ANALYSIS OF RESIDENTS' EVACUATION BEHAVIOR AFTER THE GREAT HANSHIN-AWAJI EARTHQUAKE IN JAPAN

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Abstract: This study aims to show the residents' evacuation behavior after the Great Hanshin-Awaji Earthquake in Japan. The survey was based on a questionnaire distributed to those residents in the affected area. Here we divide the phase of their evacuation during the three years after the earthquake into two stages, 1)evacuation to shelters immediately after the earthquake, and 2)evacuation before returning to permanent residences. In this paper, the actual conditions of their evacuation behavior are first shown, and then the factors that affected their behavior are also analyzed. Finally, we introduce some issues to prepare smooth evacuation measures for residents in case of future great disasters.

1.INTRODUCTION

In the Great Hanshin-Awaji Earthquake (January 17, 1995), over 120,000 buildings collapsed, as well as lifeline facilities (electricity, water, gas supply, etc.) were destroyed, and transportation networks were paralyzed. More than 230,000 residents were forced to evacuate to 600 shelters in Kobe City immediately after the earthquake. Three years after, the average ratio of reconstructed buildings to the total number of structures that had collapsed was 45%, and many residents were still forced to live in the temporary houses inside or outside the affected area. We have recognized the importance of knowing the residents' evacuation behavior at the time of a great disaster especially when emergency measures are taken and also when reconstruction plans are implemented.

In this study, we carried out a questionnaire survey among the residents of the eastern part of Higashinada-ku in Kobe City three years after the earthquake. Actual conditions of the residents' evacuation behavior after the earthquake are shown and the factors that affected their behavior are analyzed in this paper. We divide the phase of their evacuation during

thses three years after the earthquake into two stages, 1)evacuation to shelters immediately after the earthquake, and 2)evacuation before returning to permanent residences. Their behavior in these two stages differs in purpose. In the former, the residents primarily evacuate to avoid the dangers immediately after the earthquake; in the latter, they aim to secure temporary living places until the lifeline facilities are recovered and their houses are rebuilt. Finally, we introduce some issues to prepare smooth evacuation measures for residents in case of future great disasters.

2.OUTLINE OF THE STUDY AREA AND THE SURVEY

2.1 Study Area

Fig.1 shows the map of the study area in the eastern part of Higashinada-ku in Kobe City. The surrounded space is 310 ha in area and consists of 43 districts. The population is 53,710 (National census:14,258 households as of October 1990)

Fig.2 shows the ratio of damaged buildings (includes totally and partially damaged) in these 43 districts, indicating that 54% of the total number of buildings in the whole study area were damaged. As shown in the figure, damaged buildings were found in all districts, in particular they were concentrated near the boundary of Asiya and Kobe City, and between JR Kobe line and National Route 2.

Lifeline utilities (gas, water, electric supply, etc.) came to a complete halt during the earthquake. In the study area, electric supply and telephone service recovered in a week or two. In comparison , it was not until the beginning of April 1995 that gas and water supply resumed, —the area was one of the slowest places to recover from the quake.

2.2 Survey Method

The data used in this study was obtained as part of the questionnaire survey conducted by the authors in December 1997, just three years after the earthquake. The number of answer sheets distributed to the residents of the study area was 290, of which 244 effective sheets were recovered (the collection ratio was 84.1%). The characteristics of the households that answered the questionnaire were as follows; 4—member households stand at 26.5% and 3—member households represented 23.1%. Completely or partially destroyed houses accounted for 61.9%.

