Journal of Natural Disaster Science, Volume 33, Number 1, 2012, pp37-48

Prediction of Refugee Population in School Districts

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(Received May 31, 2011 Accepted December 10, 2011)

ABSTRACT

This study developed a numerical formula based on statistical data on collapsed, burnt down buildings, and refugees taking shelter in schools during the Great Hanshin Earthquake of 1995. The data on building damage used in the study were 2004 municipalities, classified into 46 junior high school districts. The independent variables were collapsed buildings, burnt down buildings, and average population of each building. The refugee population was regarded as a dependent variable in this study. The formula effectiveness in the junior high school district was 63% and 98% in administrative wards. When predicting the refugee population in schools in Kobe City using the formula, the school refugee population was 80% of all refugees in Kobe City predicted by the Hyogo Prefectural Government. This outcome was the same percentage of the population in school refuges in the Great Hanshin Earthquake. Predicting the refugee population who took shelter in other places besides school refuges and controlling other effective intermediary variables to fit different local areas are issues worth pursuing in advanced research.

Keyword: School refuge, School district, Refugee prediction, Collapsed building, Burnt down building

1. INTRODUCTION

The Great Hanshin Earthquake, with a seismic intensity of seven, occurred on January 17, 1995 at 5:46 AM. The range of the earthquake included Kobe City and Awaji Island. Over 50% of the zones destroyed were urban areas with high-density populations, and people in large numbers therefore took shelter in streets and buildings. As a result, most people went to refuges designated by the local government, and most refuges in Kobe City were nearby school refuges including elementary schools, high schools, etc. According to the investigation outcome conducted by Yokota (1998), the refugee population who took shelter in school refuges composed 60% of all refugees in Kobe City during the Great Hanshin Earthquake. Based on the phenomenon, it is important to grasp the population in school refuges in city planning for disaster prevention in urban areas. By correctly predicting the population in school refuges, relief supplies and rescue actions taken by official institutions responsible and NPOs could become more effective and appropriate. Therefore, this study correctly predicts the refugee population in school refuges by collapsed and burnt down buildings, and the population of collapsed and burnt down buildings, to provide a positive suggestion in predicting refugee population as a reference for policy-making in disaster prevention and future urban planning.

2. LITERATURE REVIEW

Studies related to predicting population in school refuges are few. Several important studies cited here describe research conducted around this issue.

(1) Kimura and Hayashi et al., in the report, "Prediction of Earthquake in Kyoto City for the Third Time" (2009) and "Development of a Method of Estimating the Number of People at Evacuation Centers in Case of Urban Earthquake Disaster" (2004), predicted population change at refuges over ten hours by the independent variable of seismic intensity. The formula was expressed as:

$$y_{10} = (0.0863x^2 - 0.7935x + 1.8108) \times \text{population}. \quad (1)$$

Here, y_{10} is rate of refugees taking shelter at the 10^{th} hour after the earthquake, and x is seismic intensity.

The study was conducted for the entire range of Kyoto City, and regarded seismic intensity as an independent variable to predict the entire refugee population in the city.

(2) Sakata (1999) used the data of every administrative ward during a 10-day period to 50 days after the occurrence of the Great Hanshin Earthquake, and regarded the decreased population in school refuges as an independent variable for building a model to explain the change in the school refugee population. The formula was expressed as:

$$Y = a \cdot \text{EXP}\,(bx). \quad (2)$$

Here, a is a constant, b is rate of decrease in the refugee population, Y is the change in refugee population, and X is the number of days after the earthquake.

(3) In the Mieno study (1999), every administrative ward in Fukuoka City was taken as the research object, and the status of refugee house damage was classified into three types: collapse of wooden buildings, collapse of non-wooden buildings, and damage to the water supply system. The independent variables were the rate of completely collapsed buildings, fire spread, and damage to the water supply system. The outcome still did not approach the area of school districts. The equation used in the study is expressed below:

$$P_E = P_{EW} + P_{ER} + P_{EL}. \quad (3)$$

Here, P_E is the total refugee population, P_{EW} is the refugee population caused by damaged wooden buildings, P_{ER} is the refugee population caused by damaged non-wooden buildings, and P_{EL} is the refugee population caused by lifeline damage.

(4) Kawasaki and Nagahashi (1996) utilized the damage rate of wooden buildings to predict the rate of refuge. The seismic intensity of an earthquake was controlled to two types: the M5 and the M7 level; the refugee population was counted by the 3-m^2 unit of space occupied by each person in a refuge. The study only considered damage to wooden buildings, and did not include other possible variables in the prediction. The equation for the rate of taking shelter is as expressed below.

$$R_P = (B_C + 0.5 \times B_H + 0.1 \times B_P) \div B_W. \quad (4)$$

Here, R_P is the rate of people who should take shelter in refuge, B_C is the number of completely collapsed buildings, B_H is the number of half-collapsed buildings, B_P is the number of partly collapsed buildings, and B_W is the number of undamaged whole buildings.

