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Study on Quantitative Evaluation Method for Earthquake Disaster Prevention Potential Based on Statistical Information

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Abstract

Recently, after 2011 Great East Japan Earthquake Disaster, many earthquakes which occurred large damages in Japan, for examples, 22 Nov. 2014 Northern Nagano Eq. (M6.7), 14 Apr. 2016 Kumamoto Eq. (M6.5), 16 Apr. 2016 Kumamoto Eq. (M7.3), 26 Oct. 2016 Central Shimane Eq. (M6.6), 18 Jun. 2018 Northern Osaka Eq. (M6.1) and 06 Sep. 2018 East Iburi Hokkaido Eq. (M6.7). These were middle scale earthquakes of magnitude about 7.0 and occurred inland along to active faults. Those earthquakes were distributed at the hole areas in Japan.

The 1995 Hanshin-Awaji Earthquake Disaster caused very serious damage to large cities in the Hanshin District, west part of Japan, mainly to Kobe City, Hyogo Prefecture. Since this devastated earthquake disaster, national government and each prefecture or municipality has been carrying out various studies concerning earthquake prevention measures according to the earthquake damage assessment. Off course, the earthquake damage assessment is very important for disaster response measures and, in general, it includes the acceptable damage evaluation due to the experimental and statistical relationship between the seismic intensities and damages.

However, considering for the future earthquake disaster prevention, the relationships between regiona1 characteristics and earthquake disaster scales have not yet necessarily been clarified, and studies regarding methods of identifying the high priority areas for earthquake disaster prevention in Japan are considered to be not yet thoroughly done. Urban earthquake disaster prevention potential is constituted from two situations. One is the natural situation related to the conditions (topography, ground, seismic source environment, etc.), and the other is urban space structures (building distribution with height, material and several characteristics, road and train lines network rate, lifeline network, etc.) including various urban facilities in each area, and the social system (population and its density, characteristics of residents, population migration, distribution of weak persons when disaster has occurred, etc.) and the disaster-preventive capability of the area (human and materia1 resources for fire-fighting, medical resources, number of administrative officials, and voluntary disaster-prevention organizations, etc.)

In this research, we have studied a method for comprehensive and quantitative evaluation of various disaster-expanding factors and disaster-restraining factors in urban areas when a big earthquake disaster is occurred, carried out trial calculation of earthquake disaster prevention potential(EDPP) in 13 cities (now, expanded to 21 cities) specially designated by government ordinance in Japan. These cities are big cities in Japan and already summarized and published the statistical information as urban characteristic data comparing the situation of city development. So, we used the statistical information and analyzed the efficient numerical weight as for the disaster-expanding factors and the disaster-restraining factors by using the Hayashi's quantification methods. Finally, we calculated the numerical value of the earthquake prevention potential for these 13 cities and compared each other. According to the result, we understand the difference of earthquake disaster prevention potential(EDPP) between these 13 cities and the priority cities for earthquake disaster prevention in Japan.

Keywords: earthquake disaster; Facilities and Social situation; statistical information; earthquake disaster prevention potential (EDPP)

1. Introduction

The 1995 Hyogo-ken Nanbu Earthquake (M7.3), generally called Hanshin-Awaji Great Earthquake Disaster, was occurred in 17th January at 5:46 am (Local time) and more than 6,000 peoples were killed, more than 40,000 peoples were injured and also more than 200,000 buildings were collapsed, many transportation, harbor, lifeline facilities were destroyed due to this earthquake. Almost all urban function around Kobe City was stopped just after the earthquake occurrence [1], [2], [3]. Then, many social systems were influenced and continued during long time after the earthquake. The characteristics of experiences of this earthquake was pointed out that it was multi-urban type seismic disaster generated by directly just under shallow big earthquake. The main causes to occurrence of such a large disaster was that the seismic activity was very low and so the awareness to seismic risk was very low, then the local government and residents living in this area didn't pay attention to the seismic disaster before the earthquake occurrence. According to this experiments of earthquake disaster, many discussion and countermeasures related to earthquake disaster prevention were considered against to the various facilities, buildings, bridges, highways, transportation systems, life line systems and also human society activity toward the disaster mitigation. Although, the causes for earthquake disaster generation are related to seismic disaster and various parameters are complexly related each other mutually, so it's very difficult to estimate the earthquake disaster exactly [4], [5]. Also, because of the difficulty to identify the active fault possible to future movement and predict the exact occurrence, it is very important to make the consensus of seismic risk and to understand the awareness to earthquake disaster and to identify the most risky area in order to develop the earthquake disaster prevention.
For this purpose, it is very useful to utilize the published statistic information data related to the areal characteristics based on same format. And it's very important to classified in detail common indexes and items summarized by own local government. According to these indexes and items, it's possible to estimate the seismic disaster vulnerability and compare the risk against to seismic disaster and then it's possible to consider and develop the seismic disaster prevention measures under disaster management plan [6], [7], [8].
In the 1995 Hanshin-Awaji Great Earthquake Disaster, Kobe City, a big city in west part of Hanshin District, including Nishinomiya City, Ashiya City, was affected destructively serious damages. The statistical data, summarized in indexes and items about social information data which are existing in the city and characterized the city. These data are covered widely distributed information of the city, so we think that these statistic indexes and items are related to the seismic disaster and they will be indicated the internal factor of seismic disaster. It's related to the seismic disaster as shown in Fig. 1. Off course, as the external factor for seismic disaster directly, the seismic activity, location of seismic fault and expected magnitude are also very important information for seismic disaster and should be considered in other way. We think that it's possible to understand the seismic vulnerability based on the statistic indexes and items.

