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EMERGENCY EVACUATION OF FUKUSHIMA RESIDENTS LIVING IN THE VICINITY OF NUCLEAR POWER STATION

Tomoaki NISHINO[1], Masaki OUCHI[2], Shin-ich TSUBURAYA[3], Takeyoshi TANAKA[4], and Akihiko HOKUGO[5]

[1] Assistant Professor, Graduate School of Engineering, Kobe University,
Kobe, Japan, tomoaki.1098@dolphin.kobe-u.ac.jp
[2] Graduate Student, Graduate School of International Cooperation Studies, Kobe University
Kobe, Japan, youandi2635@gmail.com
[3] Chief Engineer, Mitsubishi Heavy Industries,
Kobe, Japan, shinichi_tsuburaya@mhi.co.jp
[4] Professor, Disaster Prevention Research Institute, Kyoto University,
Kyoto, Japan, takey@imdr.dpri.kyoto-u.ac.jp
[5] Professor, Research Center for Urban Safety and Security, Kobe University,
Kobe, Japan, hokugo@kobe-u.ac.jp

ABSTRACT: The purpose of this study is to prepare the basic data available on the modeling of full-scale emergency evacuation behavior in nuclear disaster, by clarifying a part of the actual situation in the Fukushima Emergency Event from the following surveys: (1) interview surveys on response of local government offices to full-scale evacuation; and (2) questionnaire surveys on evacuation behavior of residents. In this paper, we described the content of the surveys and analyzed the obtained data in terms of behavior type and required time.

Key Words: full-scale evacuation, disaster response, resident evacuation, Fukushima Hamadori area

INTRODUCTION

Once radioactive materials are released at an abnormal level in the air from a nuclear facility such as nuclear power station, it is essential to make a tremendous number of residents in a broad area around the facility evacuate immediately to the area where radiation exposure hardly cause a problem. In the Fukushima Emergency Event (2011), all of the residents within 20 kilometers from a station were ordered to evacuate out of the target area by the prime minister, so that most of the municipalities in the vicinity of the station were forced to carry out a full-scale evacuation to other municipality, in spite of suffering from the Great East Japan Earthquake until just before.

In such an event, a tremendous number of residents have to rely on automobiles suitable for long-distance travel, so that there is fear that the extension of evacuation time due to traffic jams on evacuation roads may increase the amount of radiation exposure. In order to resolve such a problem, it

is important to make an effective evacuation plan in advance, considering the evacuation time. For such a planning, it is essential to develop a reasonable method which can predict the full-scale emergency evacuation behavior of individual residents in nuclear disaster in time series.

Several attempts have been made in clarifying emergency evacuation behavior in nuclear disaster. As to the JCO accident of Japan (1999), which is the first case that the protection measure was taken in Japan, the contact situation of disaster information and the reaction of residents at that time have been analyzed (Umemoto et al. 2002). However, the accident did not lead to the event that the residents all over the municipality were required to evacuate immediately; i.e. the target area of evacuation order was within a few hundred meters radius from the facility. After that, transportation choice by a resident for long-distance evacuation, such as a few dozen to one hundred kilometers, has been modeled based on the results of the attitude survey (Umemoto 2011). However, it is not still known how long each behavior is required under the issued situation of full-scale evacuation order, such as time required from the issue to the start of evacuation.

So the purpose of this study is to prepare the basic data available on the modeling of full-scale emergency evacuation behavior in nuclear disaster, by clarifying a part of the actual situation in the Fukushima Emergency Event from the following surveys: (1) interview surveys on response of local government offices to full-scale evacuation; and (2) questionnaire surveys on evacuation behavior of residents. In this paper, we described the content of the surveys and analyzed the obtained data in terms of behavior type and required time.

RESPONSE OF LOCAL GOVERNMENT OFFICES TO FULL-SCALE EVACUATION

Fig. 1 shows the destination for refuge of the local government offices which carried out full-scale evacuation, where the data were collected from newspaper reports. In the Fukushima Emergency Event, evacuation orders based on radius from the stations were issued five times from the night of the earthquake (March 11th) to the night after the day (March 12th) by the Prime Minister, according to the escalation of accident situation such as a hydrogen explosion (Nuclear Industrial