The literature does not include any studies focusing on prediction of the refugee population in school institutions in each school district. The independent variables used to predict the refugee population were the seismic intensity of the earthquake, collapse rate, rate of damage to lifelines, and change in the refugee population. The prediction objects ranged from administrative wards to the entire city or special areas. Compared to past studies, this study chose the basic unit of "school district" in city disaster prevention as the predicted object of official school refuges. To grasp the relationship between residents of damaged buildings and the refugee population, the populations of collapsed and burnt down buildings were regarded as independent variables. The purpose of this study was not only to predict the refugee population of a school refuge in a broad area of each ward or the entire city, but also to grasp information on small areas such as one school district.

3. METHODOLOGY

The methods used in this study are based on the literature and statistic analysis. The former composes the main database, and the latter is the analysis process. These methods are explained in detail below.

3.1 Literature analysis

This study used quantification of literature analysis as a research method. The building damage data used in this study were based on the document, "Final Report on the South Earthquake in Hyogo County," published by the Building Research Institute of the Ministry of Construction in 1998. Statistics on refugee population at the peak time in each school refuge on January 25, 1995 are presented in a report published by the Education Committee in Kobe City and in the research of Kashihara (1998). Household and population statistics are provided in the city census published by the General Affairs Planning Department of Kobe City Hall (1995). The data mentioned above were collected for the statistical analysis.

The data process steps are described below.

(1) First, building collapse and destruction by fire were sorted for every municipality in the school district. The 2004 municipalities were classified into 46 junior high school districts, which also included elementary school districts. School district classification was based on information provided by the Kobe Education Committee. School district distribution was according to damaged municipalities, as shown in Fig. 1. The number in each municipality indicates the junior high schools belonging to that municipality.

(2) To understand the status of damaged buildings and total refugee population in each school district, statistics on various types of damaged buildings and peak population on January 25, 1995 in every school were calculated according to the school district. Table 1 lists the manipulated data.

3.2 Process of statistical analysis

The method utilized in this study arranges rough data through "regression analysis." This method was chosen because regression built for prediction takes into account the percentage of factors chosen as independent variables (population of damaged buildings) and explains the dependant variable (refugee population). The prediction quantity can predict relief supplies and other rescue actions needed when making policies related to disaster prevention and urban planning. In this study, the dependent variable was the refugee population in school refuges in junior high school districts, and the independent variables were the number of completely collapsed buildings, number of burnt down buildings, and average population of buildings in the school district.

