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DEVELOPMENT OF THE METHOD OF ESTIMATING THE NUMBER OF PEOPLE AT EVACUATION CENTER IN CASE OF URBAN EARTHQUAKE DISASTER

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SUMMARY

In this paper, we developed a method to estimate the number of people who would stay at the evacuation centers in the impacted area after an earthquake occurs. This estimation is based on the results obtained from the random sampled social survey we conducted in 2003 which monitored human behavior and recovery processes from the 1995 Hanshin-Awaji(Kobe) earthquake disaster. We applied the results of this study to risk assessment of the next urban earthquake disaster. Whereabouts of the people in the impacted area at the first 10-hour, the first 100 hour, and the first 1000 hour after the earthquake were analyzed in relation to the estimated ground shaking intensity distribution to yield the evisceration rate at different shaking intensity. It was found that at the first 10 hour, about 10% of the people evacuated to the shelter if the ground shaking intensity exceeded JMA 5.5, about 30% at JMA 6.0, and about 50% at JMA 6.5. At the first 100-hour, evacuation rates were lowered to about 5% at JMA 5.5, 15% at JMA 6.0, and 25% at JMA 6.5. At the first 1000 hour, evacuation rate became lower 5% at JMA 6.0 and 15% at JMA 6.5.

INTRODUCTION

Background of the Study

At the disaster area of the Great Hanshin-Awaji Earthquake, to clarify the disaster processing of victims (emergency measures, restoration and reconstruction) systematically, we implemented three random sampling surveys in 1999, 2001 and 2003 (to be implemented in 2005). Among the survey results the authors examined, were those especially focusing on the "recovery of dwelling": that is the basis of the victim's life, clarified change to the victims dwelling locations after the earthquake, along the logarithmic axis through which victims behavior changes. It was revealed that those victims who fled from their homes eventually returned to their homes using various "connections" such as kinship, territorial society and personal relationships (connections at work and friends) other than conventional nonlinear public support path of "occurrence of the earthquake", "shelter", "provisional housing". Among victims who

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still stayed in shelters after 1000 hours (two months after the seismic disaster), more than 70% were those who were aiming at the reconstruction of their homes, and victims who moved to provisional housings were a little over 10%.

Objectives of the Study

Using the "instrumental seismic intensity" of every address block, data of "the number of sheltered refugees" and social survey results, we formulated an estimate equation on the number of sheltered refugees by seismic intensity. Using as our study object the "six earthquakes with significant damage" that occurred after the Great Hanshin-Awaji Earthquake with which the measurement of their seismic intensity over a wide area was made possible by the installation of measurement hardware, we clarified how many refugees were generated when an earthquake occurred, and how the numbers changed as time elapsed, to formulate an estimate equation for the number of sheltered refugees (hereinafter, refugees stands for sheltered refugees).

FORMATION OF ESTIMATE EQUATIOM

Estimation of rate of sheltered refugees using the social survey result

In the "life recovery survey in 2003", implemented by the Disaster Prevention Research Institute, Kyoto University, we asked people whether they evacuated or not and their evacuation center or shelter. Then we investigated the address of the respondents (in block unit) and instrumental seismic intensity of the address, clarified relationship between the "instrumental seismic intensity" and "rate of sheltered refugees". As a result, it was revealed that there was a strong correlation between "instrumental seismic intensity" and the "rate of sheltered refugees". It was revealed that people started to evacuate when the seismic intensity reached to 6 lower, and 20% evacuated at 6 upper, and more than 30% of people evacuated to shelters at 7. Obtained estimate equation is shown in Figure 1.

