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ANALYSIS OF EVACUATION BEHAVIORS IN DIFFERENT AREAS BEFORE AND AFTER THE GREAT EAST JAPAN EARTHQUAKE

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ABSTRACT: This study aims to obtain the insights necessary for future disaster prevention planning and management in Japan. To this end, a questionnaire survey on evacuation behaviors was administered to the residents of Yamada-machi in Iwate Prefecture and Ishinomaki-shi in Miyagi Prefecture, which had been stricken by the Great East Japan Earthquake. The obtained data were analyzed on the basis of the regional differences in said behaviors. The analytical results are summarized as follows. (1) Prevention measures, such as earthquake drills and occasional discussions regarding earthquakes, tended to be implemented in areas facing the Rias coast before the Great Earthquake occurred. (2) The interval between the occurrence of the earthquake and the initiation of evacuation was shorter in the regions fronting the Rias coast and in those located along a coastline than in areas situated on a plain and along a river. (3) Residents of the regions facing the Rias coast and the areas located along a river tended to evacuate by foot, whereas people living in other areas favored evacuation by automobile.

Keywords: Great East Japan Earthquake, evacuation behavior, Yamada-machi, Ishinomaki-shi

1. INTRODUCTION

1.1 Purpose of the study

The Great East Japan Earthquake (hereinafter referred to as the Great Earthquake) that occurred on March 11, 2011 severely damaged East Japan. The epicenter of seismic activity was located in Tohoku district and resulted in a casualty of approximately 20,000 people.

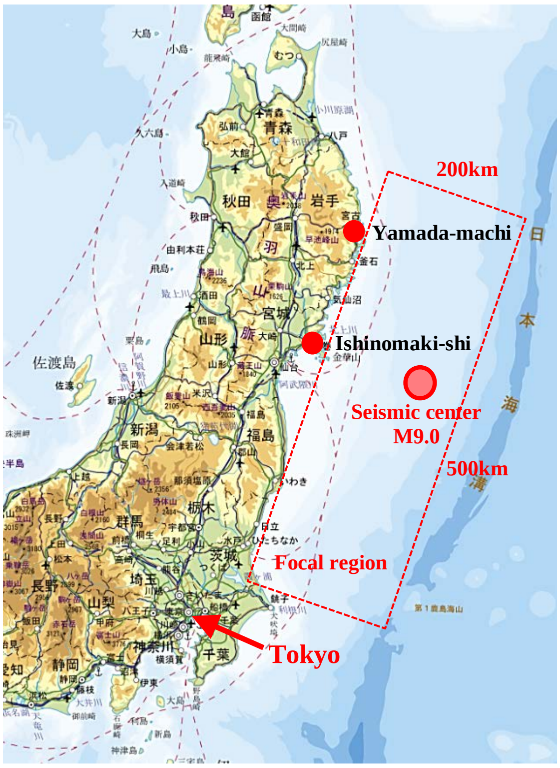
Given the necessity for safety and prevention arising from the disaster, this study aims to acquire the information essential for future disaster prevention planning and management in the country. To achieve this goal, a questionnaire survey on evacuation behaviors was administered to the residents of Yamada-machi in Iwate Prefecture and Ishinomaki-shi in Miyagi Prefecture, which had been seriously stricken by the Great Earthquake. The obtained data were analyzed on the basis of the regional differences in evacuation behavior.

1.2 Overview of the study

Research on the Great Earthquake has only recently been initiated, with several researchers comprehensively examining the evacuation behaviors of residents in disaster-stricken areas [1]-[5].

In addition, the study on simulation of the evacuation behaviors is pushed forward [6]-[7]. Previous studies focused on specific areas, but the current research deviates from the typical approach by dividing the regions of interest into four areas according to distance from a coast or a river and accordingly analyzing the dissimilarities in evacuation behaviors across the different areas.

In this study, we use basic analysis technique without simulating the evacuation behaviors.



Source: Geospatial Information Authority of Japan

Fig.1 Study regions

2. STUDY REGIONS AND SURVEY METHODS

2.1 Study regions

As previously stated, the study sites chosen for this research are Yamada-machi located in Iwate Prefecture and Ishinomaki-shi situated in Miyagi Prefecture (Fig. 1). These two regions were chosen because (1) they differ in terms of geographical characteristics but (2) are similar with regard to tsunami height witnessed in the regions and building damage ratio. The locations were therefore deemed suitable for the analysis of variances in evacuation behaviors across different areas.

The study regions experienced several times of great earthquakes in the past: 1896(Meiji Sanriku earthquake), 1933(Showa Sanriku earthquake) et al. In these earthquakes, the East Japan great earthquake disaster brought the heaviest damage.