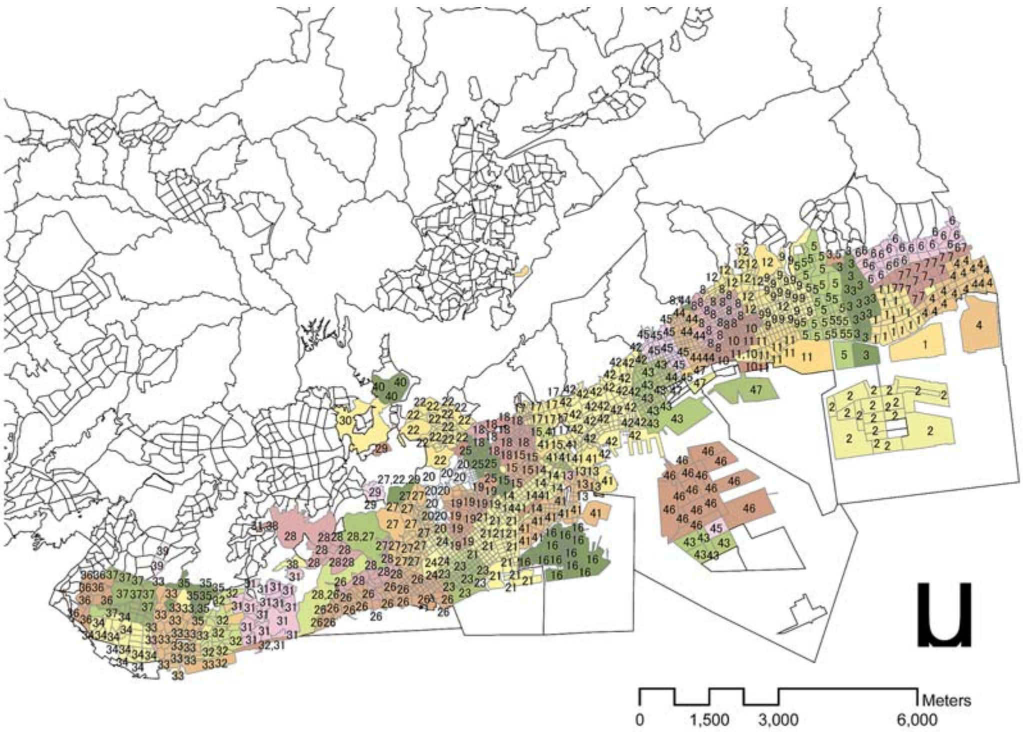

Fig. 1. Distribution of school districts in damaged municipality units

Table 1. Data on damaged buildings and refugee population in school districts

Coding Number	School District	CCB Low-rise	CCB M.H-rise	CCB Total	HCB Low-rise	HCB M.H-rise	HCB Total	CB Toatal	BB Low-rise	BB H.M-rise	BB Total	BB Mid-R	CCB Rate	HCB Rate	BB Rate	Building Total	Refugee Population
1	Uosaki	1282	58	1340	407	47	454	1794	75	3	78	133	0.25	0.09	0.01	5307	4200
2	Koyo	0	0	0	3	0	3	3	0	0	0	0	0.00	0.00	0.00	2441	0
3	Sumiyoshi	1168	63	1231	796	66	862	2093	0	0	0	16	0.22	0.15	0.00	5575	4330
4	Honjyo	1448	93	1541	574	94	668	2209	0	0	0	118	0.16	0.07	0.00	9850	6700
5	Mikage	1548	92	1640	885	97	982	2622	36	0	36	47	0.19	0.11	0.00	8601	1900
6	Motoyama	678	25	703	550	50	600	1303	0	0	0	2	0.08	0.07	0.00	8692	2100
7	Motoyama.M	2678	138	2816	472	97	569	3385	1	0	1	17	0.38	0.08	0.00	7363	6300
8	Ueno	554	34	588	575	78	653	1241	0	0	0	5	0.08	0.09	0.00	7184	3916
9	Takasho	1597	102	1699	549	81	630	2329	145	11	156	242	0.27	0.10	0.02	6408	4169
10	Harada	1316	80	1396	594	70	664	2060	1	0	1	11	0.29	0.14	0.00	4894	5069
11	Eboshi	1423	131	1554	388	71	459	2013	66	18	84	195	0.31	0.09	0.02	5041	3636
12	Nagamine	604	23	627	379	38	417	1044	69	6	75	108	0.11	0.07	0.01	5591	3416
13	Susano	629	100	729	772	194	966	1695	6	6	12	0	0.13	0.17	0.00	5566	1555
14	Hyogo	1638	248	1886	779	290	1069	2955	0	0	0	49	0.34	0.19	0.00	5512	3721
15	Minatogawa	1243	90	1333	882	101	983	2316	478	31	509	712	0.24	0.18	0.09	5537	3291
16	Yoshida	226	27	253	559	47	606	859	0	0	0	31	0.05	0.11	0.00	5388	1900
17	Minato	80	3	83	410	10	420	503	0	0	0	0	0.02	0.10	0.00	4262	1225
18	Yumeno	771	24	795	1496	38	1534	2329	0	0	0	180	0.13	0.25	0.00	6066	5300
19	Nishidai	2206	124	2330	1602	95	1697	4027	467	45	512	226	0.29	0.21	0.06	8173	5166
20	Takatoridai	549	7	556	1124	18	1142	1698	0	2	2	0	0.09	0.19	0.00	6030	4616
21	Nagata	2066	226	2292	1134	178	1312	3604	933	85	1018	1004	0.25	0.14	0.11	9076	6800
22	Hibarigaoka	52	1	53	406	9	415	468	0	0	0	0	0.01	0.05	0.00	7548	1078
23	Komagabayashi	630	30	660	705	66	771	1431	236	49	285	361	0.17	0.20	0.08	3787	8500
24	Ota	1350	69	1419	476	112	588	2007	1338	241	1579	3174	0.30	0.12	0.33	4715	2116
25	Maruyama	1218	19	1237	1265	47	1312	2549	0	0	0	24	0.23	0.25	0.00	5277	1051
26	Takatori	1352	16	1368	2046	114	2160	3528	1	62	63	19	0.18	0.29	0.01	7439	1800
27	Tobimatu	1099	2	1101	1543	53	1596	2697	57	46	103	52	0.12	0.18	0.01	8980	3043
28	Takakura	440	4	444	580	12	592	1036	0	4	4	0	0.11	0.14	0.00	4224	2180
29	Yokoo	12	0	12	9	0	9	21	0	0	0	0	0.00	0.00	0.00	3377	11
30	Sumakita	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00	0.00	68	70
31	Shioya	54	0	54	123	1	124	178	0	0	0	0	0.01	0.02	0.00	5233	96
32	Tarumi.H	28	0	28	159	0	159	187	0	0	0	0	0.00	0.03	0.00	6088	233
33	Tarumi	51	4	55	641	23	664	719	0	0	0	0	0.01	0.07	0.00	9008	258
34	Utashikiyama	17	6	23	141	14	155	178	0	0	0	0	0.00	0.03	0.00	5200	237
35	Hukuda	4	0	4	373	2	375	379	0	0	0	0	0.00	0.14	0.00	2718	123
36	Maiko	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00	0.00	2043	224
37	Seiryodai	72	6	78	258	19	277	355	0	0	0	0	0.03	0.11	0.00	2410	260
38	Momoyamadai	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00	0.00	400	27
39	Tamon.H	0	0	0	5	0	5	5	0	0	0	0	0.00	0.12	0.00	43	300
40	Todoridai	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00	0.00	1181	7
41	Kusunoki	527	68	595	717	135	852	1447	0	0	0	0	0.11	0.15	0.00	5645	3966
42	Kobeikuta	615	306	921	625	346	971	1892	14	5	19	13	0.09	0.10	0.00	9959	3800
43	Nunobiki	451	140	591	448	154	602	1193	7	3	10	15	0.11	0.11	0.00	5500	8735
44	Tutuidai	303	47	350	363	53	416	766	1	0	1	24	0.09	0.10	0.00	4060	1850
45	Hukiai	336	44	380	448	54	502	882	0	0	0	32	0.08	0.10	0.00	4888	2445
46	Minatojima	1	0	1	27	0	27	28	0	0	0	2	0.00	0.02	0.00	1192	0
47	Nagisa	8	2	10	9	7	16	26	0	0	0	0	0.03	0.04	0.00	393	0