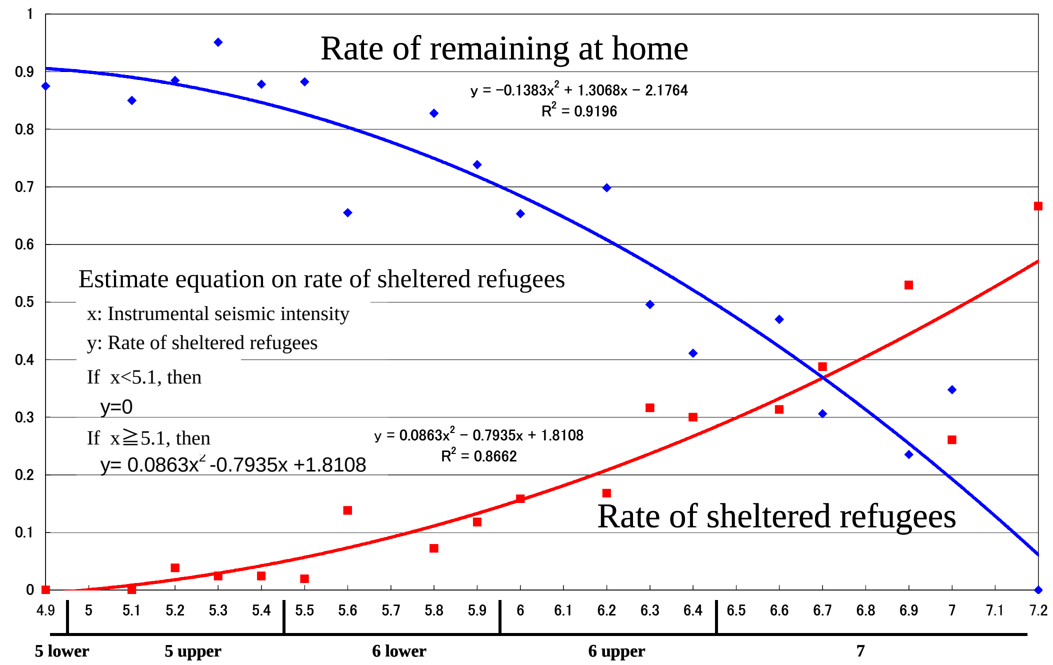

Figure 1: Estimation of rate of sheltered refugees using the social survey result

Estimation of ratio of sheltered refugees for six earthquakes since the Great Hanshin-Awaji Earthquake

The estimate equation obtained in the previous chapter was based on the data of the Great Hanshin-Awaji Earthquake. We added a further six earthquakes with significant damage that occurred after the Great Hanshin-Awaji Earthquake, to examine how many refugees were generated, and how such numbers increased or decreased as time elapsed based on administration data, to improve accuracy of the equation. The reason why we selected earthquakes after the Great Hanshin-Awaji Earthquake is that seismometers were widely installed in Japan after this earthquake and, it became possible to measure seismic intensity over a wide area. Table 1 shows six earthquakes with significant damage that occurred after the Great Hanshin-Awaji Earthquake.

For each earthquake, we clarified the relationship between instrumental seismic intensity and the rate of sheltered refugees. For the analysis, we used an hour's axis of 10 and 100 hours after the seismic disaster, which are revealed to be the "turning point of victims behavior" as a result of social survey. Figure 2 shows the plotted relationship between the refugee rate and instrumental seismic intensity in 10 hours after the seismic disaster, while Figure 3 represents 100 hours, in each block unit. With these two figures, we see that for all five earthquakes except the Tokachi-oki Earthquake, there was a significant commonality in the relationship between the instrumental seismic intensity and rate of refugees. As to the Tokachi-oki Earthquake, there were two features. 1) People evacuated with lower seismic intensity. 2) At 100 hours after the seismic disaster, evacuation behavior was completed. The evacuation was assumed to be those caused as a result of tsunami, and the behavior pattern of refugees is clearly different from those of the other five earthquakes.