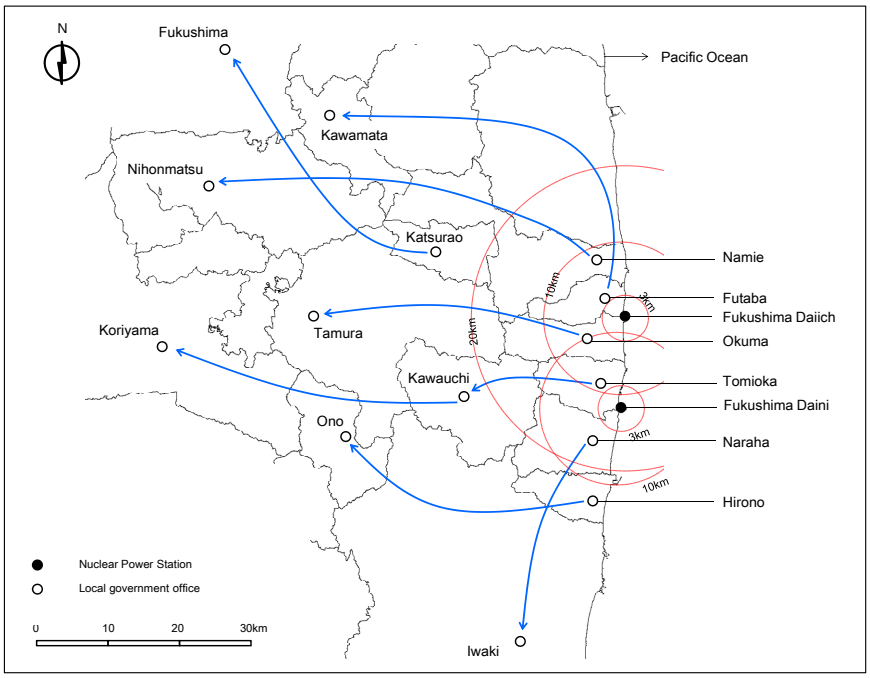


Fig. 1 Destination for refuge of local government offices.

Safety Agency 2011). Even after that, the escalation continued, so that eight municipalities carried out full-scale evacuation by March 16th. The main events of station situations and protection measures by the Prime Minister are outlined as follows: (1) at 7:03 PM on March 11th, the Prime Minister declared an emergency situation; (2) at 9:23 PM on March 11th, the Prime Minister ordered all of the residents within 3 kilometers from Fukushima Daiichi Nuclear Power Station "1F" to evacuate out of the target area; (3) at 5:44 AM on March 12th, the Prime Minister ordered all of the residents within 10 kilometers from 1F to evacuate out of the target area; (4) at 7:45 AM on March 12th, the Prime Minister ordered all of the residents within 3 kilometers from Fukushima Daini Nuclear Power Station "2F" to evacuate out of the target area; (5) at 3:36 PM on March 12th, hydrogen explosion took place at 1F; (6) at 5:36 PM on March 12th, the Prime Minister ordered all of the residents within 10 kilometers from 2F to evacuate out of the target area; (7) at 6:25 PM on March 12th, the Prime Minister ordered all of the residents within 20 kilometers from 1F to evacuate out of the target area; (8) at 11:01 AM on March 14th, hydrogen explosion took place again at 1F; and (9) at 11:00 AM on March 15th, the Prime Minister ordered all of the residents within 20-to-30 kilometers from 1F to stay indoors.

Outline of Interview Results

Generally, the municipalities included within 8-to-10 kilometers from a nuclear power station has been obligated to develop a disaster prevention plan for nuclear disaster (Nuclear Safety Commissions of Japan 2010); i.e. some municipalities owned no plans in the Fukushima Emergency Event. When an office makes residents evacuate to other municipality, the following operations are usually considered in the plan: (1) an office decides to carry out full-scale evacuation depending on the order by the Prime Minister or based on the independent judgment; (2) an office requests the accommodation of residents to other municipality; (3) an office ensures vehicles to transport residents by itself or by receiving support from the Japanese government and prefecture; (4) an office issues evacuation order and informs residents; and (5) an office makes residents gather at several points and transport them to other municipality.

Table 1 shows the content of disaster operations carried out by the local government offices of Okuma town, Tomioka town, Naraha town, Katsurao village, and Kawauchi village, where the data were obtained from interview surveys to the officers. Of these, as to the issue time of full-scale evacuation and the completion time of transportation, the positional relationship with the stations and the target area of evacuation order by the Prime Minister is illustrated in Fig. 2. The origin of an arrow indicates (1) the time when an office issued full-scale evacuation order, and (2) the straight distance of an office from a station. The end of an arrow indicates (1) the time when an office finished transporting residents to other municipality, and (2) the straight distance of destination for refuge of an office. The parenthetic number indicates the number of residents who were housed in shelters established in the municipality of destination for refuge. Okuma town and Tomioka town decided full-scale evacuation because the offices themselves were included in the range of evacuation order by

Table 1 Disaster operations carried out by local government offices.

Municipality	Okuma	Tomioka	Naraha	Katsurao	Kawauchi
Population	11,515	16,001	7,700	1,531	2,820
Households	3,955	6,141	2,576	470	950
Date of the interview	2011, 5/21	2011, 6/4	2012, 1/24	2011, 4/30	2011, 4/30
Ownership of disaster prevention plan	Own	Own	Own	Not own	Not own
Issue time of full-scale evacuation order	3/12 6:00	3/12 7:00	3/12 8:00	3/14 21:00	3/16 9:30
Municipality of destination for refuge	Tamura	Kawauchi	Iwaki	Fukushima	Koriyama
Number of vehicles for transportation	50	8	6	5	8
Vehicle support from Japanese government and prefecture	Supported	Unsupported	Unsupported	Unsupported	Unsupported
Completion time of transportation	3/12 15:00	3/12 17:30	3/12 16:00	3/14 23:00	3.16 23:00
Number of residents housed in shelters of destination	4,000	6,200	5,300	470	600

the Prime Minister. On the other hand, the other municipalities decided full-scale evacuation based on the independent judgment before the offices being including. As a result, any of the offices chose the accommodations more than 20 kilometers away from the stations as the destinations for refuge. It took more than half a day for all of the offices except Katsurao to finish the transportation of residents from when the office issued full-scale evacuation order.

As a result, we could obtain the response types of local government offices as shown in Fig. 3, by assuming the following elements as the determination elements: (A) whether or not an office owns the disaster prevention plan; (B) whether or not an office decides full-scale evacuation based on the independent judgment before the office being included in the target area of evacuation order by the Prime Minister; and (C) whether or not an office receives support of vehicles from the Japanese government and prefecture.