Note:

CCB: Number of completely collapsed buildings in the school district

HCB: Number of half-collapsed buildings in the school district

BB: Number of burnt down buildings in the school district

BB Mid-R: Report on middle by the Construction Ministry

M.H-rise: Middle- and high-rise buildings

Table 2. Pearson product moment correlation **among** variables in the study

	Variable	Population of Refugees in School Refuges (y_g)	Number of Completely Collapsed Buildings (x_c)	Number of Burnt Down Buildings (x_f)	Number of Buildings (x_b)	Population in the School District (x_p)
Pearson Product-Moment Correlation (***r*** coefficient)	y_g	1.000	.830	.317	.497	.090
	x_c	.830	1.000	.420	.540	.085
	x_f	.317	.420	1.000	.107	-.219
	x_b	.497	.540	.107	1.000	.681
	x_p	.090	.085	-.219	.681	1.000

To prove the relationship between the independent and dependent variables, the Pearson product-moment correlation (***r*** coefficient) was used to understand the basic relationship among variables in the study. Table 2 shows a positive relationship between the most independent and dependent variables. The strength of relationship from high to low is the number of collapsed buildings, the number of buildings in school districts, the number of burnt down buildings, and the school district populations. The *r* coefficient among independent variables is low and middling (<.5). When performing regression analysis, the correlation among independent variables is expected to be low and that between the independent and dependent variables is expected to be higher and therefore better.

The regression analysis function is expressed as a simple numerical formula as:

$$f(x) = y\hat{} = ax+b, \tag{5}$$

$$b= \frac{n\Sigma xy - \Sigma x \Sigma y}{n\Sigma x^2 - (\Sigma x)^2} \text{ , and} \tag{6}$$

$$a= \frac{\Sigma y - b\Sigma x}{n} . \tag{7}$$

In the basic regression formula, *y* is the dependent variable, *x* is the independent variable with *a,* which is the interception of *y,* and *b* is the slope of the regression line.

When considering regression effectiveness, R^2 or the so-called coefficient of determination, which is the square of the Pearson product-moment correlation coefficient (r) and shows the ratio of explanation to *y* when using *x* as the independent variable, should be taken into account. The R^2 formula is expressed as:

$$R^2=\left(\frac{\Sigma xy}{\sqrt{\Sigma x^2 \Sigma y^2}}\right)^2 . \tag{8}$$

When R^2 is higher, the regression effectiveness is better. The following introduces the formulas used for prediction in this study.

(1) Numerical formula for population prediction of refugees in school refuges

The formula of equation (9) listed below is a function of population prediction for refugees in school refuges in school districts.

$$|\, y_g \,| = f\left(x_c, x_f, \frac{xp}{b}\right) = 695 + \left(1.7x_c + 0.9x_f\right)\frac{xp}{b} . \tag{9}$$

Here,

y_g is the population of refugees in school refuges in school districts.

x_c is the number of collapsed buildings in school districts.

x_f is the number of burnt down buildings in school districts.

$x_{p/b}$ is the average population of buildings in school districts.

The scatter plot shown in Fig. 2 is the distribution of samples in the quadrant constructed by three variables and the plane standards for the regression equation. The direction of plot distribution is the same for the plane and shows a positive relationship. The coefficient of determination (R^2) in the formula is 0.654, which means that the independent variables can explain 65% of the dependent variables. To confirm that no interaction exists among independent