Fig. 2 shows the tsunami inundation ranges of the two regions. The ratios of tsunami inundation area to inhabitable land in Yamada-machi and Ishinomaki-shi were 19.2% and 30.1%, respectively. The number of casualties in the

Table 1 Damage of the study regions

	Yamada-machi	Ishinomaki-shi	Remarks
Population	19,270	160,826	2011, Before earthquake
Household	7,192	57,871	
Area	263 km^2	556 km^2	
Geographical features	Rias coast	Plains	
Height of tsunami	6-19 m	5.8-10.4 m	
Inundation area	5 km^2	73 km^2	
Death person	676	3,512	
Missing person	149	445	
Rail	Senseki Line, Isinomaki Line	Yamada Line	
Road	Route 45	Route 45, Route 108	

Yamada-machi

Ishinomaki-shi

: Inundation range
Source: Geospatial Information Authority of Japan

Fig. 2 Tsunami inundation ranges


Yamada-machi


Ishinomaki-shi

Source: Geospatial Information Authority of Japan

Fig. 3 Damaged areas in study regions

former was 825 (4.3% of the total population) and that in the latter was 3,957 (2.5% of the total population).

Table 1 and Fig. 3 show the situation of the damage of the study regions.

2.2 Survey methods

Table 2 presents core information on the questionnaire survey administered in the investigated localities.

Table 2 Details regarding the questionnaire survey

	Yamada-machi	Ishinomaki-shi
Period	June-September, 2011	October-December, 2011
Number of respondents	184 (approximately 1.6% of the population in the tsunami inundation range)	279 (approximately 0.2% of the population in the tsunami inundation range)
Data collection method	Hearing survey	
Location of data collection	Places of refuge and temporary dwellings	
Items	(1) Personal attributes (sex, age, and occupation) (2) Situation immediately after the occurrence of the Great Earthquake (3) Tsunami evacuation behaviors	
Investigator	The Great East Japan Earthquake Disaster Tsunami Evacuation Joint Survey Group (number of members: 30)	

3. EVACUATION BEHAVIORS IN DIFFERENT AREAS

3.1 Area classification

To understand the evacuation behavior patterns across the regions of interest, these were separated into different zones. Ishinomaki-shi was classified into zones A (along a coast), B (on a plain), and C (along a river), as determined according to distance from a coast or a river, and Yamada-machi was set as zone D, in accordance with its position fronting the Rias coast (Table 3). Table 4 lists the population in the localities, the number of

Table 3 Details of classification

Zone A (along a coast)	Ishinomaki-shi: Direct distance from a coast, less than 300 m (less than 3 m above sea level)
Zone B (on a plain)	Ishinomaki-shi: Direct distance from a coast, 300 m or higher (3 m or higher above sea level)
Zone C (along a river)	Ishinomaki-shi: Direct distance from the Old Kitakami River, less than 300 m
Zone D (facing the Rias coast)	Yamada-machi

Table 4 Details of survey responses

	Population	Number of responses	Response rate (%)	Mortality rate (%)
Zone A	10,833	105	0.97	5.83
Zone B	30,333	113	0.37	2.33
Zone C	7,085	61	0.86	8.07
Zone D	15,084	184	1.22	4.44

Table 5 Pre-earthquake behaviors in different areas

Survey items		Zone A	Zone B	Zone C	Zone D
(1) I have participated in disaster prevention drills every year.	Expected frequency	28	30	17	54
	Actual frequency	11	30	11	77
(2) I can recognize a hazard map.	Expected frequency	15	16	9	30
	Actual frequency	7	9	8	46
(3) My family has occasional discussions regarding earthquakes.	Expected frequency	43	46	27	85
	Actual frequency	41	35	16	109
(4) I evacuated from my home during/after the 2010 Chilean tsunami.	Expected frequency	41	44	25	75
	Actual frequency	41	30	19	95
(5) Estimated tsunami arrival time	[Min]	18.6	19.7	56.1	23.8

(dark grey)	Items in which the actual frequency was smaller than the expected frequency
(light grey)	Items in which the actual frequency was larger than the expected frequency

responses received from the participants, the response rates of the questionnaire, and the disaster mortality rates in the regions (the number of deaths in the area divided by the total population of the area). The disaster mortality rate was highest in zone C, followed by zones A, D, and B.

3.2 Pre-earthquake behaviors

To examine the differences in behaviors across various areas before the Great Earthquake, a chi-square test was performed to determine the plausibility of the null hypothesis that no differences exist among the regions. Table 5 lists the survey items, for which the chi-square test revealed a significant difference at the 5% level.

The number of responses was compared with the expected frequency, which was obtained on the assumption that no differences in evacuation behaviors exist among the studied areas. With regard to item #1, the actual frequency of participation in disaster prevention drills every year in zone D (fronting the Rias coast) was larger than the expected frequency; the actual frequency was smaller than the anticipated frequency in zones A (along a coast) and C (along a river). In terms of item #2, the actual number of people who could recognize a hazard map was larger than the expected number only in zone D; the values obtained for the rest of the areas were smaller than the expected values. Concerning item #3, the number of families who had occasionally discussed earthquakes was larger than the expected number only in zone D; the rest of the areas exhibited values smaller than those anticipated. With respect to item #4, the actual number of people who had evacuated from the 2010 Chilean tsunami was larger than the predicted number in zone D, whereas the expected number was smaller than the anticipated number in zones B and C. The estimated tsunami arrival time was around 20 min before the Great Earthquake in zones A, B, and D, but this estimate was more than twice as long (56 min) in zone C.

