WHAT IS THE 1995 GREAT HANSHIN-AWAJI EARTHQUAKE DISASTER?

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ABSTRACT

On January 17,1995,The Great Hanshini -Awaji Earthquake struck at 5:46 and many people were died. We have attempted to comprehend the key factors that determined the disaster status of the city of Kobe as revealed by the Great Hanshin-Awaji Earthquake, and compared them with those of other major Japanese cities. We have extracted indices of city characteristics for each city in Japan to enable us to evaluate each city's the vulnerablity against earthquakes based on a primary component analysis.

KEYWORDS

Earthquake , Social Conditions ,Urban System, Vulnerablity .

1. Introduction

The Great Hanshin-Awaji Earthquake struck at 5:46 a.m. on January 17, 1995, with victims including more than 6,000 dead and 40,000 injured. Approximately 200,000 buildings were damaged or destroyed, and various transportation systems including expressways and Shinkansen lines were crippled. Major port facilities were seriously damaged and the city's utilities (electricity, gas, and water supplies) practically ceased to function. This earthquake has also had substantial social effects. An outstanding feature is the complexity of the disaster in a city, caused by an earthquake directly above the focus. A major reason for the size of the disaster is that it occurred in a large city where the residents had little concern about earthquakes because they had not experienced such strong earthquake activity before.

The Japanese government calls this disaster "the Great Hanshin-Awaji Disaster". It caused social chaos everywhere in Japan, and the city of Tokyo was no exception. Tokyo authorities needed to reconsider their method of predicting a disaster caused by a large scale inland earthquake, and to replan several disaster prevention projects in local districts. They determined to conduct earthquake-proof analyses in order to prepare for strengthening of schools, hospitals, houses, and buildings belonging to fire and police departments, which would become important core facilities in any future disaster. This kind of work may be called "disaster prevention investment". Metropolitan Expressways and subways in Tokyo are presently being reinforced, or are slated for reinforcement. This work is being done because the earthquake damage and the number of victims were extremely high in the Greater Hanshin-Awaji Earthquake, and many of the seriously damaged and destroyed facilities of the city of Kobe had been constructed using the same earthquake-proof design technologies as those used in the Tokyo metropolitan area. The input earthquake magnitude for seismic design in Japan was believed by other seismically active countries to be reasonable for a country with such advanced earthquake disaster prevention technology. No-one in the world predicted that such a disaster could happen in Japan, even the world's foremost researchers and engineers in earthquake proof engineering. The Great Hanshin-Awaji Earthquake caused every kind of urban disaster except tsunami. As a result, it also caused what has been called the "collapse of the safety myth".

Although we recognized the Kansai area (the western region of Japan) as a Class 1 area for earthquake hazard, as mentioned before, administrative organizations, corporate entities, and inhabitants there had low consciousness concerning prevention of earthquake disasters. They simply believed that large earthquakes did not occur in the Kansai area. We should also point out that Japanese generally were relatively unconcerned about prevention of earthquake disasters, because recent earthquake disasters in Japan were relatively small. Except for tsunamis occurring on the Japan Sea coast, which are rare events, the numbers of dead in recent earthquakes have usually been about dozens of people. It should be stressed at this point that many cities in Japan need to reconsider the seismic design of important facilities, as Tokyo city has done, and to conduct the diagnostic and the necessary reinforcement work. It is clear that many cities in Japan have weak infrastructures, very similar to those we observed in the Great Hanshin-Awaji Earthquake. This is particularly true for cities in high seismicity areas.

Therefore, these is an urgent need to investigate the common factors which could contribute to vulnerablity in earthquake disasters (and potential prevention capability) by following the examples of the city of Ichikawa in Chiba-prefecture and 13 government appointed cities including Tokyo. At first, this investigation needs to be empirical. The city of Ichikawa was chosen because the author and other researchers are currently studying the earthquake disaster potential there. Furthermore, it is important to identify the city of Kobe among those targeted cities, and to find out which cities are more potentially hazardous. The major cities besides Tokyo selected for our investigation have mainstay functions for their local areas and their collapse would have a significant impact on Japan as well as the world. Many Japanese insist that any local area (or city) must be able to tolerate to an earthquake intensity of 7 according to I (JMA) determined by the Japan Meteorological Agency. However, this is unrealistic. We must determine scientifically what kind of city conditions or factors will cause serious vulnerablity in an earthquake disaster, and then set the priority for disaster preventive investment as an important financial and political task.