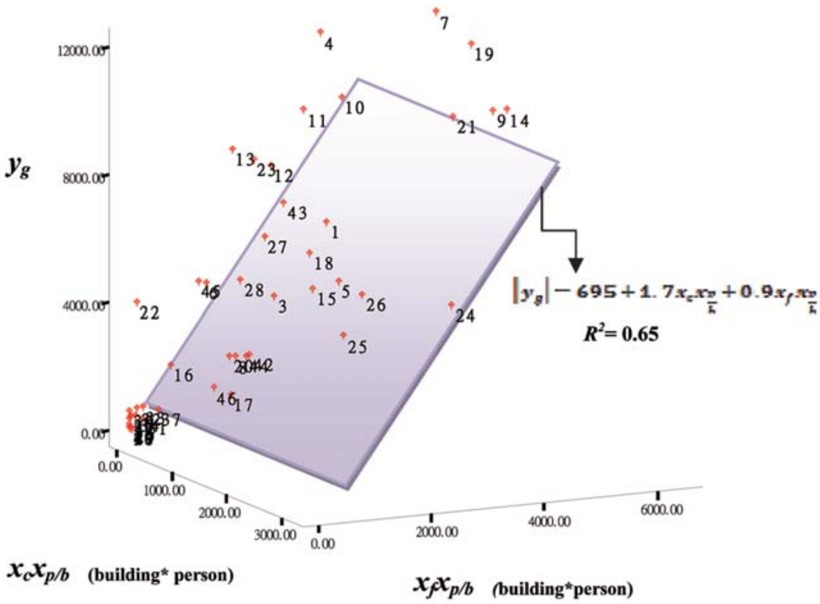

Fig. 2. Scatter plot for y_g, $xx_{p/b}$, and $x_f x_{p/b}$

variables, which is also a multicollinearity problem, the VIF value should be less than 10. The VIF value for the number of collapsed buildings was 1.058, for the number of burnt down buildings, it was 1.215, and for the average population of buildings, it was 1.087. In the equation, there was no multicollinearity problem among the three variables.

In addition to the equation for school districts, to match data based on administration ward, a formula for administration wards was also developed:

$$y_a = \sum_{i=1}^{n} y_g. \tag{10}$$

Here,

y_a is the population of refugees in school refuges in each ward.

y_g is the population of refugees in school refuges in junior high school districts.

n is the number of school districts in each ward.

R^2 of regression for administrational wards is 70%, which means that the independent variables can explain 70% of the dependent variables. The formula will be used in the fourth part of this article to compare the population prediction of refugees in entire Kobe City provided by Hyogo Prefecture.

(2) Influence of burnt down buildings on refugee population prediction

From R^2 stated above, we find that the population of collapsed buildings has higher prediction effectiveness for the refugee population than the burnt down building population. However, burnt down buildings played an important role in the study. All school districts were divided into two types, one being districts with no burnt down buildings, and the other being districts with burnt down buildings. A comparison of the effectiveness of prediction for the refugee population by the number of collapsed buildings is shown in the scatter plot of Fig. 3.

In Fig. 3, the number of genuinely collapsed buildings has a positive correlation with school district. This relationship is manifest in school districts with both burnt down buildings and no burnt down buildings. R^2 in the former is 0.628, and in the latter, it is 0.605. Therefore, the prediction of "collapsed buildings" in burnt down districts is a little higher than in non-burnt down districts. In this study, the prediction effectiveness (R^2) with the contribution of burnt down buildings is near to 0.0539, and this value is close to the difference in R^2 between collapsed buildings in these two kinds of school districts shown in Fig. 3. In other words, the "number of collapsed buildings" has a strong statistical predictive power for both kinds of school district, and the "number of burnt down buildings" can boost the prediction effectiveness of collapsed buildings in places of conflagration occurrence.