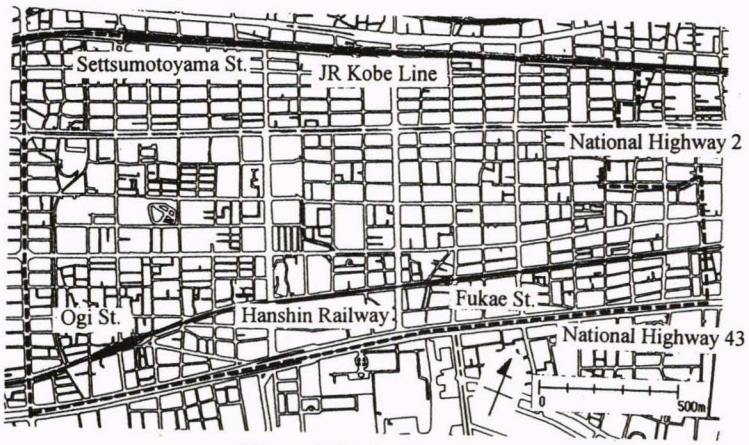

Figure1.Study Area

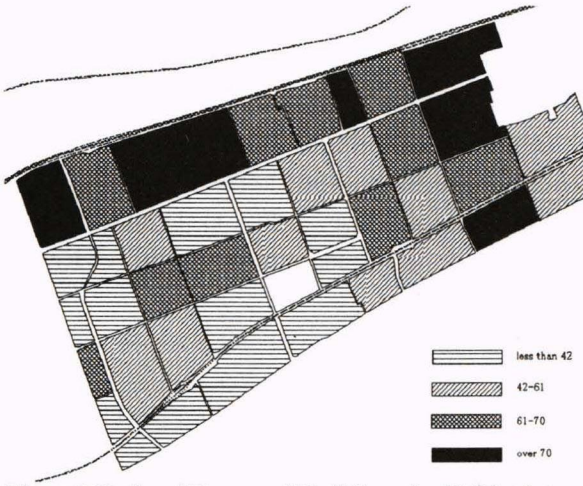

Figure2.Ratio of Damaged Buildings in 43 Districts

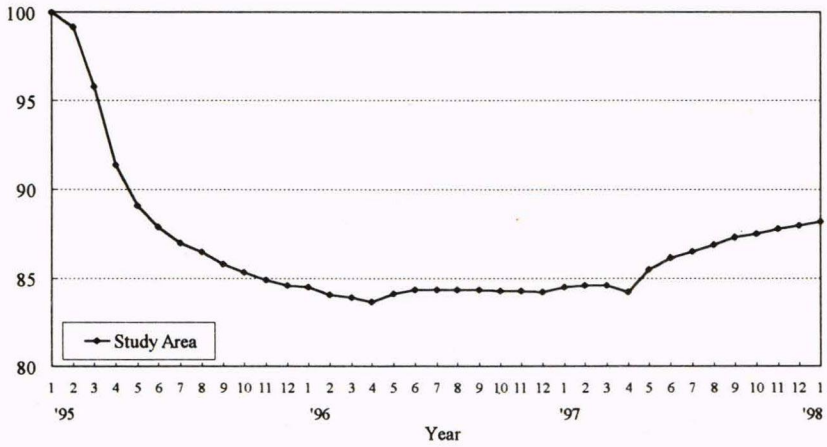

Figure3.Changes in Population after the Earthquake

3.CHANGES IN POPULATION AND RECONSTRUCTION OF BUILDINGS IN THE WHOLE STUDY AREA

3.1 Changes in Population

In Fig.3, we can see changes in population on the resident registration data during these three years after the earthquake. The index of population in January 1995 is set at 100. The population of the area decreased steeply during the next four months after the earthquake, and then continued to decrease gradually. The decrease bottomed out in April 1996 at16.4%. After that the population began to increase slightly, but it still stood at 88.2% of the initial level three years after the earthquake.

Next, we compared the rate of population decrease to the base year between the resident registration data (Oct 1995) and the national census (same date), with the rate of the latter being about 2.3 times greater. But it is important to remark that the base year of the resident registration data (Jan 1995) differs from that of the national census (Oct 1990), and we can't simply compare them because of this. We should also consider that many residents probably evacuated without changing their residency registration; therefore, the actual rate of population decrease is close to the one based on the national census, for exceeding the one based on the population data of the residents.

3.2 Accumulated Number of Removed and Reconstructed Buildings

Fig.4 shows the number of removed and reconstructed buildings every half a year after the earthquake. In this figure, more than 3,000 buildings were removed in half a year after the disaster, but the figure (number of houses removed) remained about the same over the next three years. The total number of buildings removed, however, reached 3,785, accounting for 60% of all the buildings in the study area (corresponding to the number of totally and partially damaged buildings).

The ratio of buildings reconstructed and under reconstruction stayed almost constant from 55.2% to 62.1% after Jan 1997, indicating a slow-down in the speed of reconstruction past a year and a half after the earthquake.

In this way, three years after the earthquake, the ratios of reconstructed structures, those under construction and reconstructed temporary structures were 59.2%, 2.9%, and 5.9%, respectively. Still vacant after three years were 1,212 lots, accounting for 32.0% of the total number of removed buildings. This means that it takes a long time to reconstruct the damaged buildings.

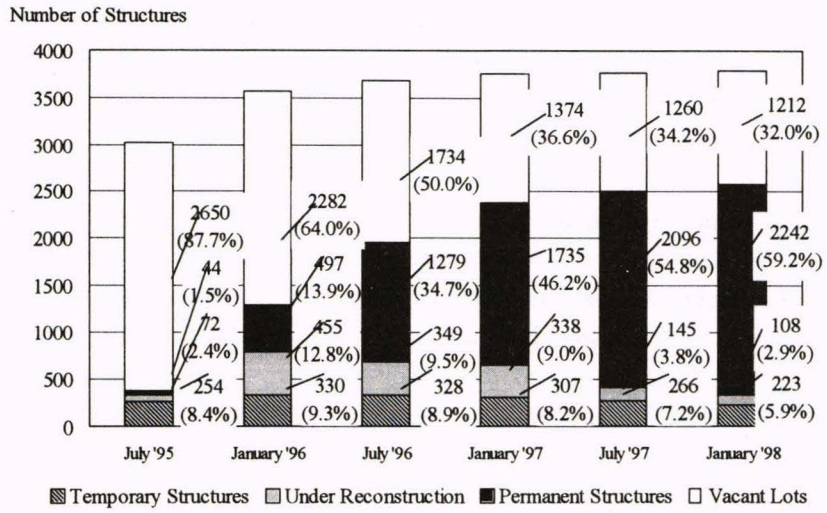

Figure4.Accumulated Number of Removed and Reconstructed Buildings in the Study Area