BEHAVIOR SURVEY ON FULL-SCALE EVACUATION OF RESIDENTS AFTER EARTHQUAKE

Before conducting the questionnaire surveys, it is essential to define the evacuation targeted in this study. By the time residents start long-distance evacuation from nuclear disaster, they usually take

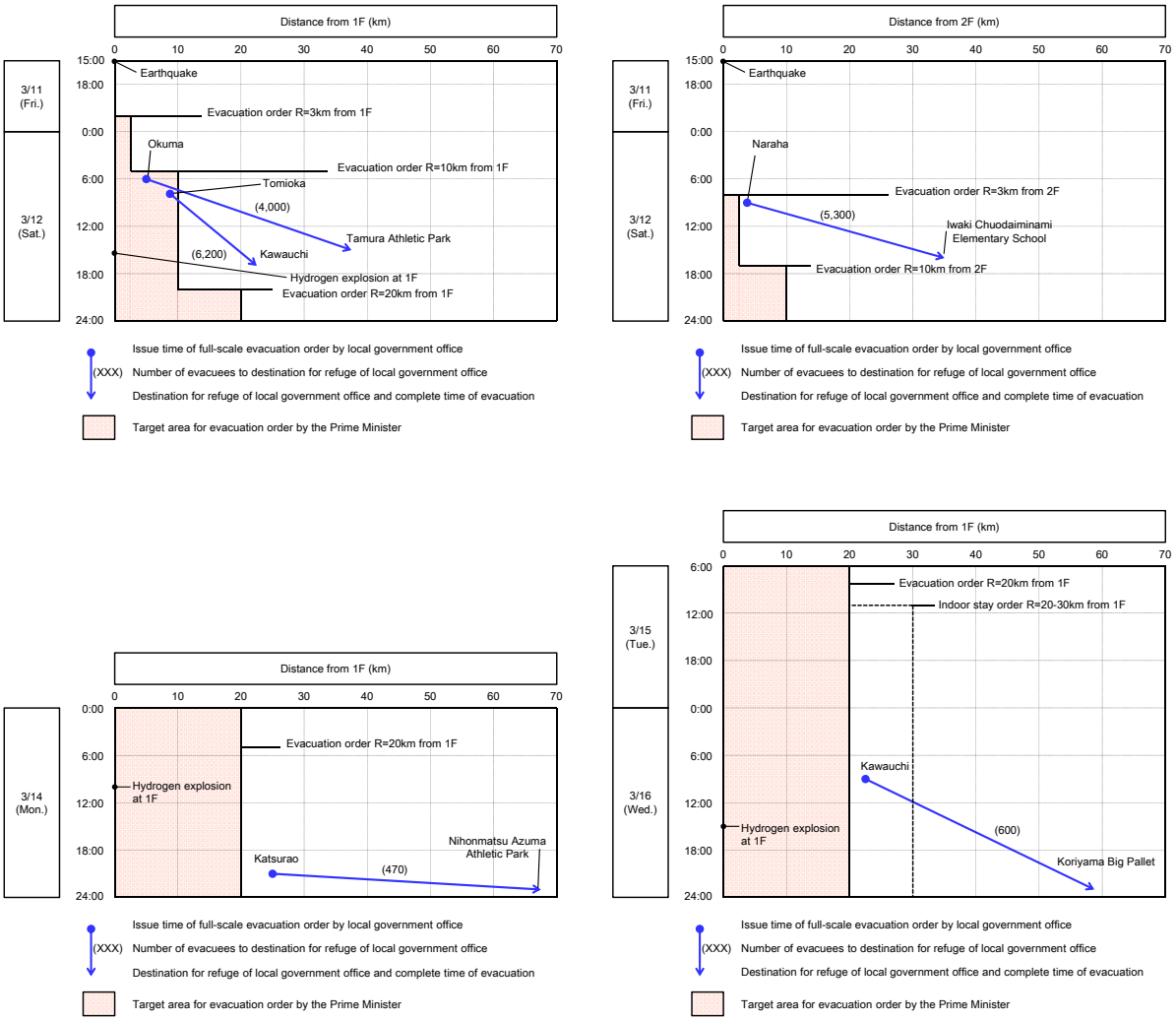


Fig. 2 Issue time of full-scale evacuation and completion time of transportation.

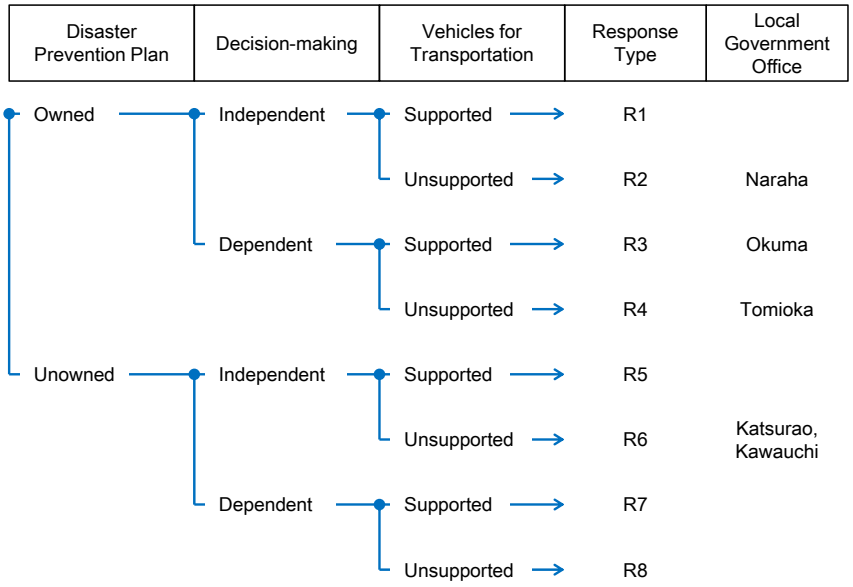


Fig. 3 Response types of local government offices.