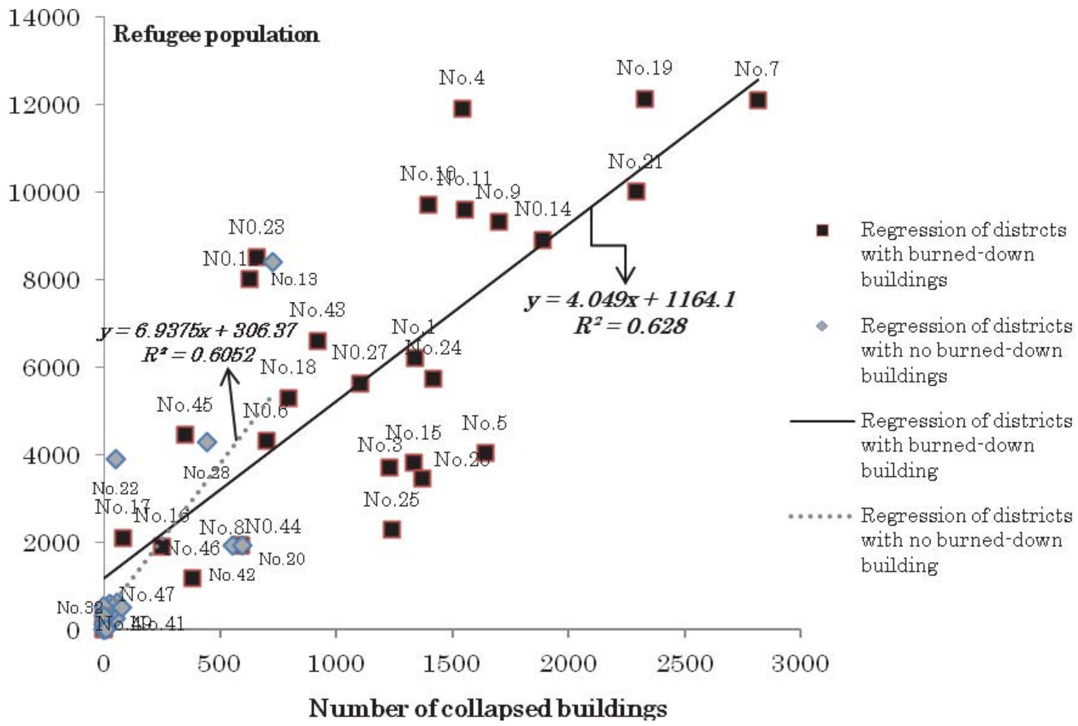

Fig. 3. Distribution of collapsed buildings and refugee population in two types of areas

4. COMPARING PREDICTION OUTCOMES BETWEEN THE STUDY AND OFFICIAL DATA

This section makes a prediction based on the formula in this study for current-day Kobe City, and then compares this prediction with the prediction by the Hyogo Prefectural Government based on the assumption that the Rokko-Awajishima fault caused the earthquake. The numerical formula used in this section is the prediction for administrative wards, such as equation (10) given in the third part of the article.

$$y_a = \Sigma_{i=1}^{n} y_g. \tag{10}$$

Similar to the information shown in Table 3, according to the prediction by the Hyogo Prefectural Government on the assumption that the Rokko-Awajishima fault caused the earthquake, the number of collapsed buildings might be 60,322, and the number of burnt down buildings might be 21,455 during the time interval from 4:00 AM to 5:00 AM during the winter season. The potential refugee population in Kobe City might be 128,236. Because the Hyogo Prefectural Government did not state the potential refugee population or building damage based on each administrative ward, the refugee population, number of collapsed buildings, and number of burnt down buildings in each ward were distributed by the percentage in each ward during the Great Hanshin Earthquake. The average building population was also calculated in the same way. Figure 4 shows a comparison of the refugee population between this study and the official data in each ward.

On the other hand, when making prediction based on the formula in this study, the population of refugees in school refuges in school districts of Kobe City was 104,375. Compared to population of refugees in entire Kobe City predicted by Hyogo Prefecture, there was a difference of 23,861 people. As described above, the prediction given by the formula in this study was 104,375 people, which is 80% of Hyogo Prefecture's assumption, 128,236 people. The reason is that the population of refugees in this study was focused on people staying in school refuges. In other words, people who take shelter in other places, such as parks, homes of relatives, and community centers, were not included when making the prediction. However, the percentage of refugee population in school refuges during the Great Hanshin Earthquake was over 60% of the refugee population in entire Kobe City. The percentage is close to the prediction in this study when compared to the refugee population in entire Kobe City predicted by the Hyogo Prefectural Government.

When comparing each administrative ward, there is a large difference between this study and prediction offices of each ward for Nagata and Tarumi Wards. The difference reflects the fact that the conflagration in these two wards would have influenced the prediction in this study, because burnt down buildings have a negative relationship with the refugee population in this study. For this reason, the prediction made in this study is lower for both Nagata and Tarumi Wards.

Table 3. Prediction of collapsed buildings, burnt down buildings, and refugee population in every ward of Kobe City

Ward	C.B	B.B	P.B	P.R	P.R (H.P)
Higashinada	12,246	1,007	1.43	15,750	35,043
Nada	11,414	1,432	1.06	16,173	20,206
Hyogo	8,529	2,896	1.11	17,615	15,183
Nagata	13,887	14,660	1.3	51,318	20,356
Suma	6,886	1,254	0.68	12,217	12,162
Tarumi	1,052	3	2.83	4,553	3,598
Kita	242	3	5.92	3,925	1,356
Chuo	5,676	200	1.35	8,631	19,305
Nishi	390	0	1.88	4,032	1,027
Kobe City	60,322	21,455	1.95	104,375	128,236

Note.
C.B: Number of collapsed buildings in the prediction
B.B: Number of burnt down buildings in the prediction
P. B: Population of damaged buildings on average in the prediction
P. R: Population of refugees in the prediction of this study
P. R (H.P): Population of refugees in the prediction based on the data of Hyogo Prefecture