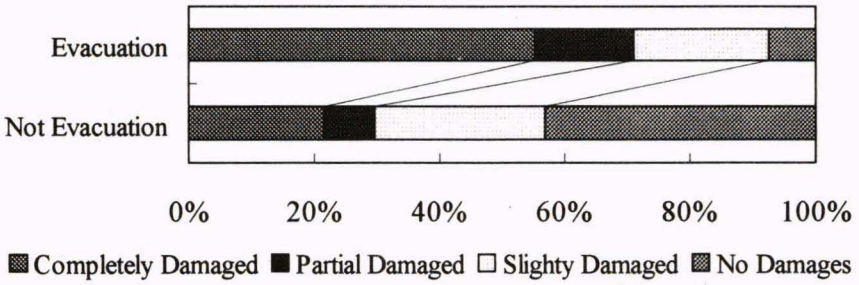

Figure5.Evacuation Ratio by Damages in Houses

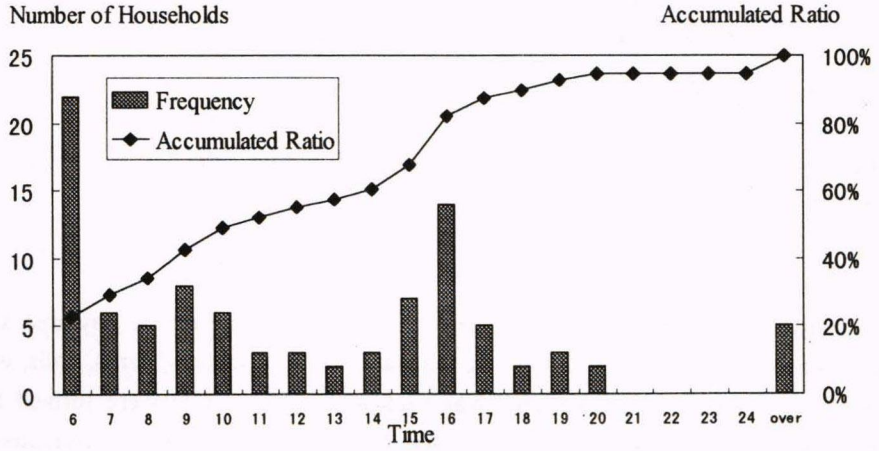

Figure6.Time of Starting Evacuation (January 17th,1995)

4.ANALYSIS OF THE RESIDENTS' EVACUATION BEHAVIOR IMMEDIATELY AFTER THE EARTHQUAKE

4.1 Evacuation Ratio and Starting Evacuation Time

(a)Evacuation Ratio by Damage to Houses

The ratio of households that evacuated immediately after the earthquake reached 83% of the total. Fig.5 shows the evacuation ratio by damages to houses. As shown in this figure, the evacuation ratio of households whose houses were completely or partially destroyed account for 70%. Including the houses slightly damaged, the evacuation ratio exceeded 90%. The houses without any serious damage represented 40%. All that means that the degree of damage of the structure influenced strongly the residents' decision to evacuate from their homes.

(b)Starting Evacuation Time

Fig.6 shows the starting evacuation time on the day of the earthquake. In this figure, the bars represent the frequency of evacuating households at each hour of the day of the earthquake and the line is the accumulated ratio. The evacuation frequency peaked at 9:00 am and at 16:00 pm. Over 90% of the total households started evacuating on the day of the earthquake.

4.2 First Evacuation Point and its Distribution

(a)Evacuation Points and Ways of Transportation

Fig.7 shows the type of immediate evacuation points. Of the total households, 37% took refuge in schools which were the most familiar places to the local residents, followed by community halls and parks with 23%, and the houses of acquaintances, relatives, and friends inside Higashinada-ku with 12%. The total ratio of households who took refuge near their houses accounted for 81%, with the rest 19% staying at the houses of their acquaintances outside Higashinada-ku (most of them already left the affected area at the first evacuation). Fig.8 shows the ways of transportation during the first evacuation. Of the total 79% went on foot because the refuge points were near their houses.

(b)Distribution of Evacuation Points

Fig.9 shows the location of residences and evacuation points inside the stay area. On this map, residences are linked with the first evacuation points (schools, parks, halls, etc.) by lines. We can see their evacuation zones each 400-500m in size were formed around schools and other shelters. It is interesting that there were a relatively few who crossed the trunk roads to reach the evacuation points.

