method of calculating the toilet supply

Supply possible number of times per hour of the existing toilet
=30(Time/Number Time)×Temporary(Number)×(1-Water outage rate)

The method of calculating the toilet demand number of times

Toilet count for each after a lapse of time after the disaster at a certain link
=The number of break person at a certain time×1(Time)×5(Time / Man / day) / 24(time / Day)

Toilet demand number of times due to shelter consumers
=The number of evacuees at a certain time×1(Time)×5(Time / Man / day) / 24(time / Day)

7.3 The number of disaster for the toilet needed to the toilet sufficiency rate to 100%

By Table 5, serious toilet shortage in the target areas became apparent. In order to solve the toilet shortage, it was examined the required number of disaster for the toilet that local government is stockpiling.

The toilets needed to the toilet sufficiency rate of 100% is shown in Table 5.

Table 5 – Disaster for the toilet of the need toilets

Need toilet				
Classification	Toilet conditions of use the shelter			Use only return home support station
	No use	Half of use	All use	
Return home's	1358	1292	1227	1317
Return home possible person (Calculation method A)	1052	985	921	1011
Stranded commuters (Calculation method A)	626	560	495	586
Return home possible person (Calculation method B)	1261	1194	1130	1220
Stranded commuters (Calculation method B)	557	491	426	517

The method of calculating the required toilets

* Need toilets=(Toilet demand number of times − Supply number of times by the disaster for toilet − Toilet supply number of times due to existing facilities) / Toilet supply capacity

8. Conclusion

Along with the reveal by simulation the distribution of each elapsed time of the people to go home on foot from Tokyo the five central wards to Kanagawa Prefecture direction, return home support in along the road, the effect of building collapse, fire spread and a large amount of walk return home's due It was extracted issues that are considered to be generated. It is shown below for the results.

By the difference of the current estimate of the number of calculation methods, assuming the number of stranded commuters number it was found to be changed 70,000 people at the maximum.

Showed each bridge transit time of the Tama River is a bottleneck on the return home route. Up to 20 hours or more also there is also a bridge needed to pass. In other words, since there is a large difference in transit time for each bridge is considered to be necessary to take measures according to the surface by and returned home pattern.

Areas where returning home and others to pass through in large quantities, sufficiency rate is significant demand occurs and consisted of decline, to clear the toilet shortage. Furthermore, it was found that currently almost not enough even using the toilet being stockpiled, disaster toilet needed to eliminate the serious toilets shortage are required in large quantities.

9. References

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[5] Cabinet Office (2008.1): For calculations related to toilet supply and demand or the like based on the return home behavioral simulation results