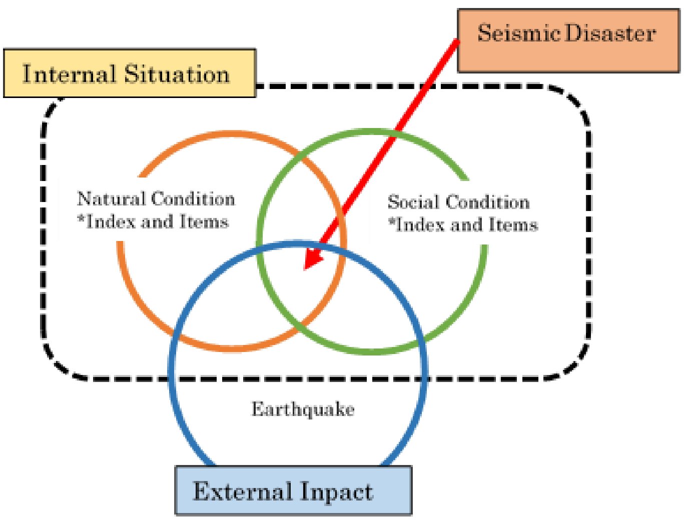


Fig. 1 Concept of seismic disaster

In this paper, we tried to approach the seismic vulnerability evaluation by using the statistic indexes and items published as “The Annual Statistic Tables on Comparison between Big Cities” [9]. At first step, we selected the several indexes and items related to seismic disaster, and then we summarized these index and items and also we classified and settled the weight as a numerical value for index and items, respectively. Then, after integrate these numerical values for each index and item in order to evaluate the seismic vulnerability. Finally, we compared the calculated value for each city as inter-city comparison of seismic disaster vulnerability.
After the 1995 Hanshin-Awaji Great Earthquake Disaster, NIED had started to open the calculated result for seismic hazard as in the National Seismic Hazard Maps for Japan in J-SHIS system on internet [10]. By using this information, we picked up the result of expected probability for earthquake occurrence of more than 6- intensity, in Japanese Seismic Intensity Scale, within 30 years at each city. And then, we compared with the final result of seismic disaster vulnerability evaluation. We would like to introduce the results.

Table 1 List of objected big cities

No.	City Name	Land Area (Sq. km)	Population (Person)	Density (Person/Sq. km)
1	Sapporo	1121.12 (1)	1,733,077 (5)	1,546 (11)
2	Sendai	788.05 (2)	951,908 (12)	1,210 (13)
3	Chiba	272.36 (11)	851,701 (13)	3,127 (7)
4	Tokyo	621.00 (4)	8,067,703 (1)	12,991 (1)
5	Kawasaki	143.85 (13)	1,199,934 (9)	8,342 (3)
6	Yokohama	433.18 (8)	3,291,144 (2)	7,598 (4)
7	Nagoya	326.37 (10)	2,158,873 (4)	6,615 (5)
8	Kyoto	610.21 (5)	1,451,897 (7)	2,379 (9)
9	Osaka	220.53 (12)	2,666,483 (3)	12,091 (2)
10	Kobe	545.78 (6)	1,510,735 (6)	2,768 (8)
11	Hirosima	740.27 (3)	1,103,107 (10)	1,490 (12)
12	Kitakyushu	482.86 (7)	1,020,670 (11)	2,114 (10)
13	Fukuoka	336.81 (9)	1,270,279 (8)	3,772 (6)

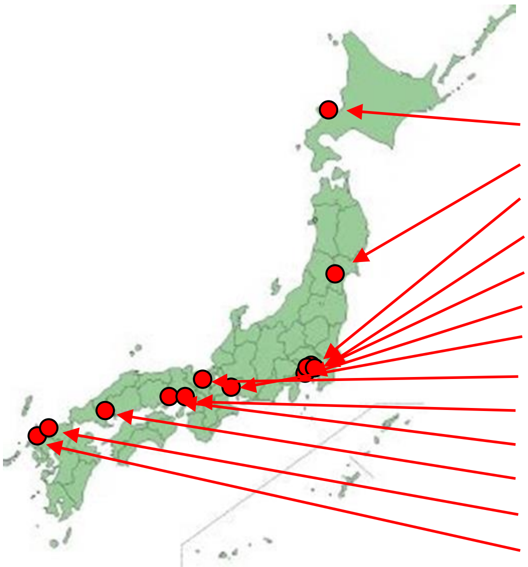


Fig. 2 Location of objected big cities

2. Obtaining of Statistic Data

In “The Annual Statistic Tables on Comparison Between Big Cities” published in 1995, same year of the Hanshin-Awaji Great Earthquake Disaster, 13 big cities in Japan are indicated and summarized in same format. So, we used these statistic data. The location and basic statistic data of these cities are indicated in Fig. 2 and Table 1. As indicated in the table, except Sendai City and Chiba City, other cities have large population, more than 1,000,000, and main cities in Japan. Also, these cities are important for economy and culture in each region. In these cities, Kobe City where affected serious damages due to the 1995 Hanshin-Awaji Great Earthquake Disaster. “The Annual Statistic Tables on Comparison between Big Cities” was published every year and reported on city’s activity and compare the basic political statistic information between 13 big cities, and then it’s presented the presence of city policy and management, but it’s not reported directly on disaster prevention.
The contents of statistic data are widely summarized in 21 social indexes, In this study, we selected 30 items from 8 indexes as shown in Table 2. For 30 items indicated in Table 2, we calculated the normalized value by population or city the land area because these values were used for comparison between 13 big cities each other. At first, we have drew the histogram of selected 30 items in order to understand the distribution for