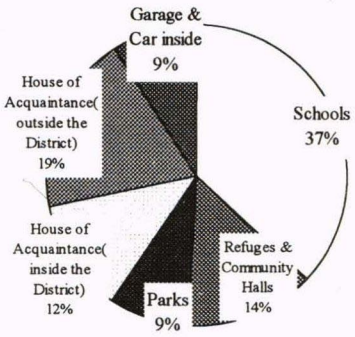

Figure7.Types of Evacuation Points

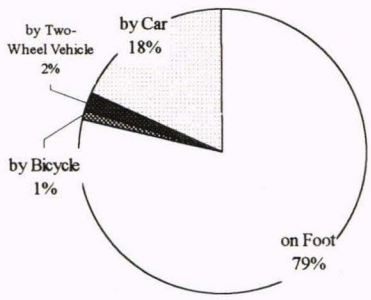

Figure8.Means of Transportation

Figure9.Distribution of Residences and Evacuation Points

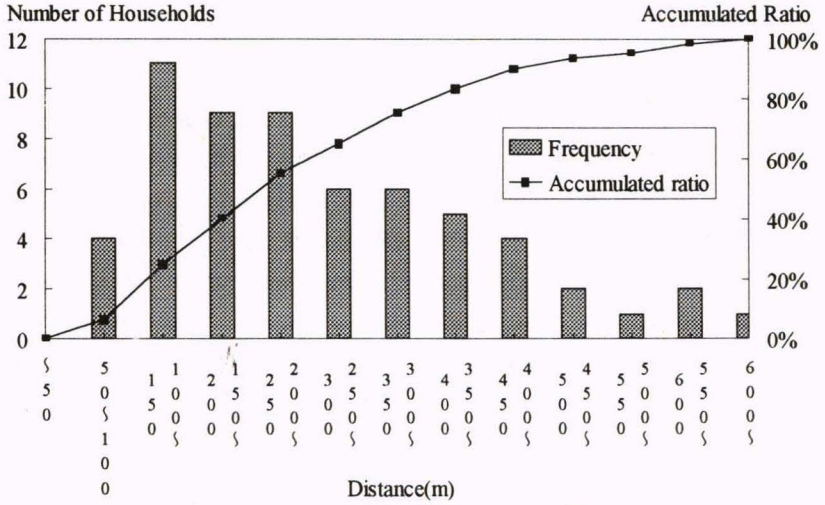

Figure10.Distances Between Residences and Evacuation Points

Fig.10 represents the distribution of distances between residences and evacuation points. The bar shows the frequency of each distance and the line is the accumulated ratio. The evacuation distance of 150m to 250m was most frequently used with 88% of the total households evacuating to points within 400m of their residences.

4.3 Residents' Evacuation Behavior during Three Days after the Earthquake

We have analyzed features of the first evacuation behavior immediately after the earthquake. Fig11 describes the residents' evacuation behavior during next three days after the earthquake. We can see that most households evacuated just once followed by those who evacuated twice, and then fewer people who did so these times.

(a)Changes in Evacuation Points by the Number of Evacuation and Ways of Transportation

Fig.12 shows the differences in the evacuation points by the frequency of evacuation. The ratio of evacuees choosing schools, parks or community halls in the neighborhood was 60% at the first evacuation, but that percentage decreased to 25% during the second evacuation and to 10% at third one. Conversely, the ratio of people evacuating to the houses of acquaintances outside the affected area increased from 19% at the first evacuation to 72% at third one.

Fig.13 shows the ways of transportation the households used for evacuation. Most households went on foot to those evacuation points close to their residences. The ratio of households going by car to acquaintances houses outside Higashinada-ku exceeds 60%. Because the public transportation networks (bus and railway) were paralyzed immediately after the earthquake, were forced to use their own cars to evacuate toward points far away from their houses.

(b)Changes in Number of Households Staying at the Evacuation Points

Changes in the number of households staying at the evacuation points (schools, parks, halls, etc.) are shown in Fig.14. The number of households there increased until 6 o'clock on the day of the earthquake (Jan 17th), then remained constant during the night because of the strong fears of another earthquake. The number of people staying at the evacuation points began to decrease in the next morning and the decrease continued toward the evening. There was a sight increase in the evening, but the numbers remained about the same during the night. This tendency continued on the second and third days.