The Japanese Islands constitute a particular earthquake hazard because approximately 10% of the earth's total energy is concentrated its small land area, which comprises only 0.9% of the total land area of the earth. However, we might argue hypothetically that it is unnecessary to distribute the huge cost of disaster prevention equally all over Japan, because there are differences in seismicity from area to area, and because we know the recurrence periods of earthquakes to a certain degree. This argument was actually the motivation for our investigation and is also an important subject of future study.

Which factors determine a city's disaster preventive capability. We have attempted to identify these factors from various pieces of city information by evaluating them on the basis of a single index corresponding to each one, but this method is questionable. However, we have confirmed that similar highly reputable investigations have been conducted, although their absolute number is small. These investigations were conducted to find ways of improving disaster preventive capability in each investigated local area (city), to determine appropriate disaster preventive investment in infrastructure, to enhance disaster prevention consciousness, and to prepare for future disasters.

The Society of Seismology warned Shizuoka prefecture of the possibility of a large scale (magnitude 7) earthquake, to be called "The Tokai Earthquake", and they reinforced many public buildings (disaster preventive investment) in the areas where it is predicted. This work was administered under Large-scale Earthquake Countermeasures Act, established by the Japanese government in 1979. We carried out on-site inspections of some of this work. Consciousness of a large scale earthquake is overwhelming at the time of an emergency, but it does not last long. Disaster countermeasures in the Tokyo metropolitan area are highly regarded nationwide, but how effective are they really? As we mentioned previously, even in Tokyo they did not start reinforcing public buildings until after the Greater Hanshin-Awaji Earthquake occurred. We conducted a survey in the city of Ichikawa to assess the disaster prevention consciousness among administrative staff and the level of preparation at home by citizens. We selected the city of Ichikawa for this study because they had themselves conducted a study on the possibility of future earthquake disasters (published in 1978 and 1979) and continued their research after 1980: well before the Greater Hanshin-Awaji Earthquake. During that period, Chiba prefecture, including the city of Ichikawa, carried out similar studies (published in 1982 and 1988). Therefore, the city of Ichikawa was considered to be advanced in disaster prevention. It may be assumed that the results of their studies would be used to determine the initial actions of administrative staff and the disaster preventive capability from the viewpoint of earthquake disaster preparation by citizens in downtown Tokyo and the cities of Chiba, Kawasaki, Yokohama, and others in the Tokyo metropolitan area, which are the subject cities in this study.

In other words, it was considered that everyday disaster prevention consciousness of administrative staff, and their preparations, in each city would determine their administrative system in an emergency situation. Therefore, the results of this investigation into such consciousness and preparations had large significance in our study.

As we observe current trends, citizens' concern about earthquakes has faded considerably, even in the Tokyo metropolitan area, even though it is only a year since the Greater Hanshin-Awaji Earthquake. Idealistically, we aspire to the construction of a nonflammable town (a disaster preventive city), but we realize that this is not practical. Thus, we would like to define the purposes of our study, which are to carry out fundamental research to determine optimal countermeasures to earthquake disasters, taking into account the characteristics of the particular city, and to develop a methodology for determining such countermeasures. Thus, the city we selected in our study is merely an example, and the methodology that we developed is intended to be applicable to any city of any size and location worldwide.