classification, respectedly. And then, considering the distribution of normalized statistic values, we classified the city's characteristics into 4 classes, from A to D. This classification was indicated in Table 3. Basically, we classified the all items, 30 items, into 4 classes, from A to D. Class A is the highest class and inversely class D is the lowest and class B, C are middle classes between A and D.

Table 2 Extracted items of urban statistic information data

Index	Item
1. Land & Population	[1] Population Density (Person/Sq. km)
	[2] Land Area Ratio of Land Use Category (%)
	[3] Area Ratio of Urbanization-area (%)
	[4] Area Ratio of Densely Inhabited District (DID) (%)
	[5] Population Raito of Densly Inhabited District(DID) (%)
	[6] Population Density of Densely Inhabited District(DID) (Person/Sq. km)
2. Economical Bases	[7] Shipment Value of Manufactured Goods (Per Person)
	[8] Sales of Manufactured Goods (Per Person)
3. Finance	[9] Index of Local Finance
	[10] Closing Accounts of Annual Expenditure (Per Person)
4. School Education	[11] Area of Public School Site (Sq. m/Person)
5. Family Finance	[12] Practical Income of Labor's Household
	[13] Ratio of Household Number Clasified Income (%)
6. Living Environment	[14] Practical Length of Road (km/Sq. km)
	[15] Number of Automobile Hold (Per 1000 Person)
	[16] Area of City Park (Sq. m/Person)
	[17] Ratio of Residence Number on Classified Site Area (%)
	[18] Ratio of Residence Number on Constructed Age (%)
	[19] Spred Ratio of Sewerage (%)
	[20] Amount of Water Suply Per Year (Cb. m/Person)
	[21] Amount of City Gas Consumption Per Year (kcal/Person)
	[22] Amount of Electric Power Consumption Per Year (kwh/Person)
	[23] Spead Ratio of Subscribed Telephone (Per 1000 Person)
7. Health and Medical Care	[24] Number of General Hospital (Per 100,000 Person)
	[25] Number of Clinic (Per 100,000 Person)
	[26] Number of Medical Doctor (Per 100,000 Person)
	[27] Number of Nurse (Per 100,000 Person)
8. Safety	[28] Number of Staffs in City (Metropolice) (Per 10,000 Person)
	[29] Number of Police Officer (Per 100,000 Person)
	[30] Number of Stuff in Fire Department (Per 100,000 Person)

Table 3 Settlement for classification values of each extracted item (x: normarized statistic value)

Index and Items		Classification of Index and Item Characteristic			
		A	B	C	D
1. Land & Population	[1] Population Density (Person/Sq. km)	8000<X	5000<X<8000	2000<X<5000	X<2000
	[2] Land Area Ratio of Land Use Category (%)	80<X	50<X<80	20<X<50	X<20
	[3] Area Ratio of Urbanization-area (%)	80<X	60<X<80	40<X<60	X<40
	[4] Area Ratio of Densely Inhabited District (DID) (%)	80<X	50<X<80	20<X50	X<20
	[5] Population Raito of Densly Inhabited District(DID) (%)	80<X<50	50<X<80	20<X<50	X<20
	[6] Population Density of Densely Inhabited District(DID) (Person/Sq. km)	10000<X	6000<X<10000	5000<X<6000	X<5000
2. Economical Bases	[7] Shipment Value of Manufactured Goods (Per Person)	3.0<X	2.0<X<3.0	1.0<X<2.0	X<1.0
	[8] Sales of Manufactured Goods (Per Person)	20<X	10<X<20	5<X<10	X<5
3. Finance	[9] Index of Local Finance	1.2<X	1.0<X<1.2	0.8<X<1.0	X<0.8
	[10] Closing Accounts of Annual Expenditure (Per Person)	60<X	50<X<60	40<X<50	X<40
4. School Education	[11] Area of Public School Site (Sq. m/Person)	3.0<X	2.5<X<3.0	2.0<X<2.5	X<2.0
5. Family Finance	[12] Practical Income of Labor's Household	600<X	500<X<600	400<X<500	X<400
	[13] Ratio of Household Number Clasified Income (%)	80<X	50<X<80	40<X<50	X<40
6. Living Environment	[14] Practical Length of Road (km/Sq. km)	15<X	10<X<15	5<X<10	X<5
	[15] Number of Automobile Hold (Per 1000 Person)	500<X	400<X<500	300<X<400	X<300
	[16] Area of City Park (Sq. m/Person)	8.0<X	6.0<X<8.0	4.0<X<6.0	X<4.0
	[17] Ratio of Residence Number on Classified Site Area (%)	70<X	50<X<70	30<X<50	X<30
	[18] Ratio of Residence Number on Constructed Age (%)	30<X	20<X<30	10<X<20	X<10
	[19] Spred Ratio of Sewerage (%)	90<X	80<X<90	70<X<80	X<70
	[20] Amount of Water Suply Per Year (Cb. m/Person)	0.2<X	0.15<X<0.2	0.1<X<0.15	X<0.1
	[21] Amount of City Gas Consumption Per Year (kcal/Person)	4.0<X	3.0<X<4.0	2.0<X<3.0	X<2.0
	[22] Amount of Electric Power Consumption Per Year (kwh/Person)	6.0<X	5.0<X<6.0	4.0<X<5.0	X<4.0
	[23] Spead Ratio of Subscribed Telephone (Per 1000 Person)	700<X	600<X<700	500<X<600	X<500
7. Health and Medical Care	[24] Number of General Hospital (Per 100,000 Person)	10.0<X	8.0<X<10.0	6.0<X<8.0	X<6.0
	[25] Number of Clinic (Per 100,000 Person)	100<X	80<X<100	60<X<80	X<60
	[26] Number of Medical Doctor (Per 100,000 Person)	250<X	200<X<250	150<X<200	X<150
	[27] Number of Nurse (Per 100,000 Person)	800<X	600<X<800	500<X<600	X<500
8. Safety	[28] Number of Staffs in City (Metropolice) (Per 10,000 Person)	140<X	120<X<140	100<X<120	X<100
	[29] Number of Police Officer (Per 100,000 Person)	600<X	400<X<600	200<X<400	X<200
	[30] Number of Stuff in Fire Department (Per 100,000 Person)	140<X	120<X<140	100<X<120	X<100