5.ANALYSIS OF RESIDENTS' EVACUATION BEHAVIOR FOR THREE YEARS AFTER THE EARTHQUAKE

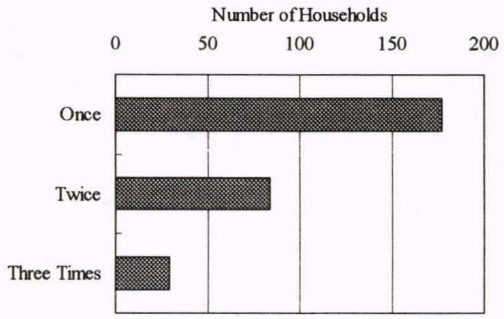

Figure11.Number of Households by Evacuation Frequency

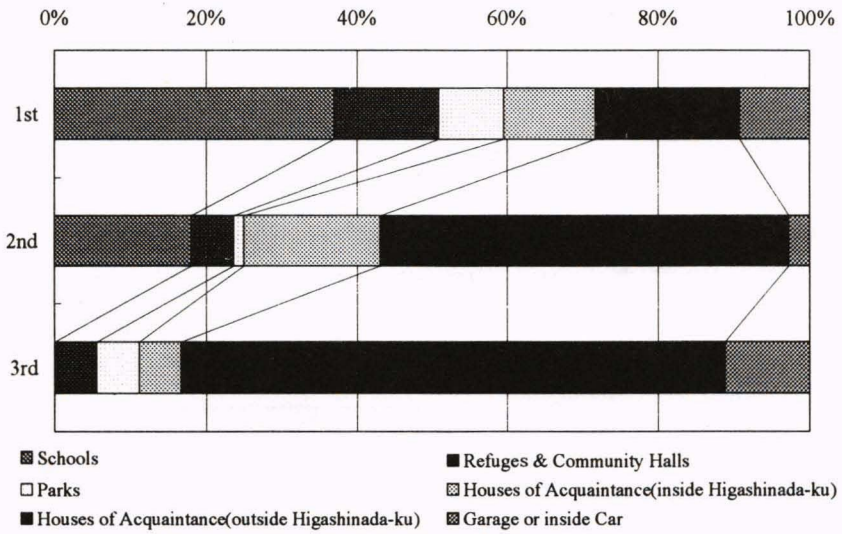

Figure12.Changes in Location of Evacuation Points

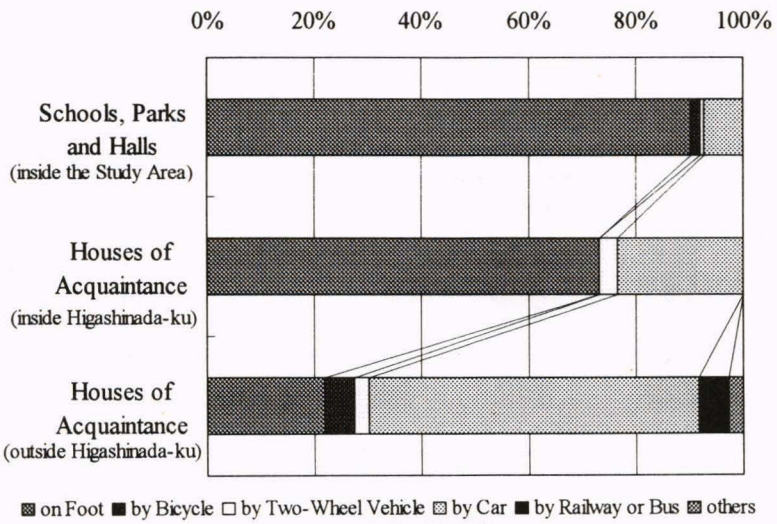

Figure13.Means of Transportation for Evacuation

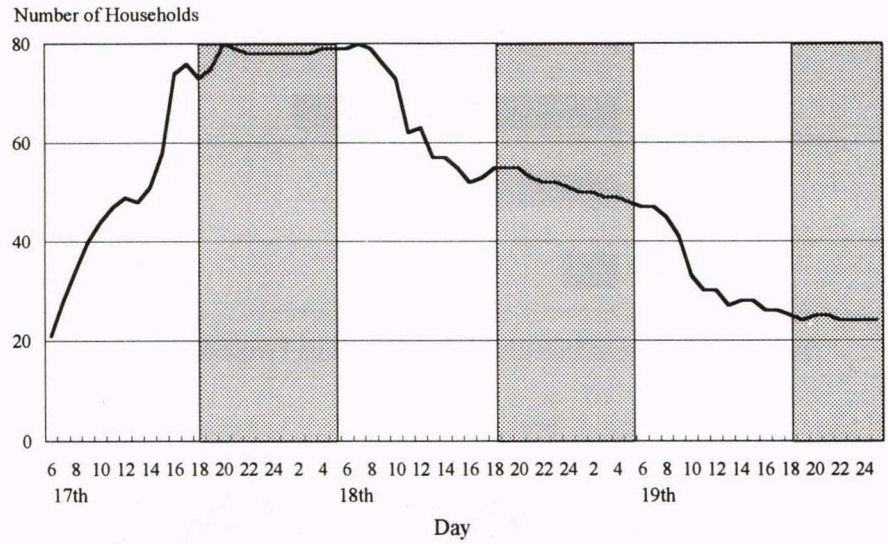

Figure14.Changes in the Number of Households Staying in the Evacuation Points

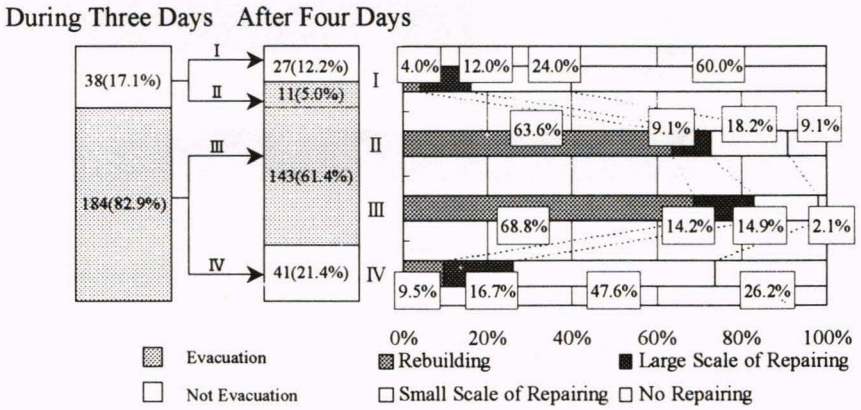

Figure15.Evacuation Ratio by the Need to Rebuild or Repair Houses

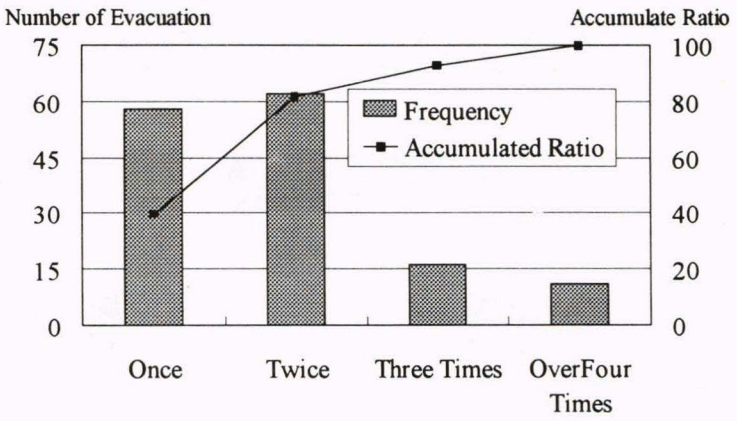

Figure16.Frequency of Evacuation

5.1 Evacuation Ratio by Damage to Houses

We classified residents' evacuation behavior into four patterns by evacuation periods after the earthquake. The frequency and accumulated ratio of households of each pattern are shown in Fig.15, and the degree of damage to the houses are also indicated for each pattern.