2. Collection and organization of city information

The various sources of information for the fourteen selected cities in our investigation are (1) A comparative statistical almanac, (2) A statistical report on each city, (3) A fire-fighting almanac, (4) Water service statistics, (5) Appendices of land classification chart, (6) Gas line data from the Japan Gas Association, and so on. These sources contain data for 1993. The data on the disaster in the city of Kobe were obtained from the Bureau of Fire-fighting in Kobe (1995), and include a "Report on Fire-Fighting Activity during the Greater Hanshin-Awaji Earthquake", and others. We used forty items of characteristic city information in the first phase of our investigation, as shown in Table . We conducted a survey of experts in disaster prevention, based on these forty items . After receiving their responses, we selected twenty-eight items as an index of factors contributing to earthquake disasters. Finally, we determined sixteen additional items other than those concerning utilities (water and gas lines) as vital for re-organizing the data. The disaster prevention experts were earthquake disaster researchers from several universities, administrative personnel of departments related to disaster prevention, and engineers. We received 53 valid responses from them.

The following describes the procedure of our survey. First of all, we showed the forty items of characteristic city information to disaster prevention experts and asked them to determine the degree to which each item would contribute to an earthquake disaster. The forty items are listed in Table , and classified into six categories: "Nature/land", "Population and its shift", "Economics, financial administration, and home economics", "Residential environment", "Medicine", and "Administration/safety". Each item is listed with an index, which is one of five numbers (-2, -1, 0, +1, +2) indicating its contribution to an earthquake disaster. The negative (-) numbers indicate the vulnerablity of the item to earthquake disasters. Conversely, the positive (+) numbers indicate the contribution of the item to disaster prevention. The disaster prevention experts were asked to rate all of the forty items by themselves. We selected twenty-eight items and then reduced this number to sixteen. The indices of the final sixteen items were used to indicate the vulnerablity of the city to earthquakes or its disaster prevention capability.

3. Data analysis for comparing vulnerablity to earthquake disasters of selected cities

Based upon the data obtained from the disaster prevention experts, we selected various parameters for characterizing each city. To qualitatively compare vulnerablity to earthquake disasters in the selected cities, we conducted various multi-variate analyses. Figure 1 shows some of the results, which were obtained by a primary component analysis.

The twenty-eight items which we selected to characterize fourteen cities are as follows:

A. Social conditions: overall population density, DID(population density in the Density Inhabited District,daytime population index (defined as [total population] - [night time population] , which indicates the population shift based on the degree of utilization of city land), and the ratio of the number of persons over 65 to the total population, as an indication of the proportion of senior citizens in the total population.

B. Natural conditions: seismicity (this is related to the input magnitude of earthquakes for building design, and is indicated in the Japanese construction standards as 0.8 for Kitakyushu and Fukuoka; 0.9 for Sapporo, Sendai, and Hiroshima; and 1.0 for the rest), topography (the ratio of soft ground area to total city area), and the ratio of DID to total city area.

C. Damage factors: the number of low income families, the ratio of the number of small residential houses to the total number of residential houses, the ratio of the number of old residential houses (built before the amendments of the Construction Standards in 1981) to the total number of residential houses, the ratio of nonflammable old houses to the total number of residential houses, the ratio of water lines installed after 1976 to the total water lines (after 1976, design was enhanced for water and gas lines), the ratio of gas lines installed after 1976 to the total gas lines, the number of fire incidents during ordinary times (some believe that more fires will break out in areas where the number of fire incidents during ordinary time is larger).

D. Social capacity: the number of doctors per person, the numbers of nurses and medical technicians per person, the number of administrative staff per person, the number of police officers per person, the number of fire fighters per person, the number of part-time fire fighters per person, and the rate of participation in voluntary defense organizations.

E. Facility capacity: the area of elementary and middle high school land per person, the area of city park land per person, the rate of ownership of portable or cellular telephones, the number of clinics per person, and the total volume of water reservoir available for fire fighting.

A city's characteristics of vulnerablity in an earthquake disaster or disaster prevention capability is indicated by the strength of disaster preventive capability based on the city's preparation for earthquake disasters. Therefore, the time period concerned in our investigation is from the time of an earthquake's occurrence to the time emergency aid/reconstruction (construction of utilities and temporary residential houses) are established. Following the shock of the Great Hanshin-Awaji Earthquake, there have been many movements to reinforce existing improperly designed buildings constructed before the amendments to the Construction Standards in 1981. However, this is not financially feasible for all buildings and earthquake proofing will in reality be limited to public buildings. At present, actions are being taken to install many earthquake measuring instruments based on the CUBE system of Los Angels, California, U.S.A., and to establish management organizations for administration, life lines and support systems for emergency aid to residents.