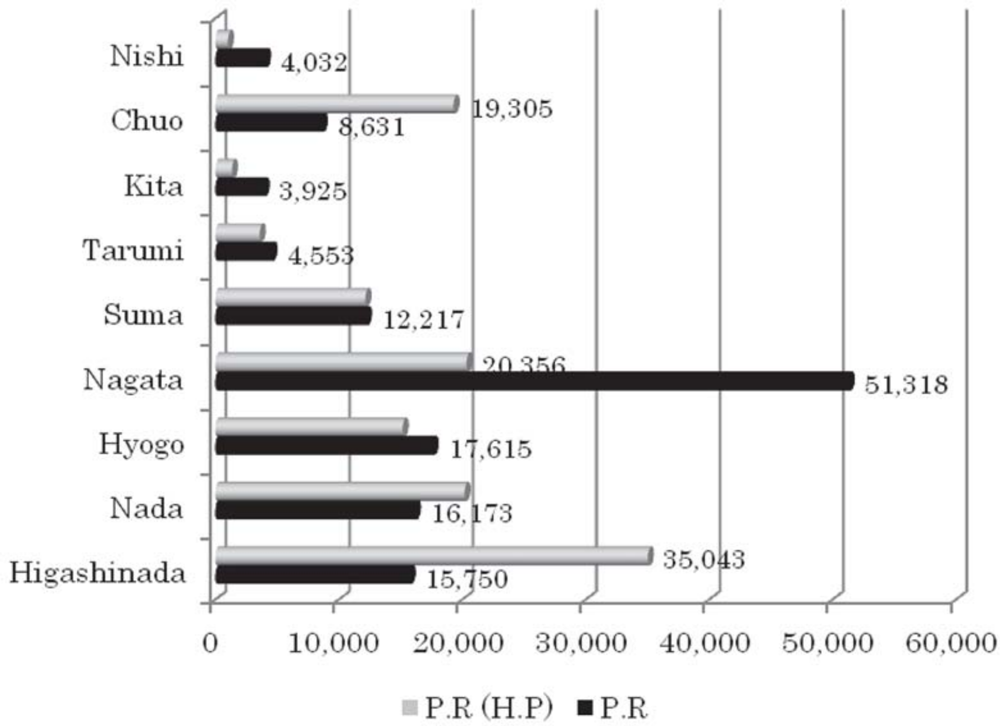

Fig. 4. Comparison of refugee populations in wards

To confirm whether the difference between this study's prediction and that of Hyogo Prefecture is statistically significant or not, a *t*-test was conducted. The *t*-test formula is expressed as:

$$t_a = \frac{\overline{y_a} - \mu_a}{\frac{s_a}{\sqrt{n_a}}} \quad . \tag{12}$$

Here,

t_a: is the t value of the refugee population in school refuges in wards.

$\overline{y_a}$: is the mean refugee population in school refuges in wards.

μ_a: is the mean refugee population in Kobe City.

S_a is the standard deviation of refugee population in school refuges in wards.

n_a is the number of wards.

When conducting the *t*-test, the null hypothesis is set with no difference between the prediction by this study and that by prediction offices. The *t*-value is 4.07 with a probability of 0.004 if the null hypothesis is rejected by mistake. Because the significance level is less than 0.01, the prediction in this study showed a significant difference from the entire population of refugees in Kobe City, and a random error with a probability of only 0.4% could hardly result in overestimation. The probability of error is so small that the 80% prediction of refugee population in school refuges in school districts of all refugees in Kobe City can be supported by the confidence interval.

Furthermore, the prediction of refugee population in three wards shows a large difference (more than twice) from the prediction of Hyogo Prefecture. These wards are Higashinada, Nagata, and Chuo Wards. In order to explain the reason for the difference, we will give an illustration of these three wards from the viewpoint of data used for prediction.

(1) Higashinada Ward

In Higashinada Ward, the potential refugee population predicted by this study is 15,750 people, with a refugee population of 35,043 as predicted by Hyogo Prefecture in entire Kobe City, which is a multiplication of 27% the percentage of the refugee population in Higashinada Ward in the Great Hanshin Earthquake. The difference between these two predictions is 19,293 people. The reason for the difference is that we only use data on collapsed buildings and burnt down buildings to predict the refugee population in the same district. However, in the Great Hanshin Earthquake, refugees who took shelter in schools are not only from the same district; some of them are from other school districts and wards. For this reason, when prediction of whole Kobe City conducted by Hyogo Prefecture is multiplied by the percentage (27%) of the refugee population in Higashinada in the Great Hanshin Earthquake, the predicted refugee population will be much larger than that predicted by this study. The difference of 19,293 refugees implies that they are from other wards or those taking shelter not because of collapsed or burnt down houses but because, for example, of damage to the water supply system or emotional factors.