3.3 Behaviors immediately after the Great Earthquake

With respect to immediate behaviors after the Great Earthquake, Fig. 4 shows the interval between disaster occurrence and evacuation initiation in each area, and Fig. 5 indicates the ratio of residents who returned home to the total population (returnee ratio hereafter) in each area after the occurrence of the Great Earthquake. The interval between the occurrence of the Great Earthquake and the initiation of evacuation was shortest in zone D, followed by zones A, B, and C. The returnee ratio was lowest in zone B and highest in zone D.

To examine the differences in evacuation methods among the areas, a chi-square test was carried out to determine the plausibility of the null hypothesis that no differences exist across the

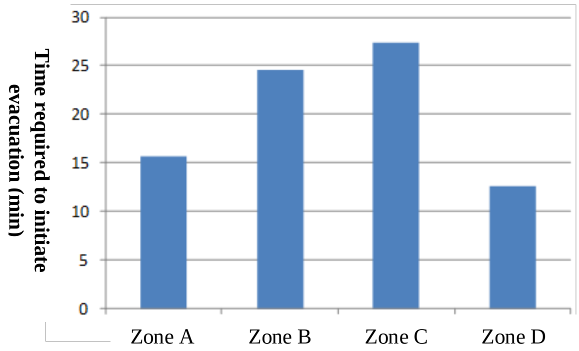


Fig. 4 Time taken to initiate evacuation

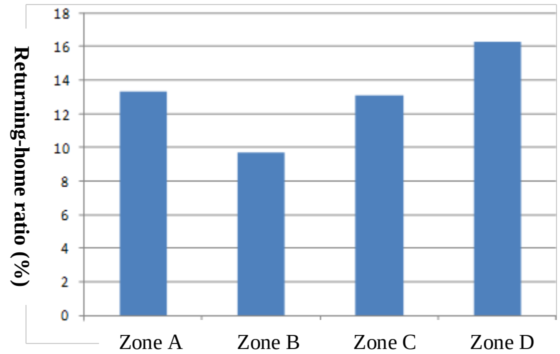


Fig. 5 Returnee ratio to Houses

Table 6 Analytical results on evacuation methods

Survey items		Zone A	Zone B	Zone C	Zone D
Means of evacuation	By foot			○	○
	By car	○	○	○	
Evacuation sites	Bridges and places located at higher elevations	○			
	Upper floors of houses and office buildings		○	○	
	Upward slopes or hills				○

○ = items that exceeded the expected values studied regions. Table 6 lists the survey items, for which the chi-square test indicated a significant difference at the 5% level. With regard to "means of evacuation," the people in zones A and B tended to evacuate by automobile, those in zone C favored both evacuation by car and by foot, and those in zone D tended to evacuate by foot. In terms of "evacuation sites," the people in zone A tended to evacuate to bridges and places that were located at higher elevations to avoid the erosion caused by the earthquake; the residents of zones B and C preferred evacuating to the upper floors of their houses and office buildings; and the residents of zone D tended to evacuate to upward slopes or hills.

4. CONCLUSION

4.1 Analytical results

The analytical results are summarized as follows.

(1) With regard to pre-earthquake behaviors, prevention measures, such as earthquake drills and occasional discussion on earthquakes, tended to be implemented in areas facing the Rias coast. No prevention measures were taken in Ishinomaki-shi.

(2) The interval between the occurrence of the Great Earthquake and the initiation of evacuation was shortest in zone D, followed by zones A, B, and C. The people living in these four areas tended to return home, even though they had evacuated early after the occurrence of the Great Earthquake.

(3) The people living in the areas fronting the Rias coast and those located along a river favored evacuation by foot, whereas the residents of other regions tended to evacuate by car. With reference to evacuation sites, the people living in the four studied areas tended to evacuate to easily accessible sites.

4.2 Future tsunami disaster prevention and management measures

On the basis of the analytical findings, the following recommendations for future tsunami disaster prevention and management were formulated.

The analytical results on the evacuation behaviors indicate that participation in earthquake drills, the recognition of a hazard map, and in-family discussions of earthquakes are important preventive measures that increase survival rates. In relation to means of evacuation, the facilities to be occupied by evacuees should be examined to determine whether these are accessible by automobile or other means. An important requirement for facilitating auto-based evacuation is the construction of roads that are easily cleared of traffic jams even after a given area is struck by an earthquake. With reference to evacuation by other means, safe evacuation sites must be established within walking distance given the travel constraints imposed by disasters. For houses and office buildings located on plains, an essential measure is to design effective anti-tsunami measures, in addition to constructing tsunami evacuation buildings.

The strongest tsunami waves caused by the Great Earthquake arrived approximately 30 min after the occurrence of the earthquake. In the case of Tokai, Tonankai, and Nankai consolidated earthquakes, the strongest tsunami wave is predicted to arrive less than 30 min after earthquake occurrence. Therefore, people living in areas susceptible to such earthquakes must be evacuated within a short period. Achieving this goal necessitates prevention and management measures that are specific to the evacuation behaviors of residents in different regions.

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