action against earthquake and tsunami, such as return home and escaping into local shelter. However, it is difficult to grasp such actions of several phases at once and the analysis is fraught with complications. So in this study, we only addressed the travel toward the other municipality across the boundary of the resident municipality as the evacuation, by ignoring the previous action due to earthquake and tsunami. And we regarded the end of the evacuation as the time when a resident escapes into a safe accommodation of the other municipality for the first time.

Evacuation Types of Residents

In order to design the survey, it is essential to assume the evacuation types of residents targeted for data preparation. In this study, we assumed that the evacuation of a resident is determined by the following elements:

(a) start position of evacuation,
(b) decision-making of evacuation,
(c) transportation for evacuation,
(d) municipality of destination for refuge.

Start position of evacuation

Given the action following earthquake and tsunami, such as return home and escaping into local shelter, most of the residents are likely to start evacuation from home or shelter. So in this study, we classified the start position of evacuation into two kinds of “home” and “shelter”, and did not consider other positions such as employment place and relative’s home.

Decision-making of evacuation

When a resident decides the evacuation, there may be the following two patterns: (A) a resident judges the need for evacuation independently of evacuation order (voluntary); and (B) a resident is forced to evacuate by receiving evacuation order (involuntary). So in this study, we classified the decision-making of evacuation into two kinds of “voluntary” and “involuntary”. In order to judge if a survey respondent meets the voluntary evacuation or the involuntary evacuation, it is essential to define the classification basis. In this study, we classified them by comparing the issue time of evacuation order targeted at the start position with the departure time from the start position; i.e.:

(A) If the departure time is earlier than the issue time, the respondent evacuates “voluntary”,
(B) If the departure time is later than the issue time, the respondent evacuates “involuntary”.

Note that we assumed a resident who starts evacuation from shelter as an involuntary evacuee for simplicity.

Transportation for evacuation

As one of the methods to travel a long distance between municipalities, public transportation such as a railroad is usually used. However, as the public one is often shut down after a major earthquake, evacuees have to rely on private transportation such as a family-owned automobile. On the other hand, as to the residents owning no private one, it is being planned that local government office helps with evacuation by arranging the shared buses. So in this study, we classified the transportation for evacuation into three kinds of “family car”, “other’s car”, and “shared bus”. Note that we assumed that a resident who starts evacuation voluntary before the issue of evacuation order cannot use the shared bus arranged by the local government office.

Municipality of destination for refuge

As local government office makes residents evacuate to other municipality, it is being planned that the office requests the accommodation of the residents to the municipality in advance and gives the residents an instruction on the municipality of destination for refuge. However, all of the residents may not travel according to such an instruction and a part of the residents is likely to evacuate to a municipality different from the requested one. So in this study, we classified the municipality of destination for refuge into two kinds of “requested” and “unrequested”. Note that a resident who uses shared bus for evacuation arrives the requested municipality by the office inevitably. However, we cannot apply such a classification based on the request to a resident who starts evacuation voluntary before the issue of evacuation order.

Time Required for Each Evacuation Type

In order to evaluate the effectiveness of emergency evacuation, it is essential to formulate the time required to complete evacuation from an earthquake, which determines the amount of radiation exposure of an evacuee. So in this study, we regarded the scenario of a resident to complete evacuation as the following two kinds, according to the classification of decision-making of evacuation:

(A) voluntary evacuee,
- (A1) he percepts the abnormal situation of a nuclear facility after the earthquake,
- (A2) he thinks whether or not to evacuate and prepares for evacuation,
- (A3) he travels to other municipality of destination for refuge;

and (B) involuntary evacuee,
- (B1) evacuation order is issued to the position of him,
- (B2) he receives the evacuation order,
- (B3) he thinks whether or not to evacuate and prepares for evacuation,
- (B4) he travels to other municipality of destination for refuge.

Thus the time when a resident completes the evacuation t_E is expressed as follows:

$$t_E = \begin{cases} t_{A1} + t_{A2} + t_{A3} & (t_{A1} + t_{A2} < t_{B1}) \\ t_{B1} + t_{B2} + t_{B3} + t_{B4} & (t_{A1} + t_{A2} \geq t_{B1}) \end{cases} \quad (1)$$

where t_{A1}, t_{A2}, t_{A3}, t_{B1}, t_{B2}, t_{B3}, and t_{B4} are respectively the times required for the process A1, A2, A3, B1, B2, B3, and B4. Note that $t_{A1}+t_{A2}$ or $t_{B1}+t_{B2}+t_{B3}$ correspond to the time when a resident leaves home or shelter.