The four evacuation patterns are 1)not evacuated at all (pattern Ⅰ), 2)evacuated after the first three days of the earthquake (pattern Ⅱ), 3)evacuated after the earthquake (pattern Ⅲ), 4)evacuated only during the first three days after the earthquake (patternⅣ). Among those four patterns, patternⅢ shows the highest frequency at 61.4%.

Next, we indicate the degree of damage to the houses in each pattern. Houses that require rebuilding in both pattern Ⅱ and Ⅲ (evacuated for a long period) exceed 60%. On the other hand, the ratios of those structures in pattern Ⅰ (not evacuated at all) and patternⅣ (evacuated only during the first three days) are less than 10%, and the degree of damage in these patterns is smaller than that in pattern Ⅱ and Ⅲ. Moreover, when we compare pattern Ⅰ with Ⅳ, it can be pointed out that the ratio of houses that require rebuilding or large repairs is small in both patterns and that the ratio of houses needing small rapirs in patternⅣ(evacuated only for three days) is about 50%, but that the ratio of houses requiring no repairs in pattern Ⅰ (not evacuate at all) is 60%. This shows that damage in pattern Ⅰ is smaller than that in patternⅣ.

As stated above, some households evacuated immediately after the earthquake though damage to their houses was small. The degree of damage however had a stronger influence on the households' long term evacuation behavior (three years or longer after the earthquake) because it took a long time to rebuild or repair the houses.

5.2 Residents' Evacuation Behavior during the Three Years after the Earthquake

(a)Changes in Evacuation Points

The distribution of the number of evacuations and its accumulated ratios are shown in Fig.16. We can see that about 80% of the total households evacuated once or twice, and that the ratio of households who evacuated three times or more decreased to about 20%. What this means is that most of these households finished evacuation after they moved once or twice.

Next Fig.17 shows changes in the location of evacuation places. Over 60% moved to places outside Higashinada-ku (most are inside Hyogo Prefecture and inside Kinki Area) during their first or second evacuation. However, when the frequency of evacuation