We selected the sixteen items because we observed that the analysis of the primary components of the twenty-eight items showed some ambiguity (low cumulative contribution rate). The sixteen items for the fourteen cities are as follows:

A. Social conditions: overall population density, population density in the DID, the ratio of the number of persons over sixty-five to the total population.

B. Natural conditions: seismicity, topography (the ratio of soft ground area to the total city area).

C. Damage factors: the ratio of the number of small residential houses to the total number of residential houses, and the ratio of nonflammable old houses to the total number of residential houses.

D. Social capacity: the number of doctors per person, the numbers of nurses and medical technicians per person, the number of fire fighters per person, the number of fire men per person.

E. Facility capacity: the area ratio of roads per person, the area of city parks per person, the number of general hospitals per person, the number of clinics per person, and the total water reservoir volume available for fire fighting.

4. Comparison of vulnerablity against earthquakes among Japanese cities

How should the city of Kobe, the central city of the Great Hanshin-Awaji Earthquake, be classified in relation to other cities in Japan from the viewpoint of vulnerablity against earthquakes? Figure 1 indicates five categories of vulnerablity against earthquakes. Figure 2 indicates vulnerablity against earthquakes for fourteen selected cities based on the same sixteen items, considering overall city characteristics. According to these figures, the city of Kobe is not ranked very high compared with thirteen other Japanese cities. In fact, they indicate that the cities of Ichikawa, Kawasaki, Yokohama, Chiba, Osaka, Fukuoka, and Sendai would have been damaged more seriously than the city of Kobe was with an earthquake of the same input magnitude. Next, we describe the city characteristics of each city that influence vulnerablity against earthquakes.

The city of Ichikawa

The geological conditions are poor, i.e., the ratio of soft ground area to total city area is high. There are insufficient medical personnel to cope with a major disaster. There is a relatively small area of city parks, and their facilities are poor. The medical facilities are poor.

The city of Kawasaki:

The ratio of soft ground area to total city area is high. The day-time population is less than the night-time population because many residents commute to Tokyo. There are relatively few medical facilities, medical personnel, and administrative personnel. There is a relatively small area of city parks.

The city of Yokohama:

The population density of the entire city, and of the DID in particular, is high. The day-time population is less than the night-time population, because many residents commute to Tokyo. The topographical conditions are good, because there are many hills. There are a large number of low income families and old houses. There are relatively few medical and administrative personnel, and there are insufficient facilities. In particular, there are few hospitals and parks in this city.

The city of Chiba:

Many residents commute to Tokyo. The ratio of the number of the small site houses to the total number of houses, as defined by the damage factors, is high. The ratio of nonflammable houses to the total number of houses is low. There are relatively few administrative personnel, police officers, and medical facilities.

The city of Osaka:

The population density is high and aging of residents is increasing. The ratio of soft ground area to total city area and the ratio of DID to total city area are high. There are many low income families, small site houses, and old houses. Many water and gas lines are old. The number of fire incidents at ordinary times is high.

The city of Fukuoka:

The population density is somewhat low. The ratio of soft ground area to the total city area is high.

The total volume of water reservoir available for fire fighting is low. This city is very typical among other major Japanese cities with respect to vulnerablity against earthquakes.

The city of Sendai:

The geological conditions are good. Average incomes are high, but the ratio of nonflammable houses to the total number of houses is low. There are relatively few administrative personnel, fire-fighters, and police officers. The ratio of road area to the total city area is low. There are relatively few general hospitals.

Vulnerablity against earthquakes in the 23-ward area of Tokyo is relatively low. This is because the ratio of nonflammable houses, which belongs to the damage factor category, is high. However, the population density, the DID population density, the day-time population index, and the ratio of persons over 65 are all high. Furthermore, the ratio of naturally soft ground area to total city area and the ratio of the DID to total city area are both high. There is a high ratio of low income families. There are many small site houses and old houses. However, the numbers of medical personnel, administrative personnel including fire-fighters and police officers, part time fire fighters, and local volunteer groups for preventive actions are very high. Furthermore, the facility capacity, as indicated by the ratio of road area to total city area, the number of clinics, and the total volume of water reservoir available for fire fighting, is very large. However, the overall score for the relative evaluation of vulnerablity against earthquake disaster is high.