Outline of Behavior Survey

In this study, we designed the questions of the survey sheet for the main purpose of measuring the following items:

(1) occurrence frequency of evacuation types,

(2) time required for each process of t_{A1}+t_{A2}, t_{B2}, t_{B3}, and t_{B4}.

Note that we regarded the issue time t_{B1} as the earlier time when the prime minister or the local government office issued the evacuation order, and adopted the values described in Table 2. Table 2 shows the main questions of the sheet. As to the questions asking the start position of evacuation and the transportation for evacuation, we set options in advance. As to the question asking the municipality of destination for refuge, we adopted the free description where prefecture, city, and town are set to the response unit. On the other hand, as to the question asking the each time, we also adopted the free description where month, day, hour, and minute are set to the response unit.

The outline of the surveys is shown in Table 3. The surveys consist of the following questionnaire surveys targeted at three municipalities, where a full evacuation of residents to other municipality was ordered: (1) the survey carried out from June 10th, 2011 to June 13th, 2011 at shelters where the

Table 2 Main questions of survey sheet.

No.	Question item	Response format	Related measurement item
Q1	Home address before the earthquake	Free description	Decision-making of evacuation
Q2	Damage situation of home just after the earthquake	Single choice	−
Q3	Departure position for evacuation or deciding position of evacuation	Single choice	Start position of evacuation
Q4	Departure time from the above position	Free description	Decision-making of evacuation, t_{A1}+t_A, t_{B1}+t_{B2}+t_{B3}
Q5	Receiving time of evacuation order	Free description	t_{B1}+t_{B2}
Q6	Receiving source of evacuation order	Single choice	−
Q7	Main transportation using for evacuation	Single choice	Transportation for evacuation
Q8	Main road going through for evacuation	Free description	−
Q9	Municipality escaping into a safe accommodation for the first time	Free description	Municipality of destination for refuge
Q10	Time escaping into a safe accommodation for the first time	Free description	t_{A1}+t_{A2}+t_{A3}, t_{B1}+t_{B2}+t_{B3}+t_{B4}

Table 3 Outline of behavior surveys.

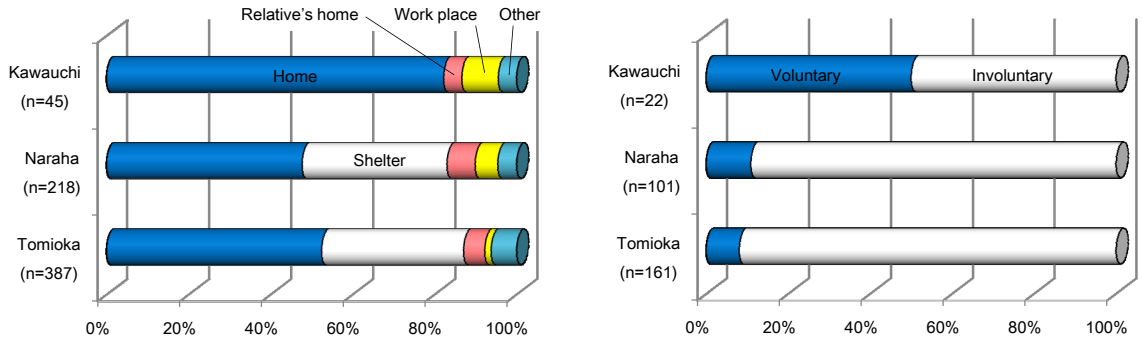
Target municipality		Tomioka			Naraha			Kawauchi		
Population (Household)		16,001 (6,141)			7,700 (2,576)			2,820 (950)		
Survey sheet		Self-administered questionnaire			Self-administered questionnaire			Self-administered questionnaire		
Date of the distribution		June 10th, 2011			September 23th, 2011			July 9th, 2011		
Site of the distribution (Municipality)		Shelters (Koriyama, Miharu, Otama)			Temporary houses (Iwaki, Aizumisato)			Temporary houses (Koriyama)		
Method of the distribution		Entrustment to administrators			Drop into mailboxes			Drop into mailboxes		
Number of the distributed sheets		1,300			712			310		
Condition of the respondents		Over the age of 18			Representative of each occupant			Representative of each occupant		
Date of the collection		June 13th, 2011			October 14th, 2011			July 29th, 2011		
Method of the collection		Entrustment to administrators			Collection by mail			Collection by mail		
Number of the collected sheets		524			233			88		
Collection ratio		40.3%			32.7%			28.4%		
Breakdown (sex, age, address could be all confirmed)		Male	Female	Total	Male	Female	Total	Male	Female	Total
	18-24 years	6	4	10	1	2	3	0	0	0
	25-34 years	11	14	25	4	8	12	1	1	2
	35-44 years	20	25	45	8	14	22	1	1	2
	45-54 years	27	26	53	17	16	33	4	6	10
	55-64 years	59	45	104	38	27	65	9	5	14
	65-74 years	53	42	95	29	19	48	8	3	11
	75 years-	35	35	70	25	13	38	12	1	13
	Total	211	191	402	122	99	221	35	17	52
Collapse ratio		4.5%			5.0%			0.0%		
Inundation ratio		6.0%			7.2%			0.0%		
Blackout ratio		91.3%			54.8%			19.2%		
Water cut-off ratio		85.1%			86.9%			11.5%		