Table 1: Six earthquakes with significant damage

1. Great Hanshin-Awaji Earthquake (Jan. 17, 1995)
   M 7.3, Maximum JMA seismic intensity scale of 7

2. Tottori-ken-seibu Earthquake (Oct. 6, 2000)
   M 7.3, Maximum JMA seismic intensity scale of 6 upper

3. Heisei Geiyo Earthquake (Mar. 24, 2001)
   M6.7, Maximum JMA seismic intensity scale of 6 lower

4. Miyagi-ken-oki Earthquake (May 26, 2003)
   M7.1, Maximum JMA seismic intensity scale of 6 lower

5. Miyagi-ken-hokubu Earthquake (Jul. 26, 2003)
   M6.4, Maximum JMA seismic intensity scale of 6 upper

6. Tokachi-oki Earthquake (Sep. 26, 2003)
   M8.0 Maximum JMA seismic intensity scale of 6 lower

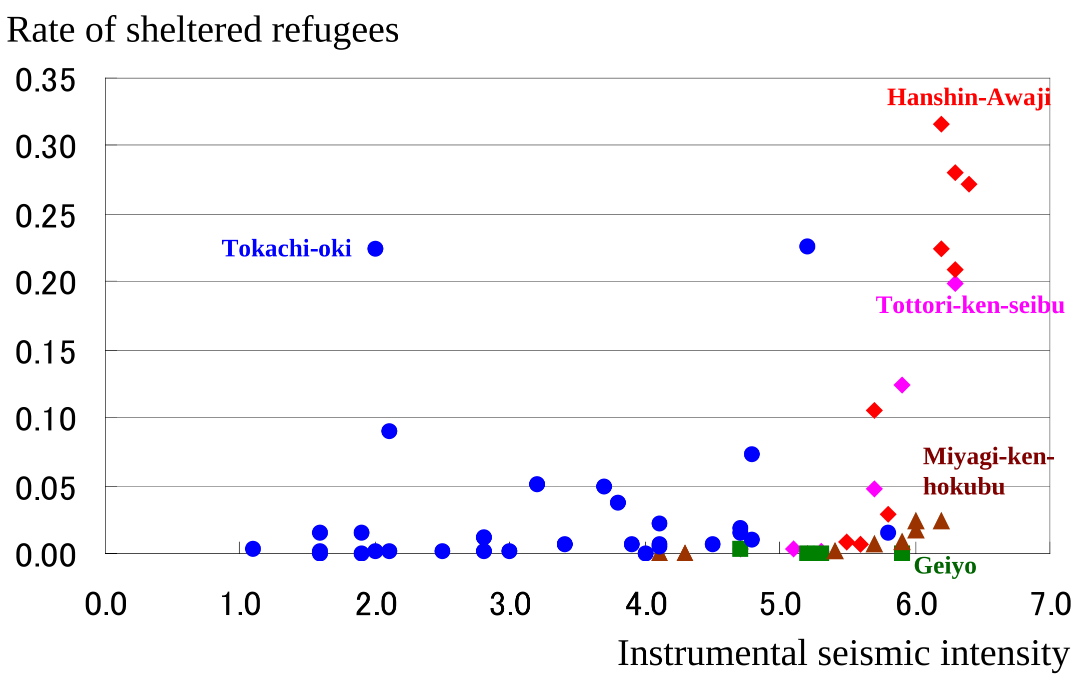

Figure 2: Relationship between the refugee rate and instrumental seismic intensity in 10 hours