The city of Kobe at the time of the earthquake disaster had a relatively low population density. However, the population was concentrated in the inner city area where huge damage was observed. Topographically, there are many mountains and hills because the Rokkos are close to the coast line. The ratio of soft ground area to total city area is high because most of the lower land area is alluvial fan and there is a lot of reclaimed land in the port area. The ratio of DID to total city area is low because the ratio of suburban areas, such as Kita-ward and Nishi-ward, to the total city area is very large. There are relatively few low income families and small site houses, but there are many old houses. The ratio of nonflammable houses to the total number of houses is high and the ratios of new water and gas lines to the totals are high. There is a relatively large number of medical personnel, but relatively few police officers and fire fighters. However, there is a relatively large number of fire men. The ratios of voluntary groups for preventive actions are relatively high because of the relatively large number of fires and typhoons at normal time. The ratio of road area to total city area is low, but the ratio of city park area to total city area is high. The total volume of water reservoirs is relatively small. As seen in Figures 1 and 2, the city of Kobe was very typical with respect to the vulnerablity in earthquake disasters.

Figures 1 and 2 show the relative vulnerablityes against earthquakes in major Japanese cites from the macroscopic point of view. They also indicate the necessity for disaster preventive investment for those cities which have the larger negative values.

5. Conclusion

We have attempted to comprehend the key factors that determined the disaster status of the city of Kobe as revealed by the Great Hanshin-Awaji Earthquake, and compared them with those of other major Japanese cities. We have extracted indices of city characteristics for each city in Japan to enable us to evaluate each city's the vulnerablity against earthquakes based on a primary component analysis. As a result, we have found that the city of Kobe before the Great Hanshin-Awaji Earthquake was a typical major Japanese city, and that many major Japanese cities were weaker than Kobe. Therefore, implementation of earthquake-proof countermeasures in those cities is now an urgent requirement. For example, we have found that the cities of Ichikawa, Kawasaki, Yokohama, Chiba, Osaka, Fukuoka, and Sendai are weaker than the city of Kobe.

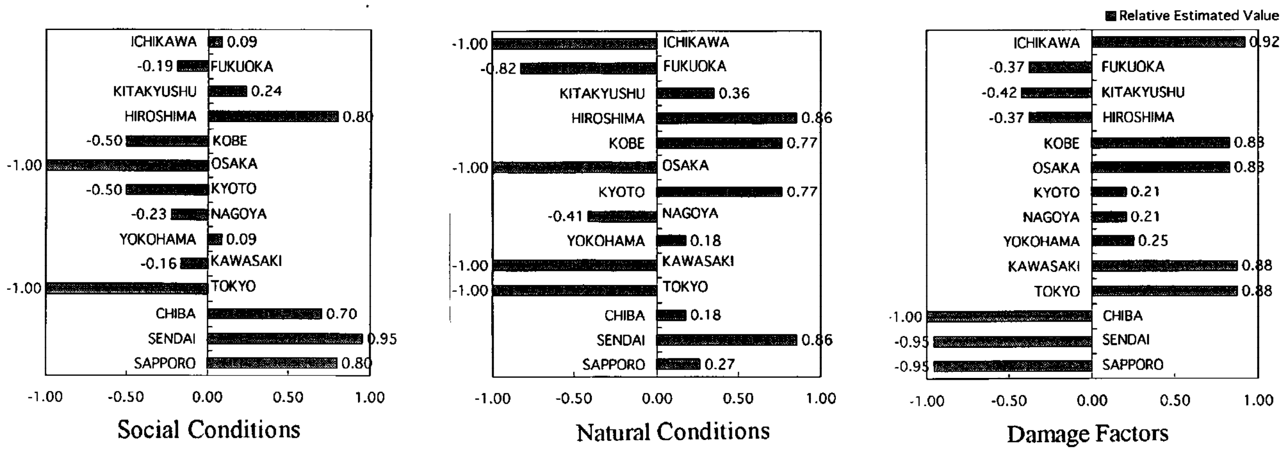
It will be necessary to invest a large amount of money to construct a disaster-proof city. We must provide earthquake control systems in future structures to prevent future disasters. As we described before, public buildings and facilities are being reinforced or moved to alternative locations (cities) in Japan. Some cities have established financial aid systems promote anti-earthquake reinforcement for private buildings. These administrative actions have been conducted because the major facilities in the city of Kobe were ruined by the Great Hanshin-Awaji Earthquake, and our central and local governments have made political decisions to reinforce facilities that are potentially hazardous to people and city functions, to ensure that those facilities can tolerate an input seismicity of magnitude 7. This is the maximum scale determined by the Japanese Meteorological Agency. However, it is not certain that this decision will encourage the progress of reinforcement of private buildings. This is because of the fact that the memories of ordinary residents are quickly fading away. In fact, their concern about disaster prevention began to fade within only a few months of the Great Hanshin-Awaji Earthquake.