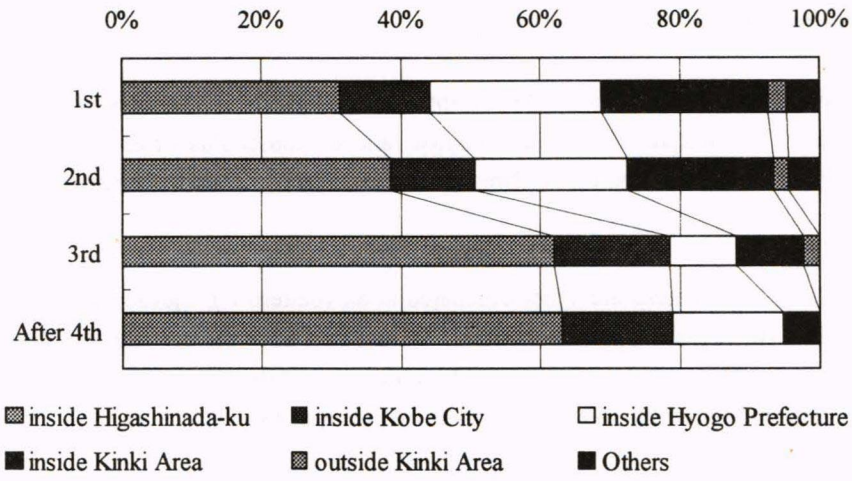

Figure17.Changes in Locations of Living Places

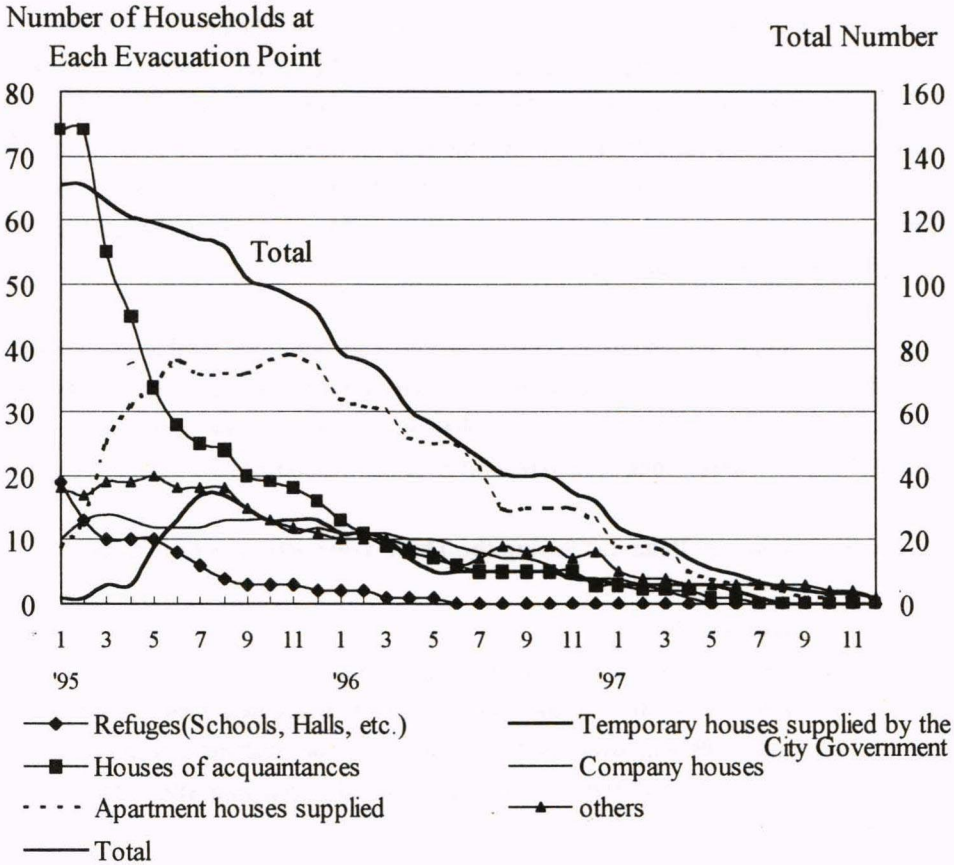

Figure18. Number of Households Staying on Different Evacuation Places

increases to three or four times, the ratio inside Higashinada-ku exceeds 60%. This indicates that as the frequency of evacuation increases, the households have tendency to try to secure temporary living places near their original residences.

The total number of households that continued to stay at the evacuation points decreased as time passed as shown in Fig.18. The number of households who took refuge in the houses of their acquaintances was very high at first, but then began to decrease sharply one or two months after the earthquake. During the same period, however, it is remarkable that the number of households staying in the apartment houses supplied by the private sector and in temporary houses supplied by the local government began to increase. This shows that it took a while to build temporary houses during the early period after the earthquake, and that as time passed, more evacuated households began to move from their temporary refuges (schools, parks, etc.) to living spaces where they could lead more independent lives. The number of households staying in private companies houses remained constant for over a year after the quake, indicating that these houses played important roles as temporary living places for the affected people.

(b)Total Evacuation Period

Fig.19 shows the frequency of evacuation and accumulated ratio of total evacuation period aggregated every three months. The frequency, as the graph shows, fell shortly half a year after the earthquake, reflecting the fact that many residents returned to their original homes as the lifeline facilities had been almost restored by then. The accumulated ratios remained almost constant after about the 18 months of the earthquake, reflecting that the pace of building reconstruction slowed dawn past that period as shown before in Fig.4.

The total evacuation period was 8.5 months in average, but it depends on the levels of damage to the buildings. The evacuation period of households who needed rebuilding was 13.6 months and was the longest. Next, those whose houses required large and small repairs evacuated for 5.1 months and 2.9 months, respectively. On the other hand, those whose structures sustained no damage evacuated for 1.7 months and it was the shortest. As damage to the houses became heavier, reconstruction took much longer and therefore the evacuation period became more extended.

(c)Factors Causing Delays in Reconstruction of Buildings

Main factors that caused delays in the reconstruction of damaged houses are shown in Fig.20. The factors related to a shortage of funds, difficulties in obtaining financial support and complicated application procedures were pointed out by the residents. Also frequently cited were small housing lots and narrow roads adjacent to such lots.