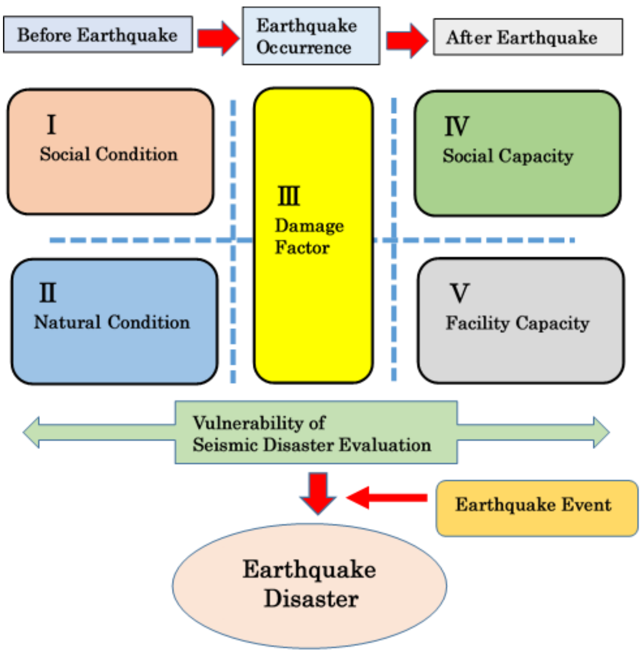


Fig. 3 Evaluation of seismic disaster vulnerability due to inner factors

3. Data Arrangement for Relative Evaluation

Considering the characteristics of histogram for 30 items, the items which were not appeared clear difference between cities and the items which were similar contents and tendency in histogram distribution selected only one item and the other items were canceled. In this study, we tried to perform the inter-cities comparison of seismic disaster vulnerability evaluation settled by using above mentioned relative evaluation for classification of each items. As mentioned above, the external factor, seismic fault and expected seismic intensity etc. are not considered in this relative evaluation. As generally understanding, in the 1995 Hanshin-Awaji Great Earthquake Disaster, the characteristics of urban type seismic disaster is very multi-aspect and complex related many items. This multi-aspect is strongly influenced by internal factors existed in each city and it's not directly related with above mentioned external factor. And these internal factors are possible to relate with the time dependence in time from before and after occurrence of earthquake. That is to say, as indicated in Fig. 2, three time periods, the before period (period before the earthquake occurrence), the occurrence period (period just occurred the earthquake event) and the after period (period after the earthquake occurrence) are considered. In this 3 periods, the before period is divided "I. Social condition", "II. Natural condition". And the occurrence period is summarized to "III. Damage Affected Condition" and the after period is divided to "IV. Social Capacity" and "V. Facility Capacity". Considering above, we arranged the items of statistic data, indicated in Table 4, to the result as indicated in Table 5. And we thought that the items which are contributed to reduce the seismic disaster or seismic damages, in this case, we put the weight in "+" as the disaster prevention factor and, inversely, the items which are contribute to amplify the seismic disaster or seismic damages, in this case, we put the weight in "-" as the disaster expand factor. Finally, as consideration of data analysis, we put the integer value to directly proportional in case of "+" weight, and to inverse proportional in case of "-" weight. The weight values are settled as indicated in Table 6 referred the divided contents, A - D, which are indicated as the characteristics based on the 30 items at the beginning. According to this settlement, higher weight value means lower seismic vulnerability and inversely lower weight value means higher seismic vulnerability. Actually, we think that the weight values are very important and complex in relation with this paper, so it's necessary to perform the multi-variable statistical analysis in order to confirm the weight value, unfortunately there are no information about the statistical data in past experienced seismic disaster. Then, we put the weight values as assumed values from experienced imagination.