evacuees from Tomioka town were accommodated; (2) the survey carried out from September 23th, 2011 to October 14th, 2011 at temporary houses where the evacuees from Naraha town were accommodated; and (3) the survey carried out from July 9th, 2011 to July 29th, 2011 at temporary houses where the evacuees from Kawauchi village were accommodated. In the survey for Tomioka town, we entrusted the distribution and collection of the survey sheets to the administrators of the shelters, and the survey sheets were distributed to 1,300 evacuees over the age of 18 years old. In the surveys for Naraha town and Kawauchi village, we dropped 712 sheets and 310 sheets into mailboxes of temporary houses respectively, and collected by mail after having the representative of each occupant fill out questionnaires. As a result, the number of each survey respondent was 524, 233 and 88 in order of Tomioka, Naraha and Kawaychi, whose collection ratio was in the range of 30 to 40 percent. Of these, the number of each survey respondent whose sex, age, and address before the earthquake could be all confirmed was 424, 221 and 52 in the order, and the mail respondents aged 55 to 64 years old were the most in any surveys. Note that four kinds of ratios in Table 3 are defined as follows: (1) collapse ratio means the ratio of the respondents who answered “home collapsed perfectly by the shake” or “home inclined steeply by the shake”; (2) inundation ratio means the ratio of the respondents who answered “home was destroyed by the tsunami” or “home was inundated by the tsunami”; (3) blackout ratio means the ratio of the respondents who answered “home lost power”; and (4) water cut-off ratio means the ratio of the respondents who answered “water was cut off at home”.

TEDENCY OF EVACUTION TYPES OF RESIDENTS

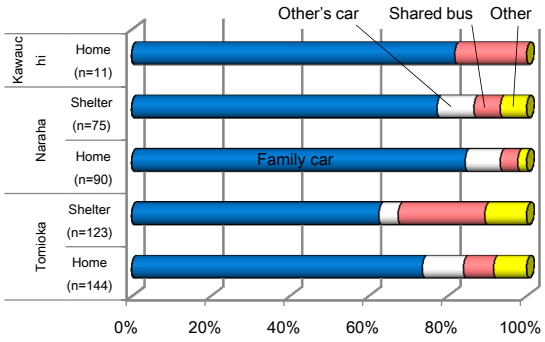
Fig. 4 (a) shows the breakdown of start position of evacuation answered by the respondents in each municipality. In any of the municipalities, the respondents who started evacuation from home or shelter accounted for a large fraction of the total. In both towns of Tomika and Naraha which spread on the Pacific coast, a certain number of residents had escaped into local shelters due to earthquake and tsunami in advance. On the other hand, in Kawauchi village, where the damage by the earthquake was a little because of the inland location, local evacuation before nuclear disaster might hardly take place.

Fig. 4 (b) shows the breakdown of voluntary evacuee and involuntary evacuee, as to the respondents who started evacuation from home. In any towns of Tomika and Naraha located in the vicinity of the stations, most of the residents started evacuation after the issue of evacuation order by the Prime Minister or the local government offices. On the other hand, as many as half of the respondents of Kawauchi village judged the need for evacuation independently before the issue, which is located more than ten kilometers away from the stations. Such a regional difference indicates the possibility that the residents living in the vicinity of the stations could not receive the information of

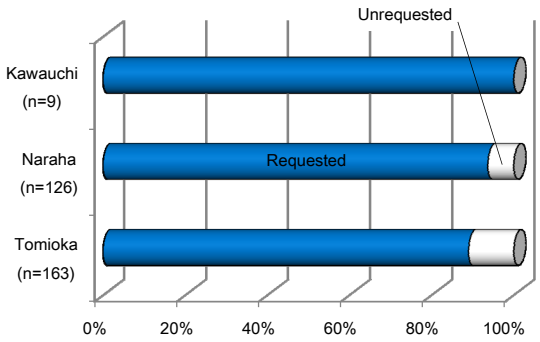


(a) Start position of evacuation (b) Decision-making of evacuation

Fig. 4 Tendency of evacuation types of residents.



(c) Transportation for evacuation



(d) Municipality of destination for refuge

Fig. 4 Tendency of evacuation types of residents.

the accident and concern their safety until the morning on March 12th when the evacuation order was issued by the administrative agency, because of the invisibleness of radioactive materials and the blackout. On the contrary, the residents far from the ocean might have been able to recognize the seriousness of the event by perceiving the order situation around the stations, because of the smallness of the earthquake impact. As a result, they could have enough time for thinking whether or not to evacuate until the evacuation order was issued for Kawauchi.

Fig. 4 (c) shows the breakdown of transportation for evacuation by the respondents who started evacuation after the issue according to start position. In any of the municipalities, most of the respondents used the private transportation such as family car and other's car, even where shelter. This may be influenced by the fact that any of the offices recommended the residents to evacuate with a family-owned automobile.