(2) Nagata Ward

In Nagata Ward, the refugee population predicted by this study is 51,318 people, with 20,356 people predicted by Hyogo Prefecture in entire Kobe City, which is a multiplication of 16%; this is the percentage of the refugee population in Nagata Ward in the Great Hanshin Earthquake. The difference between these two predictions is 30,962 people, and the prediction of this study is larger than Hyogo Prefecture's. The reason is that the number of burnt down buildings (6,814) in Nagata Ward in the Great Hanshin Earthquake was greater than in other wards, and many residents died or were injured by conflagration of their houses. In the study, we use the number of collapsed buildings and number of burnt down buildings to predict the refugee population; the greater the number of damaged buildings, the greater the refugee population. However, deceased residents and people who cannot evacuate are not calculated in equation (9). As a result, when the prediction of entire Kobe City conducted by Hyogo Prefecture is multiplied by 16% in the Great Hanshin Earthquake, the prediction was much lower than the prediction of this study. The percentage shows the living refugee population, but the prediction of this study only shows the people who might take the shelter because their houses have burnt down or collapsed. Furthermore, the statistics on damaged buildings in Nagata Ward may have suffered double counting of burnt down and collapsed buildings. The data on building damage in Nagata Ward should be revised again based on other reliable resources, besides the data of the Building Research Institute.

(3) Chuo Ward

The refugee population predicted by this study is 8,631 people, with 19,305 refugees predicted by Hyogo Prefecture in entire Kobe City, which is a multiplication of 15.8%, or the percentage of the refugee population in Chuo Ward in the Great Hanshin Earthquake. The case of Chuo Ward is like Higashinada Ward, the extreme difference being a result of refugees from other school districts or wards. Moreover, there are refugees who evacuate for other reasons, besides collapsed and burnt down houses. In particular, there were many downtown refuge sites in Chuo Ward during the period of the Great Hanshin Earthquake accommodating many refugees from other wards. The difference of 10,674 people shows the refugee population from other wards and evacuation for other reasons than collapsed and burnt down houses.

CONCLUSION

In this study, the prediction effectiveness for school districts is 65% and 70% for the administrative wards. When considering the prediction effectiveness between individual variables, the number of collapsed buildings was a powerful factor in predicting refugee population, but in school districts with conflagration, it was powerless to predict the refugee population. This is because the death of residents caused by conflagration as well there being refugees from other school districts influenced the relationship between the independent and the dependent variables.

Regarding application of the formula, this study also conducted a comparison of prediction outcomes from this study and those from the Hyogo Prefectural Government. The prediction of refugee population in this study was 80% (104,375 people) of the refugee population (128,236 people) in entire Kobe City predicted by Hyogo Prefecture. According to the *t*-test, the difference approached statistical significance. Therefore, the prediction in this study was proven, and the percentage was also supported by the data on the Great Hanshin Earthquake. An irregular difference was found between individual wards in the refugee population. This was because the prediction by Hyogo Prefecture was for entire Kobe City, but not for each ward. The prediction for each ward from the prediction office was based on the percentage of the refugee population of each ward in the Great Hanshin Earthquake. For this reason, there was an irregular difference in prediction between this study and that of the prediction office in each ward. Continuous exploration of further information about the prediction of each ward by other offices or other institutions would enable a comparison with the prediction of this study for a more accurate outcome.

Based on the above findings, the contribution of this study encompasses several points. First, the prediction of refugee population in this study can include school districts and administrative wards with significant statistical levels. The equation formula shows the influence of damaged buildings on the refugee population, which provides more detail than using the seismic intensity of an earthquake as an independent variable. Finally, the prediction of school refugee population enables an accurate calculation of essential relief supply and the adoption of more effective rescue action as a basic reference for policy-making in disaster prevention and urban planning.

Future research would be to investigate how to predict the refugee population among those who do not take shelter in school refuges and to improve the prediction effectiveness. Controlling the influence of intermediary variables, such as refugees from other school districts and fatality count, could apply to predictions made by other cities. In the Great East Japan Earthquake on March 11, 2011, besides schools, other refuge sites also played an important role as refugee accommodation and supply distribution.

Based on the survey conducted by the Cabinet Office of the Japan Government and the Reconstruction Headquarters in Response to the Great East Japan Earthquake on June 2nd and September 22nd, the refugees in schools and public halls in Fukushima, Miyagi, Iwate, and other prefectures damaged in the Earthquake were 41,143 people on June 2nd and 2,840 people on September 22nd. The refugees taking shelter in hotels were 28,014 people on June 2nd and 4,337 people on September 22nd. Those taking refuge at relatives' or friends' houses were 32,483 on June 2nd and 17,683 on September 22nd. Refugees living in temporary housing, hospitals, and other prefabricated houses were 22,954 people on June 2nd and 2,840 people on September 22nd. From the whole image of the change in refugee population in different refuge sites, compared to the Great Hanshin Earthquake, because many schools and designated refuge sites were destroyed by the tsunami caused by the earthquake, the refugee population taking shelter in hotels is greater than in the Great East Hanshin Earthquake. Moreover, the population in temporary housing, hospitals, and other prefabricated houses continued increasing from June to September. The phenomenon indicates that refugees selected temporary housing and other public prefabricated houses to live in for middle- and long-term refuge.

The data on the Great East Japan Earthquake described above should be regarded as an important reference and adjusted to the equation of the formula developed in the study. Finally, building a prediction model to fit not only west Japan, but also northeast Japan in urban areas, rural areas, and harbor villages and providing suggestions for the planning of disaster prevention in different areas are essential in future research.

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