Table 4 Inner-cities comparison of classification on each extracted item

Index and Items		City Number (*Refere on Table 1)												
		1	2	3	4	5	6	7	8	9	10	11	12	13
1. Land & Population	[1] Population Density (Person/Sq. km)	D	D	C	A	A	B	B	C	A	C	D	C	C
	[2] Land Area Ratio of Land Use Category (%)	C	C	C	A	B	B	B	C	A	C	C	C	C
	[3] Area Ratio of Urbanization-area (%)	C	D	C	A	A	B	A	D	A	D	C	C	C
	[4] Area Ratio of Densely Inhabited District (DID) (%)	D	D	C	A	A	B	A	C	A	C	D	C	C
	[5] Population Raito of Densly Inhabited District(DID) (%)	A	A	A	A	A	A	A	A	A	A	A	A	B
	[6] Population Density of Densely Inhabited District(DID) (Person/Sq. km)	C	C	C	A	B	B	B	A	A	A	C	C	A
2. Economical Bases	[7] Shipment Value of Manufactured Goods (Per Person)	D	C	C	C	A	C	B	B	B	B	B	B	D
	[8] Sales of Manufactured Goods (Per Person)	C	B	C	A	D	D	A	C	A	C	B	D	B
3. Finance	[9] Index of Local Finance	D	C	B	A	B	C	B	D	B	C	C	D	D
	[10] Closing Accounts of Annual Expenditure (Per Person)	C	C	D	A	C	C	C	C	A	A	B	B	B
4. School Education	[11] Area of Public School Site (Sq. m/Person)	B	A	A	D	D	C	C	C	D	C	A	A	A
5. Family Finance	[12] Practical Income of Labor's Household	B	B	B	A	B	A	B	B	B	C	C	C	B
	[13] Ratio of Household Number Clasified Income (%)	B	B	C	B	C	D	B	B	A	B	B	A	A
6. Living Environment	[14] Practical Length of Road (km/Sq. km)	D	D	B	A	A	A	A	C	A	C	C	C	B
	[15] Number of Automobile Hold (Per 1000 Person)	B	A	B	C	C	B	A	B	C	C	B	B	C
	[16] Area of City Park (Sq. m/Person)	A	C	C	D	D	D	B	D	D	A	B	A	B
	[17] Ratio of Residence Number on Classified Site Area (%)	D	D	D	B	C	C	C	B	A	C	C	D	D
	[18] Ratio of Residence Number on Constructed Age (%)	C	C	B	B	B	B	A	A	A	A	B	A	B
	[19] Spred Ratio of Sewerage (%)	A	B	D	A	B	A	A	A	A	A	C	A	A
	[20] Amount of Water Suply Per Year (Cb. m/Person)	C	C	A	B	B	C	B	B	A	C	C	C	C
	[21] Amount of City Gas Consumption Per Year (kcal/Person)	D	D	C	B	A	C	B	B	A	C	D	D	D
	[22] Amount of Electric Power Consumption Per Year (kwh/Person)	D	C	C	A	A	C	A	B	A	B	B	A	B
	[23] Spead Ratio of Subscribed Telephone (Per 1000 Person)	C	C	D	A	C	D	B	C	A	C	C	C	A
7. Health and Medical Care	[24] Number of General Hospital (Per 100,000 Person)	A	D	D	C	D	D	B	B	B	C	C	C	B
	[25] Number of Clinic (Per 100,000 Person)	C	C	C	A	C	C	C	A	A	B	B	B	B
	[26] Number of Medical Doctor (Per 100,000 Person)	B	B	C	A	C	C	B	A	A	B	B	B	B
	[27] Number of Nurse (Per 100,000 Person)	A	B	C	B	D	D	B	A	A	B	A	A	A
8. Safety	[28] Number of Staffs in City (Metropolice) (Per 10,000 Person)	C	C	D	B	C	C	A	B	A	B	B	C	D
	[29] Number of Police Officer (Per 100,000 Person)	D	D	D	C	D	D	B	D	A	D	D	D	D
	[30] Number of Stuff in Fire Department (Per 100,000 Person)	D	D	C	A	C	D	C	B	B	D	C	D	D