In this study, we have attempted to systematically evaluate overall earthquake damages. We have described the damage to the city of Kobe caused by the Great Hanshin-Awaji Earthquake and that of the city of Sendai caused by the 1978 Miyagiken-oki Earthquake in terms of each city's characteristic indices. Although we have not done a complete analysis, we believe that we have obtained a preliminary result which can provide a reasonably accurate estimate of earthquake damage to each city. We will carry out a more comprehensive study to evaluate all features of earthquake damage in terms of economics in our next study. We also believe that it is important to establish a method of examining the effects of investment in disaster prevention. We may have to wait for the completion of reconstruction in the area damaged by the Great Hanshin-Awaji Earthquake, including the city of Kobe, before we can test a method. However, we are currently carrying out a study to establish such a methodology.

Table : The various sources of information for the fourteen selected cities

	Item	SAPPORO	SENDAI	CHIBA	TOKYO	KAWASAKI	YOKOHAMA	NAGOYA	KYOTO	OSAKA	KOBE	HIROSHIMA	KITAKYUSHU	FUKUOKA	ICHIKAWA
Basic Data	Population (1993.10.1)	1731670	950893	850631	8080286	1199707	3288464	2158713	1452240	2588989	1509395	1102047	1019996	1268626	447165
	Population (1990)	1671742	918398	829455	8163573	1173603	3220331	2154793	1461103	2623801	1477410	1085705	1026455	1237062	436596
	Number of Households	695947	368982	306285	3479464	496403	1234554	825105	564928	1076908	569206	424785	379705	523235	181576
	DID Population (1990)	1570733	774143	728308	8163573	1158209	3080051	2085136	1360640	2622808	1356779	948634	910137	1164226	426185
	City Area (㎢)	1121.1	788.1	272.4	621.0	143.9	433.2	326.4	610.2	220.5	545.8	740.3	482.9	336.8	56.4
	DID area (1990) (㎢)	202.4	113.3	110.0	617.8	127.7	325.0	264.6	132.4	219.4	129.6	131.4	152.8	141.9	46.8
A.Social Conditions	Population density (Per ㎢)	1544.6	1206.6	3123.2	13012.0	8340.0	7591.0	6614.3	2379.6	11739.8	2765.6	1489.0	2112.4	3767.0	7882.0
	DID Pop. density (Per ㎢)	7760.5	6832.7	6621.0	13213.9	9069.8	9477.1	7880.3	10276.7	11954.5	10469.0	7219.4	5956.4	8204.6	9107.0