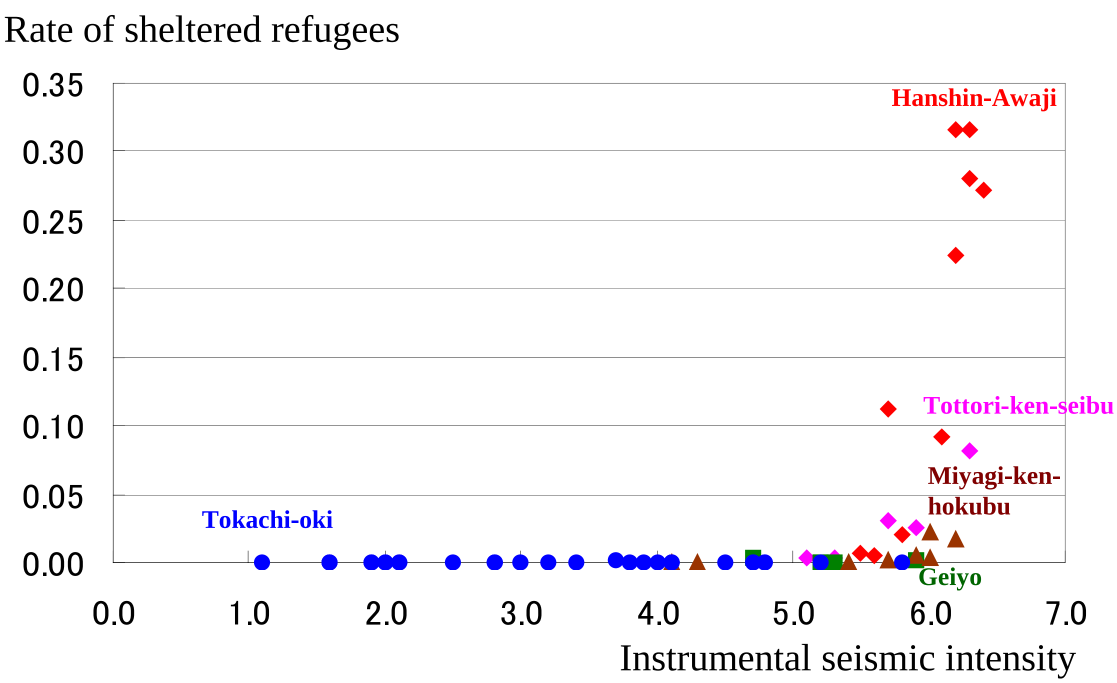

Figure 3: Relationship between the refugee rate and instrumental seismic intensity in 100 hours

For all five earthquakes except the Tokachi-oki Earthquake, we calculated the refugees estimate equation for 10 and 100 hours after the seismic disaster, and obtained the estimate equations shown in Figure 4 and Figure 5. Features of these estimate equations are as follows. 1) People begun to evacuate when the seismic intensity got stronger than 5 lower. 2) Rate of sheltered refugees was higher when instrumental seismic intensity was larger. 3) Rate of sheltered refugees in 10 hours after the seismic disaster was higher than in 100 hours. It was especially revealed that 1) and 2) had the same trend as that of the social survey data.

Using the obtained estimate equation, we calculated the estimated value rate of refugees at 10 and 100 hours after the seismic disaster, and verified such refugee rate with measured data. As a result, it was revealed that there was strong correlation between the estimated value and the observed value at 10 hours after the seismic disaster. At 100 hours after the seismic disaster, the correlation was relatively high, but this high correlation could be interpreted due to the fact that the refugee rate of the Great Hanshin-Awaji Earthquake has a large proportion in the overall trend. As to other three earthquakes, factors other than instrumental seismic intensity might be influencing behavior to evacuate to shelters. Therefore, we further formulated an estimate equation using analysis results of the social survey for 100 hours after the seismic disaster.

Formulation of estimate equation on rate of sheltered refugees at 100 hours after the seismic disaster using social survey

To formulate an estimate equation for 100 hours after the seismic disaster, we obtained factors that define the rate of sheltered refugees from replies to social surveys. Variables used for the analysis are personal attributes (sex, age, number of family members, family member structure, profession, type of the dwelling, house structure, total income per household), external force (instrumental seismic intensity), damage (personal damage, damage to buildings and furniture, ratio of total damage, lifeline damage). We obtained an estimate equation with a generalized linear model, and found that three variables are effective for the estimate: the number of refugees in 10 hours, the number of inhabitants in completely collapsed buildings and the number of inhabitants in completely destroyed buildings. The completely collapsed building stands for those with certain stories completely crushed or turned into rubbish without leaving any space for people to survive in destroyed houses.

In the social survey, the average number of family members per household of respondents at the time of the seismic disaster was 3.38, while the number of family members in Kobe City at the time of the seismic disaster was 2.63, we multiplied the coefficient of estimate equation by 1.3 and we used the figure obtained from the calculation as the final coefficient for the estimate equation. We estimated the number of shelter refugees and observed value at 100 hours after the seismic disaster using the estimate equation. As a result, we obtained a correlation between the estimated value calculated by the estimate equation and the observed value.

Formulation of estimate equations for time point other than 10 and 100 hours after the seismic disaster

The turning points of victim’s behavior are at 10 and 100 hours after the seismic disaster. However, social surveys revealed that decision making, for example, such as a "period when information on houses was required" or "the period when they made decisions on their dwellings" are not limited within these time frames. Therefore, we tried to formulate an estimation equation that can estimate by seismic intensity for time frames other than 10 and 100 hours after the seismic disaster. The process of our estimation measures is as follows. 1) By integrating all data from the six earthquakes, we compiled data on the number of refugees by seismic intensity. 2) We calculated the ratio of the number of refugees (time factor) as time elapsed taking the 100 hours after the seismic disaster as the reference point. 3) To