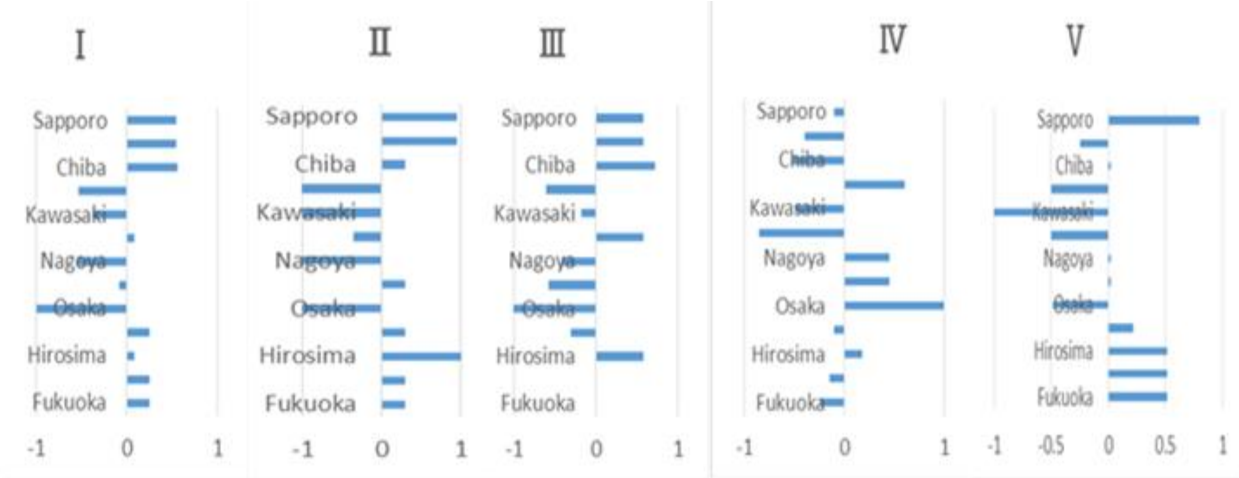


Fig. 4 Relative evaluation of index for seismic disaster vulnerability

In this study as a trial analysis, we performed the seismic vulnerability evaluation by simple method using the weight values indicated in Table 6. In "IV. Social Capacity", Osaka, Tokyo, Nagoya and Kyoto City indicate high value in "+", Yokohama, Kawasaki and Chiba City indicate low value in "-". In "V. Facility Capacity", Sapporo, Hiroshima, Kitakyushu and Fukuoka City indicate high Value in "+" and inversely Kawasaki City indicate very low value in "-", Also, Kobe City indicate middle value in all 13 cities in the I - V factors.

Table 5 Correspond table of index for seismic disaster vulnerability evaluation and extracted items

Factors for Seismic Vulnerability Evaluation	Selected Items
(I) Social Condition	[1] Population Density (Person/Sq. km)
	[3] Area Ratio of Urbanization-area (%)
	[7] Shipment Value of Manufactured Goods (Per Person)
	[8] Sales of Manufactured Goods (Per Person)
	[9] Index of Local Finance
	[10] Closing Accounts of Annual Expenditure (Per Person)
	[12] Practical Income of Labor's Household
	[17] Ratio of Residence Number on Classified Site Area (%)
(II) Natural Condition	[2] Land Area Ratio of Land Use Category (%)
	[4] Area Ratio of Densely Inhabited District (DID) (%)
	[5] Population Raito of Densly Inhabited District(DID) (%)
(III) Damage Factor	[6] Population Density of Densely Inhabited District(DID) (Person/Sq. km)
	[14] Practical Length of Road (km/Sq. km)
	[15] Number of Automobile Hold (Per 1000 Person)
	[16] Area of City Park (Sq. m/Person)
	[18] Ratio of Residence Number on Constructed Age (%)
	[19] Spred Ratio of Sewerage (%)
	[20] Amount of Water Suply Per Year (Cb. m/Person)
	[21] Amount of City Gas Consumption Per Year (kcal/Person)
	[22] Amount of Electric Power Consumption Per Year (kwh/Person)
	[23] Spead Ratio of Subscribed Telephone (Per 1000 Person)
(IV) Social Capacity	[26] Number of Medical Doctor (Per 100,000 Person)
	[27] Number of Nurse (Per 100,000 Person)
	[28] Number of Staffs in City (Metropolice) (Per 10,000 Person)
	[29] Number of Police Officer (Per 100,000 Person)
	[30] Number of Stuff in Fire Department (Per 100,000 Person)
(V) Facility Capacity	[11] Area of Public School Site (Sq. m/Person)
	[13] Ratio of Household Number Clasified Income (%)
	[16] Area of City Park (Sq. m/Person)
	[24] Number of General Hospital (Per 100,000 Person)
	[25] Number of Clinic (Per 100,000 Person)

Table 6 Settlement of weight value for each extracted item

Index and Items of Statistic Data		Weight			
		A	B	C	D
1. Land & Population	[1] Population Density (Person/Sq. km)	0	-1	-2	-3
	[3] Area Ratio of Urbanization-area (%)	0	-1	-2	-3
	[4] Area Ratio of Densely Inhabited District (DID) (%)	0	-1	-2	-3
	[6] Population Density of Densely Inhabited District(DID) (Person/Sq. km)	0	-1	-2	-3
2. Economical Bases	[7] Shipment Value of Manufactured Goods (Per Person)	0	-1	-2	-3
	[8] Sales of Manufactured Goods (Per Person)	0	-1	-2	-3
3. Finance	[9] Index of Local Finance	3	2	1	0
4. School Education	[11] Area of Public School Site (Sq. m/Person)	3	2	1	0
5. Family Finance	[13] Ratio of Household Number Clasified Income (%)	0	-1	-2	-3
6. Living Environment	[14] Practical Length of Road (km/Sq. km)	3	2	1	0
	[16] Area of City Park (Sq. m/Person)	3	2	1	0
	[17] Ratio of Residence Number on Classified Site Area (%)	0	-1	-2	-3
	[18] Ratio of Residence Number on Constructed Age (%)	0	-1	-2	-3
	[19] Spred Ratio of Sewerage (%)	0	-1	-2	-3
	[20] Amount of Water Suply Per Year (Cb. m/Person)	0	-1	-2	-3
	[21] Amount of City Gas Consumption Per Year (kcal/Person)	0	-1	-2	-3
	[22] Amount of Electric Power Consumption Per Year (kwh/Person)	0	-1	-2	-3
	[23] Spead Ratio of Subscribed Telephone (Per 1000 Person)	0	-1	-2	-3
7. Health and Medical Care	[24] Number of General Hospital (Per 100,000 Person)	3	2	1	0
	[25] Number of Clinic (Per 100,000 Person)	3	2	1	0
	[26] Number of Medical Doctor (Per 100,000 Person)	3	2	1	0
	[27] Number of Nurse (Per 100,000 Person)	3	2	1	0
8. Safety	[28] Number of Staffs in City (Metropolice) (Per 10,000 Person)	3	2	1	0
	[29] Number of Police Officer (Per 100,000 Person)	3	2	1	0
	[30] Number of Stuff in Fire Department (Per 100,000 Person)	3	2	1	0