	Pop. over age 65 (1990)	152053	80433	61085	910507	93798	278000	221936	184959	306199	169316	106591	130423	112654	32111
B.Natural Conditions	Seismicity	0.9	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.9	0.8	0.8	1.0
	Topography	17756.0	8005.0	7884.0	31283.0	8205.0	9658.0	12437.0	5700.0	18153.0	1378.0	6957.0	12986.0	15945.0	4363.0
C.Damage Factors	Num. of Housing Unit built before 1970	76570	56790	63820	853330	96160	262650	237320	169780	381740	174940	96200	119340	96730	25920
	Total Number of Housing Units	660750	346710	285960	3300140	443570	1111640	783660	553410	1038250	540200	397210	362770	493990	161930
	Num. of Nonwooden Houses	33513	30994	25410	1063150	189565	88320	97709	99254	305531	175362	44098	35629	37065	140610
	Num. of Wooden and Nonwooden House	342173	298571	186655	2236439	413071	586629	452878	502185	764272	417241	296754	244340	249912	161930
D.Social Capacity	Number of Doctors	5909	3276	2580	30092	3731	7796	8131	6497	12533	4921	3857	3860	5658	568
	Number of nurses	16468	6601	4853	48727	5764	14828	15822	13387	23731	10520	8897	10466	12323	1312
	Number of Fire fighters	1693	914	931	12342	1367	3170	2259	1771	3368	1347	1116	955	999	497
	Number of Fire Men	1918	2164	796	14276	1252	7424	6262	4550	Nothing	4000	2541	1910	2612	386
E.Facilities Capacity	Road Area (㎢)	55.3	24.6	16.6	92.9	15.4	53.8	51.5	21.2	38.8	26.3	24.6	28.1	25.3	5.8
	City Park Area (100㎡)	143078.0	69074.0	50392.0	219341.0	43154.0	118163.0	135012.0	39522.0	82052.0	226686.0	71045.0	91224.0	99484.0	11798.0
	Number of Hospital	192	46	38	411	28	102	146	113	189	87	75	60	103	15
	Number of Clinic	1085	681	505	8626	737	2055	1636	1564	3016	1363	1034	899	1049	256
	Total Fire Fighting Cistern Capacity	27960.0	51300.0	65660.0	765980.0	51100.0	99460.0	108340.0	94740.0	57380.0	52120.0	69120.0	83640.0	36040.0	48880.0

note: DID=Density Inhabited District



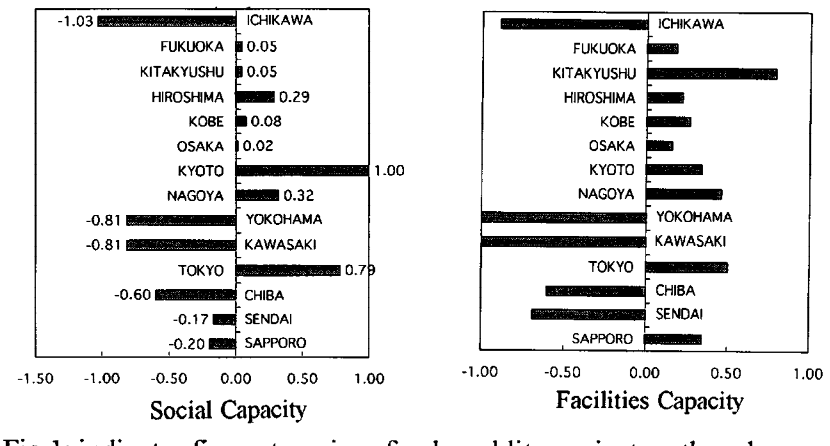


Fig.1: indicates five categories of vulnerablity against earthquake

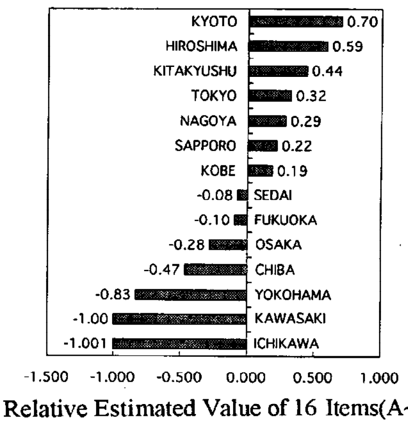


Fig.2 : indicates vulnerablity against earthquake for forteen selected cities baased on the sixteen items