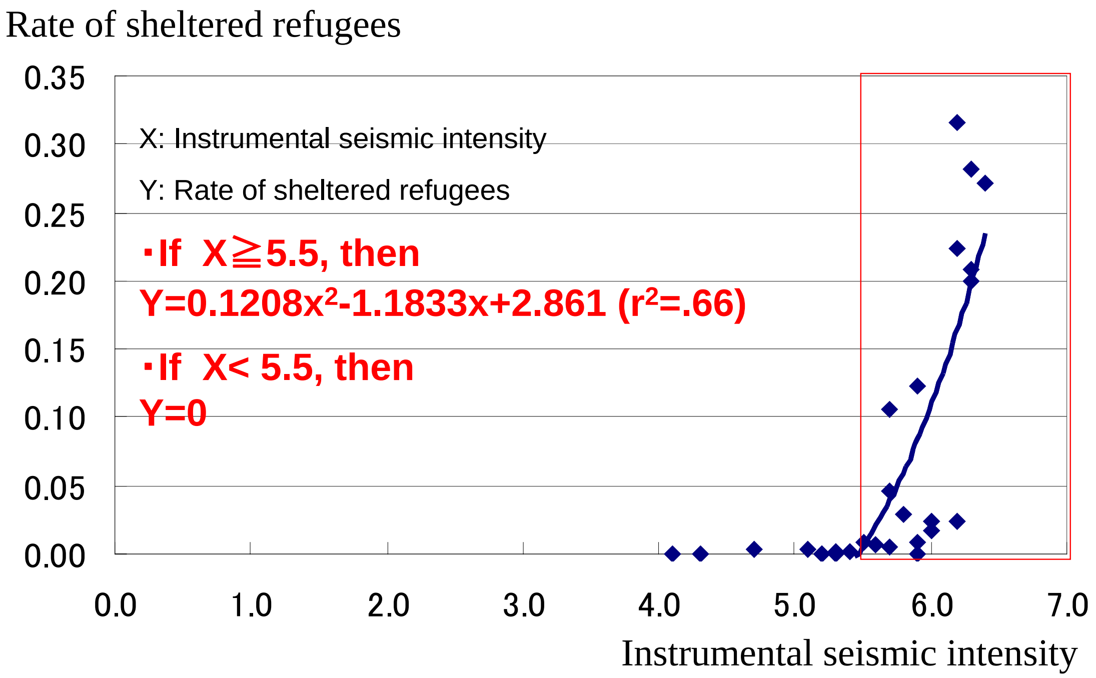

Figure 4: Refugees estimate equation for 10 hours after the seismic disaster

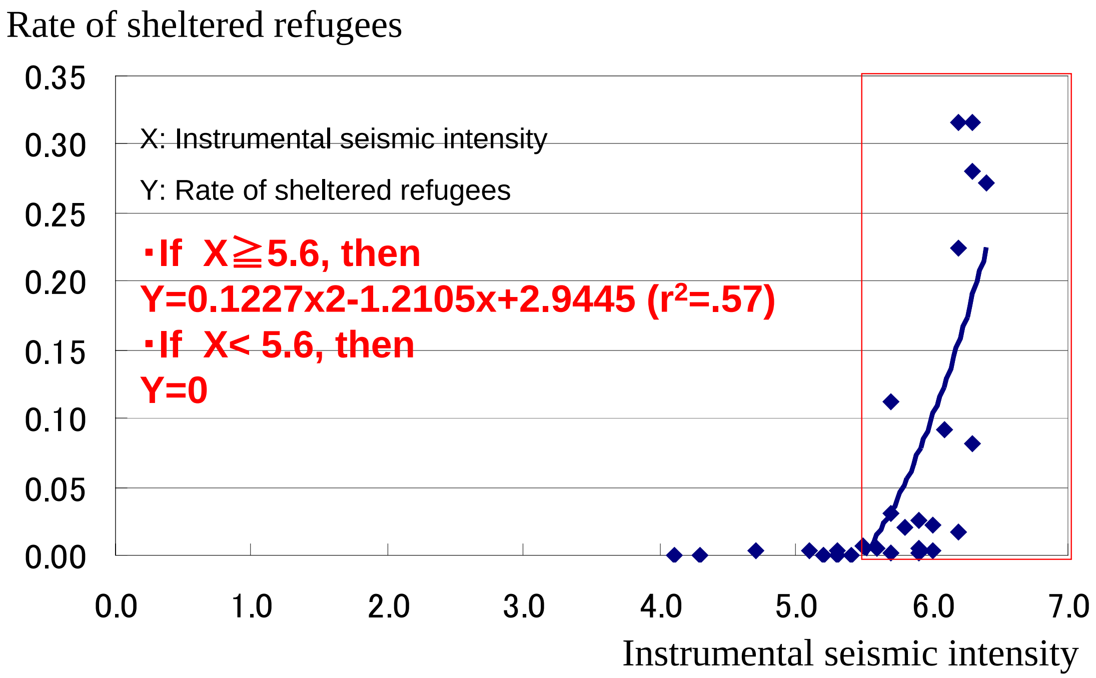

Figure 5: Refugees estimate equation for 100 hours after the seismic disaster

obtain approximated curve for transition of the number of refugees as time elapses, we formulated an estimate equation by seismic intensity. Figure 6 shows the result.

Features of the formulated estimate equation are listed below. 1) The number of refugees decreased as time elapsed. 2) The number of the refugees was largest on the day of the seismic disaster or on the second day after the disaster. 3) The larger the seismic intensity, the higher the rate of sheltered refugees. 4) When an approximated curve was drawn, it revealed that it was expressed as logarithmic function with elapsed time.

Then we verified the formulated estimate equations. We performed verification with the following process. 1) We used two estimation equations to examine the relationship between observed value and estimated value. The two equations are equation for intensity 6 upper that represents the maximum estimated number of refugees and equation for intensity 5 upper that represents the minimal estimated number of refugees. 2) Taking 10 and 1000 hours after the seismic disaster as examples, we examined the relationship between the estimate equation and the observed value. With only the Great Hanshin Awaji Earthquake, there were refugees generated 1000 hours after the seismic disaster, so we tried to verify this with data from the Great Hanshin Awaji Earthquake. As a result, 1) Both for maximum estimated value and minimal estimated value, these values matched fairly well for 10 hours after the seismic disaster. 2) However, those values did not match well in case of the 1000 hours data. Estimated value of 1000 hours after seismic disaster will not be used in urgency after the occurrence of a disaster. It may be appropriate to use the value as a reference for formulation of proactive measures and expost measures.