4. Inter-city Comparison of Seismic Vulnerability Evaluation

Using the analysis method explained above chapters, we performed the relative evaluation of factors from "I" to "V". Then we also exceeded to the seismic vulnerability evaluation of 13 cities and compared with each other. Namely, according to each factor from "I" to "V". We calculated the seismic vulnerability evaluation by adding the values from "I" to "V" at each city, respectively.

We added the weight values, "I" to "V" simply and settled to 0 in average and absolute maximum value was 1.0 and then we compared the normalized value between in 13 cities. The result was shown in Fig.3. From this figure, in "I. Social Condition", Sapporo, Sendai, Chiba City are high value "+", inversely Osaka is very low "-", Nagoya, Tokyo, Kawasaki City are following to low "-". In "II. Natural Condition", it was not so many items included, Sapporo, Sendai, Hiroshima City are relatively high value "+", inversely, Osaka, Nagoya and Tokyo were low value "-". In "III. Damage Factor", Chiba, Sapporo, Sendai, Yokohama and Hiroshima City were low value "-". The weight values of "IV" and "V" were same tendency. Then we calculated the relative seismic vulnerability evaluation based on the weight values, we added these weight vales simply using same method in the calculation of relative evaluation. The result was shown in Fig.4. From Fig. 4, Sapporo City was lowest value of seismic vulnerability evaluation and Kawasaki City was the highest value. Hiroshima, Sendai and Chiba City were low, inversely, Osaka, Tokyo, Nagoya were relatively high and Kobe, Kyoto City was evaluated in middle value.

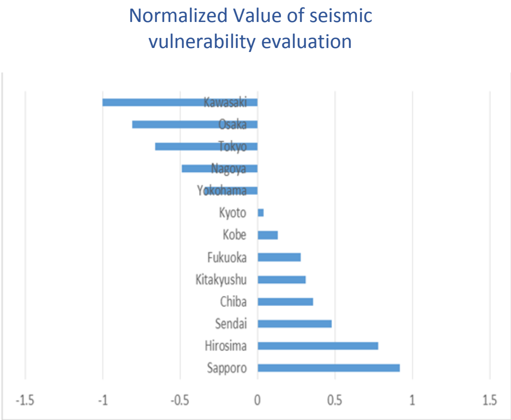


Fig. 5 Inter-cities relative comparison based on seismic disaster vulnerability evaluation

5. Seismic Hazard Estimation by J-SHIS

In Japan, after the 1995 Hanshin-Awaji Great Earthquake Disaster, NIED, National Research Institute for Earth Science and Disaster Resilience, had started to open the calculated result for seismic hazard as in the National Seismic Hazard Maps for Japan in J-SHIS system on internet. It's covered all Japanese territories based on approximately 1kmx1km meshed map as indicated in Fig.6. The most popular result is distributed as probability of earthquake occurrence expected probability during 30 years. The expected probability re-calculated every year and open the result at 1st day of January. By using this information, we used the 2008 edited version, the first calculated result in J-SHIS and most close version to the occurrence year of the Hanshin-Awaji Great Earthquake Disaster. We picked up the result of expected probability in case of exceed probability at 3 %. The result is summarized in **Table 7**. From this Table, Kawasaki, Yokohama and Nagoya City are recognized very high value which is more than 30 %, Chiba and Osaka City are also high probability and Tokyo and Hiroshima City are followed nest, more than 10%. Other cities are less than 10%. Finally, we compared the result of relative seismic vulnerability and the expected probability value obtained from J-SHIS. The result is shown in Fig. 7. According to Fig.7, Tokyo, Kawasaki, Yokohama, Nagoya and Osaka City are estimated in very high seismic vulnerability and high probability of seismic hazard map.