Fig. 4 (d) shows the breakdown of whether or not the municipality of arrival for refuge was the

Start Position	Decision-making	Transportation	Municipality of Destination	Evacuation Type	Frequency (%)		
					Tomioka	Naraha	Kawauchi
Home	Voluntary	Family car		T1	4.7	5.0	50.0
		Other's car		T2	0.0	1.3	0.0
	Involuntary	Family car	Requested	T3	38.4	44.7	40.9
			Unrequested	T4	3.0	3.1	0.0
		Other's car	Requested	T5	6.0	5.0	0.0
			Unrequested	T6	0.0	0.0	0.0
		Shared bus	Requested	T7	4.7	2.5	9.1
Shelter	Involuntary	Family car	Requested	T8	24.1	29.6	0.0
			Unrequested	T9	4.7	1.9	0.0
		Other's car	Requested	T10	2.2	3.1	0.0
			Unrequested	T11	0.4	0.6	0.0
		Shared bus	Requested	T12	11.6	3.1	0.0

Fig. 5 Evacuation types of residents obtained from the surveys.

municipality which the resident office requested the accommodation, as to the respondents who started evacuation with family car after the issue of the order. In any of the municipalities, most of the respondents escaped into the municipality which the resident office desired. This may be influenced by the fact that any of the offices referred to the destination to go in the instruction. On the contrary, we might be able to regard the ratio of the evacuees who cannot follow the instructed destination as around 10 percent, ignoring the difference in regional characteristics such as road network.

As a result, the evacuation types of residents were obtained as shown in Fig. 5 according to municipality. In the respondents of Tomioka and Naraha, the following evacuation types were dominant:

- T3 (home - involuntary - family car - requested),
- T8 (shelter - involuntary - family car - requested),

and the occurrence tendency of the other types was also similar. On the other hand, the responses of Kawauchi residents concentrated on the following evacuation types:

- T1 (home - voluntary - family car),
- T3 (home - involuntary - family car - requested).

REQUIRED TIME OF TYPE 3 NARAHA RESIDENTS

In this chapter, we focused on the Naraha respondents whose evacuation type were T3 (home - involuntary - family car - requested), and analyzed the time required for each process of that type.

Fig. 6 shows the frequency distribution of the departure time from home (t_{B1}+t_{B2}+t_{B3}), where the horizontal axis indicates the time from 6:00 AM to 12:00 PM on March 12th, and the left and right vertical axes are respectively relative frequency and cumulative relative frequency. And dotted lines indicate the occurrence time of the main events of station situations and protection measures. The relative frequency distribution showed the single-peaked distribution with the bias to left side, whose peak was 9:00 AM to 10:00 AM on March 12th. Most of the respondents started home within one-to-three hours after the issue of full-scale evacuation order by the office, and such generation of evacuees roughly settled in the evening. However, the cumulative relative frequency was estimated to be about 80 percents by four hours after the issue by the office and be about 97 percents by 12:00 PM on March 12th.

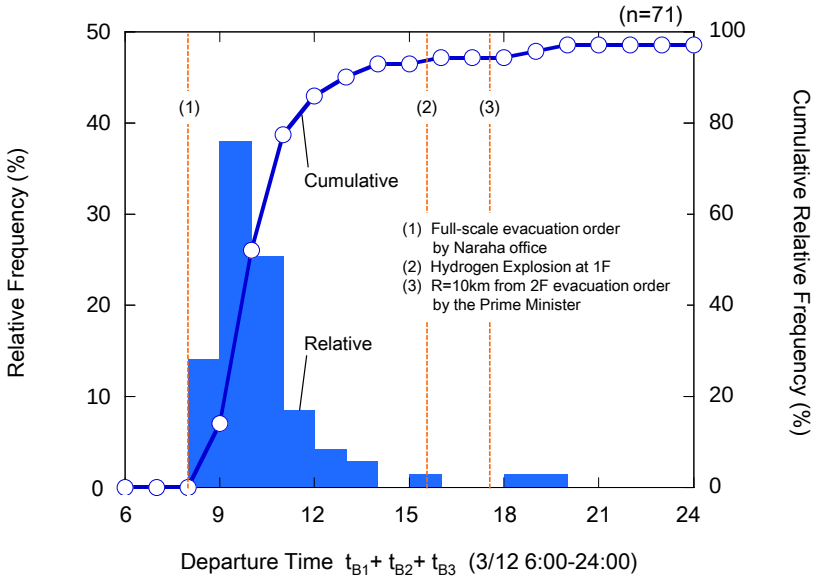


Fig. 6 Distribution of departure time from home (Type 3 Naraha respondents).

Fig. 7 shows the breakdown of the receiving source of evacuation order. Outdoor speaker contributed the most for the respondents staying home to receive the evacuation order. Including the respondents who answered PR car or local officer, the administrative approach from Naraha office was more than 80 percents. The mass media such as TV and radio could not function effectively for informing the order immediately. One of the contributing factors of this is thought to be unavailable for the equipment because of the blackout as show in Table 3.

As to the respondents who received the evacuation order from the outdoor speaker, Fig. 8 shows the frequency distribution of the following time: (a) the required time from when the office issued the order till when the respondent received the order (propagation time t_{B2}); and (b) the required time from when the respondent received the order till when the respondent left the home (preparation time t_{B3}). The propagation time showed the double-peaked distribution whose peaks were 0-to-0.5 hours and 1-to-1.5 hours. Such a difference in the required time to obtain the order may imply the existence of the residents who could be easy to listen to the announcement from the speaker and those who could not. On the other hand, the preparation time also showed the double-peaked distribution whose peaks