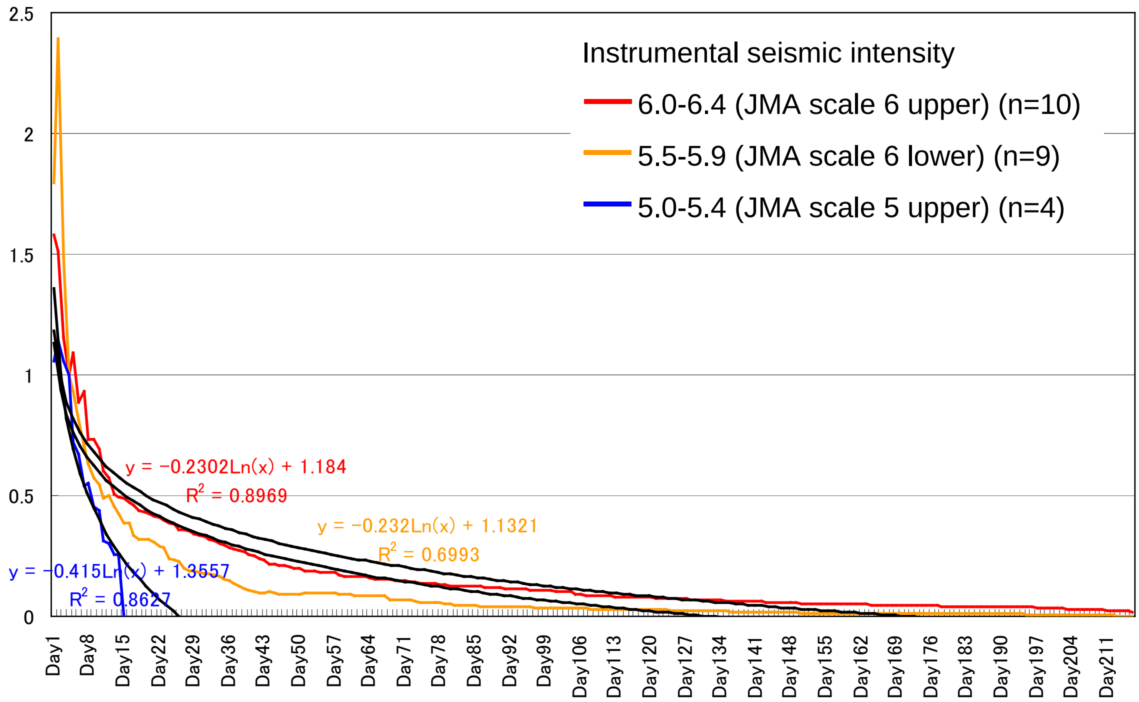

Figure 6: Approximated curve for transition of the number of refugees as time elapses by seismic intensity

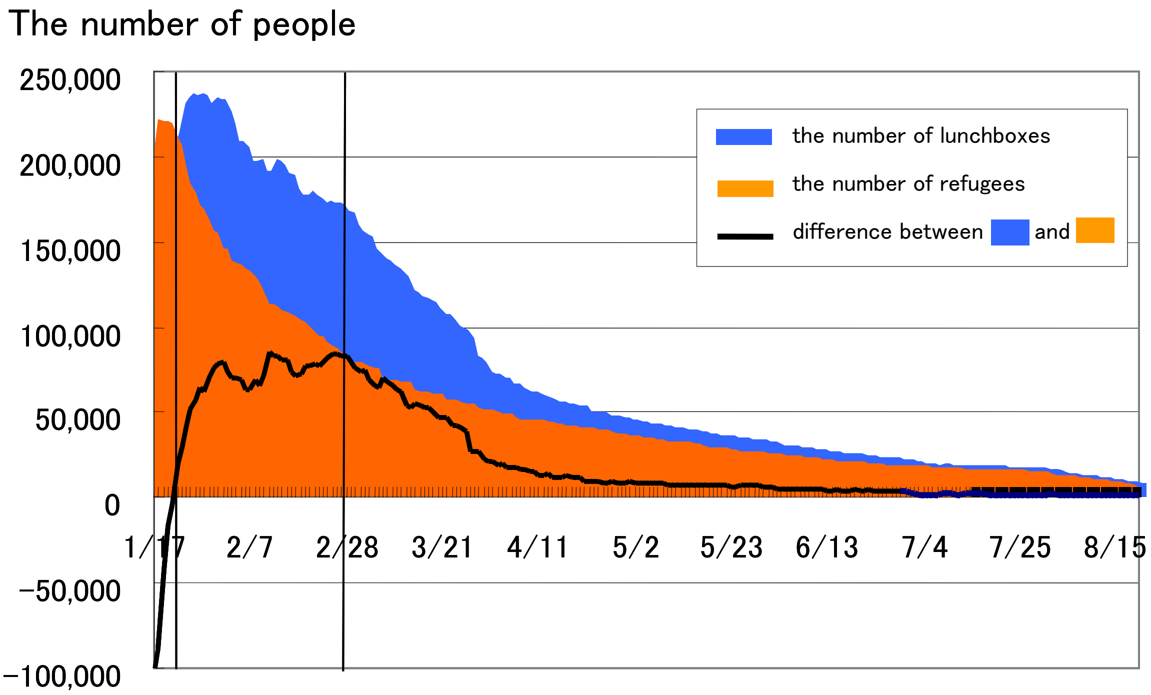

Figure 7: Number of refugees who stayed in shelters and the number of lunchboxes distributed in Kobe City

Table 2: Food Coefficient (FC)