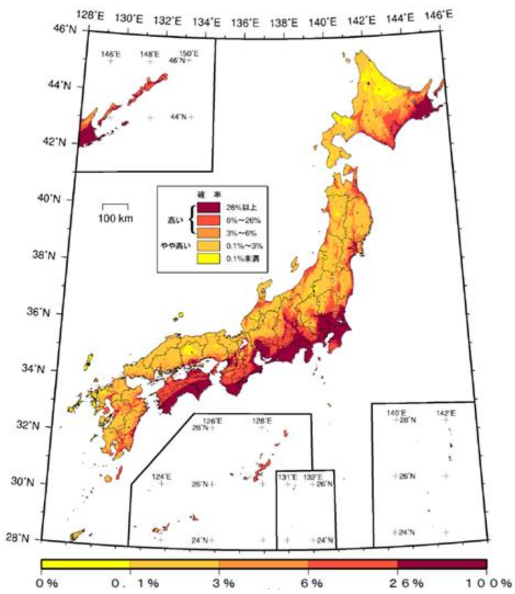
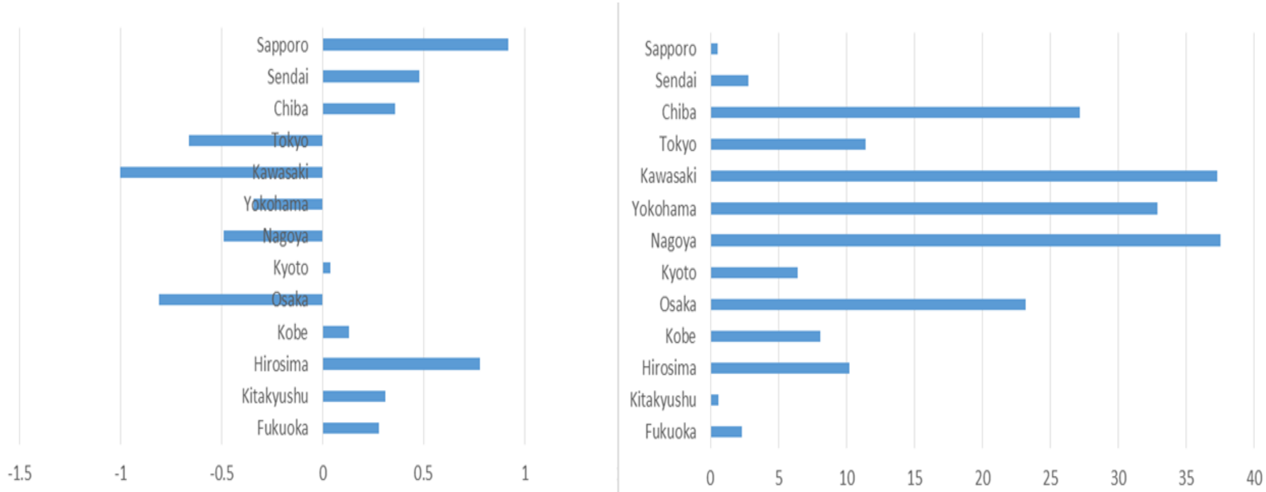


Fig. 6 Example of Seismic hazard map obtained from J-SHIS System (2018)

Table 7 Results of seismic disaster vulnerability evaluation and seismic hazard evaluation based on J-SHIS System

No.	Name	Inner Factor							J-SHIS (%)
		I	II	III	IV	V	Σ	Norm.(Σ)	
1	Sapporo	0.54	0.95	0.58	-0.1	0.8	2.77	0.92	0.5
2	Sendai	0.55	0.95	0.58	-0.4	-0.25	1.43	0.48	2.8
3	Chiba	0.56	0.3	0.72	-0.52	0.02	1.08	0.36	27.2
4	Tokyo	-0.54	-1	-0.6	0.6	-0.5	-2.04	-0.66	11.4
5	Kawasaki	-0.38	-1	-0.18	-0.5	-1	-3.06	-1	37.3
6	Yokohama	0.08	-0.35	0.58	-0.85	-0.5	-1.04	-0.34	32.9
7	Nagoya	-0.55	-1	-0.42	0.45	0.02	-1.5	-0.49	37.5
8	Kyoto	-0.08	0.3	-0.58	0.45	0.02	0.11	0.04	6.4
9	Osaka	-1	-1	-1	1	-0.48	-2.48	-0.81	23.2
10	Kobe	0.25	0.3	-0.3	-0.1	0.22	0.37	0.13	8.1
11	Hirosima	0.08	1	0.58	0.18	0.52	2.36	0.78	10.2
12	Kitakyushu	0.25	0.3	0	-0.15	0.52	0.92	0.31	0.6
13	Fukuoka	0.25	0.3	0	-0.25	0.52	0.82	0.28	2.3



(a) Relative seismic disaster vulnerability Evaluation value

(b) Provability of more than intensity 6- within 30 years by J-SHIS

Fig. 7 Comparison between seismic disaster vulnerability evaluation and seismic hazard evaluation based on J-SHIS System

6. Conclusion

In this study, we tried to estimate the relative seismic vulnerability evaluation of big cities in Japan based on the well summarized statistic information published in “The Annual Statistic Tables on Comparison between Big Cities”. The methodology was very simple and very useful for the complexity of seismic disaster, especially, urban type complex of seismic disaster, as like as Kobe City due to the 1995 Hanshin-Awaji Great Earthquake Disaster. The result shows clear difference on seismic vulnerability evaluation and we can understand the characteristics of each city. Kobe City, suffered serious damages in the 1995 Hanshin-Awaji Great Earthquake Disaster, was evaluated in middle position in this study, and Kawasaki Osaka, Tokyo and Nagoya, big cities constitute three urban mega regions in Japan, were high vulnerability. So, it's considerable, if the earthquake as same as the 1995 Hanshin-Awaji Great Earthquake Disaster, three cities will be suffered more serious damages. According to this study, we think that it's very important to make the useful methodology in order to evaluate the seismic vulnerability evaluation based on the statistic information data. Finally, we picked up the result of expected probability in case of exceed probability at 3 %. According to the result, Kawasaki, Yokohama and Nagoya City are recognized very high value which is more than 30 %, Chiba and Osaka City are also high probability and Tokyo and Hiroshima City are followed nest, more than 10%. Other cities are less than 10%. Tokyo, Kawasaki, Yokohama, Nagoya and Osaka City are estimated in very high seismic vulnerability and high probability of seismic hazard map. So, we think that these cities have very high risk for the seismic disaster in Japan.

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