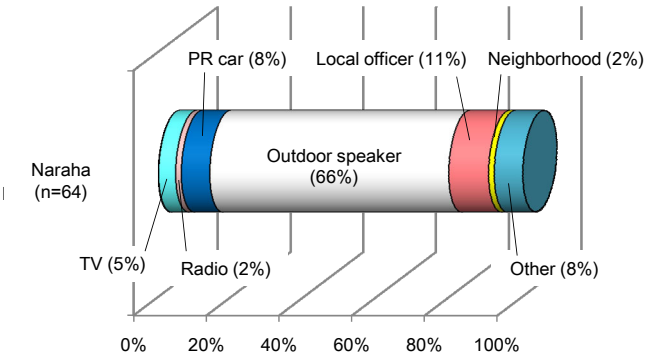
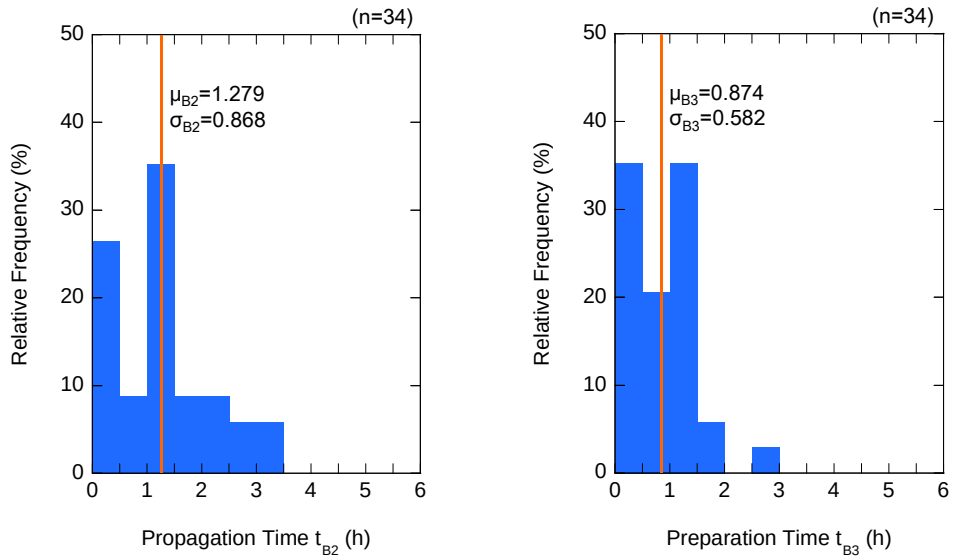


Fig. 7 Receiving source of evacuation order (Type 3 Naraha respondents).



(a) Propagation time (b) Preparation time

Fig. 8 Distribution of propagation time and preparation time (Type 3 Naraha respondents).

were 0-to-0.5 hours and 1-to-1.5 hours. This may imply the existence of the residents who left home with fear immediately after listening to the order and those who could not recognize the seriousness of the situation immediately.

Fig. 9 shows the distribution of travel time (t_{B4}) according to departure time from home, when the evacuees generated remarkably. Note that this travel time corresponds to the time to reach a safe accommodation in Iwaki city, where Naraha office instructed to go for refuge. It took as much time as five-to-seven hours on average to reach the first destination for refuge. As the distance between Naraha office and Iwaki office along the main roads is roughly 35 kilometers, the average travel speed was estimated to be 5-to-7 kilometers per hour. This may imply the occurrence of traffic jams on evacuation roads.

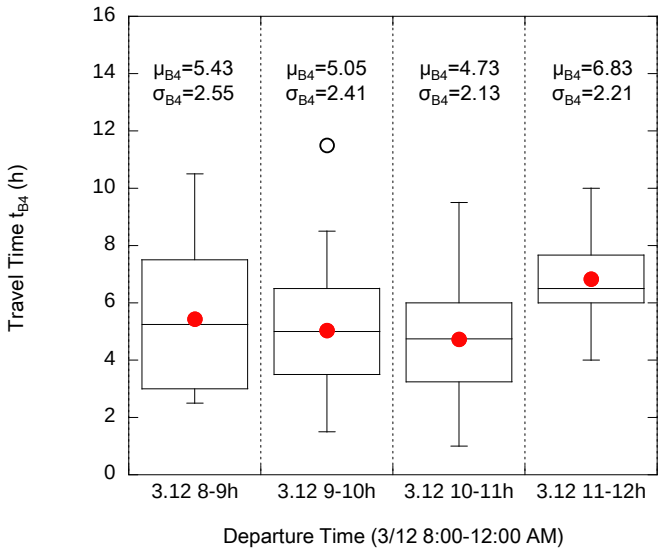


Fig. 9 Distribution of travel time according to departure time (Type3 Naraha respondents).

CONCLUSIONS

In this study, we clarified a part of the actual situation in the Fukushima Emergency Event in terms of evacuation types of residents and required time for involuntary evacuation, by counting the obtained data from the questionnaire surveys. However, more detail analysis on the following things is essential: (1) information contact and reaction of local government offices requiring emergency evacuation; and (2) the governing factors of required time for each behavior of a resident.

REFERENCES

Nuclear and Industrial Safety Agency. (2011). "*Report on seismic damage."* (in Japanese).

Nuclear Safety Commission of Japan. (2010). "*Preparations for disaster at nuclear facilities."* (in Japanese).

Umemoto, M., Ishigami T and Kobayashi K. (2002). "The inhabitants' Reaction after Contact with Disaster Information at the JCO Critically Accident." *Journal of Social Safety Science*, No. 4, 231-240 (in Japanese).

Umemoto, M. (2011). "A Study on Citizens' Choices of Means of Transportation for Long Distance Evacuation Extending to the Next Prefecture." *Journal of the City Planning Institute of Japan*, Vol. 46, No. 2, 131-141 (in Japanese).