Day	FC	Day	FC	Day	FC	Day	FC	Day	FC	Day	FC
1	1.00	41	1.96	81	1.36	121	1.23	161	1.22	201	1.07
2	1.00	42	1.98	82	1.35	122	1.25	162	1.19	202	1.08
3	1.00	43	2.00	83	1.35	123	1.24	163	1.19	203	1.08
4	1.00	44	1.99	84	1.33	124	1.24	164	1.20	204	1.08
5	1.00	45	1.95	85	1.30	125	1.24	165	1.20	205	1.09
6	1.10	46	1.93	86	1.29	126	1.25	166	1.13	206	1.15
7	1.14	47	1.96	87	1.31	127	1.22	167	1.11	207	1.11
8	1.21	48	1.88	88	1.28	128	1.23	168	1.08	208	1.11
9	1.28	49	1.87	89	1.28	129	1.26	169	1.07	209	1.11
10	1.32	50	1.86	90	1.28	130	1.25	170	1.07	210	1.12
11	1.37	51	2.01	91	1.31	131	1.25	171	1.08	211	1.11
12	1.37	52	1.98	92	1.28	132	1.25	172	1.11	212	1.12
13	1.44	53	1.94	93	1.28	133	1.25	173	1.12	213	1.16
14	1.49	54	1.92	94	1.30	134	1.24	174	1.12	214	1.16
15	1.50	55	1.90	95	1.23	135	1.24	175	1.12	215	1.18
16	1.55	56	1.79	96	1.23	136	1.26	176	1.11		
17	1.50	57	1.78	97	1.23	137	1.21	177	1.11		
18	1.50	58	1.87	98	1.24	138	1.21	178	1.13		
19	1.51	59	1.87	99	1.21	139	1.21	179	1.13		
20	1.50	60	1.85	100	1.21	140	1.21	180	1.13		
21	1.47	61	1.84	101	1.25	141	1.19	181	1.12		
22	1.47	62	1.83	102	1.23	142	1.18	182	1.13		
23	1.53	63	1.77	103	1.24	143	1.20	183	1.11		
24	1.52	64	1.77	104	1.23	144	1.19	184	1.11		
25	1.59	65	1.82	105	1.25	145	1.19	185	1.12		
26	1.75	66	1.73	106	1.23	146	1.19	186	1.12		
27	1.73	67	1.74	107	1.23	147	1.21	187	1.12		
28	1.74	68	1.74	108	1.26	148	1.19	188	1.12		
29	1.73	69	1.69	109	1.24	149	1.19	189	1.12		
30	1.74	70	1.50	110	1.24	150	1.22	190	1.11		
31	1.69	71	1.49	111	1.24	151	1.20	191	1.11		
32	1.68	72	1.50	112	1.24	152	1.20	192	1.11		
33	1.70	73	1.43	113	1.23	153	1.20	193	1.11		
34	1.75	74	1.41	114	1.23	154	1.22	194	1.11		
35	1.77	75	1.41	115	1.24	155	1.19	195	1.11		
36	1.82	76	1.39	116	1.21	156	1.20	196	1.10		
37	1.81	77	1.40	117	1.21	157	1.23	197	1.17		
38	1.84	78	1.36	118	1.21	158	1.22	198	1.14		
39	1.89	79	1.35	119	1.24	159	1.21	199	1.12		
40	1.94	80	1.39	120	1.22	160	1.21	200	1.07		

Estimation of the volume of necessary food

For the Great Hanshin Awaji Earthquake, there are two types of refugees in Kobe City. They are those who stayed in the shelters and those who did not stay in the shelters but came to the shelters to get lunchboxes. As we think that shelters have a variety of functions, it will be insufficient to estimate the number of refugees who stayed in shelters, we formulated an estimate method for the number of lunchboxes. However the number of the lunchboxes might be influenced by many factors, so we took Kobe City as an example, we calculated "food coefficient" first, and then we calculated the amount of necessary food by multiplying food coefficient to the number of refugees.

We defined the food coefficient as follows. As shown in Figure 7 and Table 2, the food coefficient was calculated from the ratio of the number of refugees who stayed in shelters and the number of lunchboxes distributed in Kobe City. In the data of Kobe City, the number of refugees exceeds the number of refugees staying in shelters except in the first five days after the occurrence of the seismic disaster. From the ratio of "refugees/refugees stayed in shelters" during each time frame, we calculated the food coefficient. However, in the first five days after the seismic disaster, the food coefficient was smaller than 1.0, so we rounded them all up to 1.0. It is because it is logically estimated that "all refugees who stayed in shelters were obliged to take food at shelter". By combining these four factors: 1) rate of refugees estimate equation on the day of the seismic disaster (10 hours), 2) the number of refugees estimate equation at 100 hours after the seismic disaster 3) time coefficient of estimate equation, 4) food coefficient, we formulated an estimate method for the number of refugees who evacuated to shelters.

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