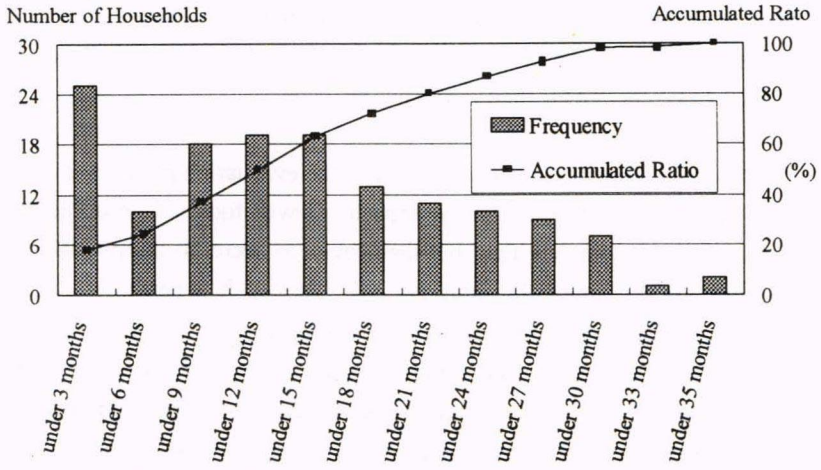

Figure.19 Changes in the Total Period of Evacuation

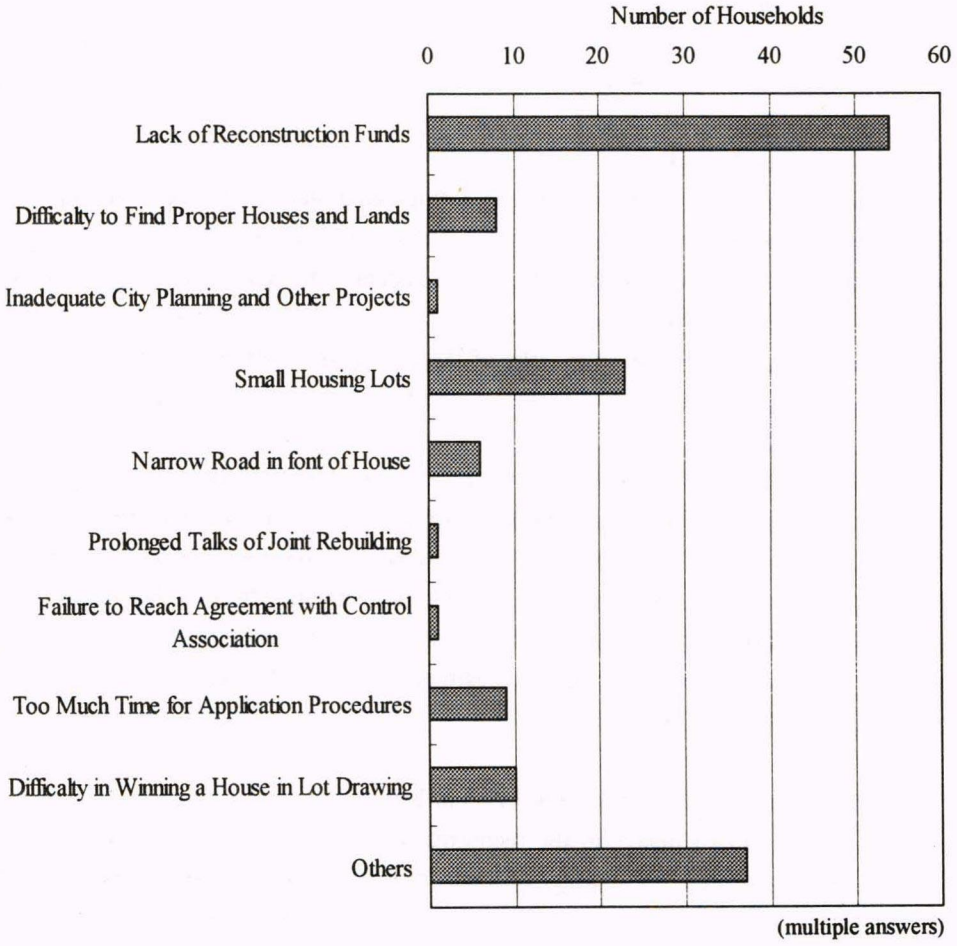

Figure.20 Causes of Reconstruction Delays

6.CONCLUSIONS

The objective of this paper was to analyze the residents' evacuation behavior after the Great Hanshin-Awaji Earthquake in Japan. The sources of this study were based on the results of a questionnaire survey taken three years after the quake among the residents in the study area of Higashinada-ku the Kobe City, one of the most seriously damaged areas. The main findings are as follows :

(a)Residents' Evacuation Behavior during Three Days Immediately after the Earthquake.

How badly the houses were damaged strongly influenced the residents' decision to evacuate. As for the frequency of evacuation, it peaked immediately after the quake, then at 9:00 am and at 16:00 pm on the same day. Over 90% of the total households started evacuating on the day of the disaster. Almost all of the residents went on foot to public evacuation points in the neighborhood, such as schools, parks, halls, etc.—88% of these places were within 400m from their residences.

As the frequency of evacuation increased, the location of refuges changed from the neighborhood to the houses of acquaintances. As a result, cars were increasingly used as a means of transportation because of the long distances. The number of households that stayed at these evacuation points steadily declined as the days passed but more people stayed there during the night than during the day, apparently because of the fear of another earthquake.

(b)Residents' Evacuation Behavior for Three Years after the Earthquake

We classified residents' evacuation behavior into four patterns by evacuation periods after the earthquake. Among these four patterns, patternIII is predominant. Some households evacuated immediately after the earthquake though damage to their houses was small. The degree of damage to structures however strongly influenced more on the households' evacuation behavior after the earthquake because it would take a long term to rebuild or repair the houses. About 80% of the households evacuated once or twice during this period. People tended to evacuate far, to places outside Higashinada-ku, in the first or the second evacuation. When the furequency of evacuation increased, however, they took refuge inside Higashinada-ku more often. The total number of households that configured to stayed at those evacuation points decreased after a while. The number of households who took refuge in the houses of their acquaintances decreased rapidly one or two months after the earthquake, while there increased the number of households staying in privately owned apartments and in temporary houses supplied by the local government.

The duration of the total evacuation period was 8.5 months on average. As damage to the

houses became heavier, their reconstruction took longer and therefore the length of evacuation increased. Factors contributing to the end of evacuation were the recovery of the lifeline facilities and the reconstruction of damaged buildings. On the other hand, a shortage of funds, difficulties in obtaining financial support and, small lots and narrow adjacent roads were cited by residents as causes delaying the building reconstruction work.

Finally, measures for residents' evacuation at the time of future great disasters are described below.

1.Most households took refuge at schools, which are the most familiar to the local residents, and other evacuation points within 400m of their residences. The number of households that stayed at these evacuation points peaked during the night. To deal with the evacuation behavior immediately after the earthquake, it is important, therefore, to properly allocate these evacuees to refuges inside the neighborhood areas, and to secure enough capacity each evacuation point to accommodate the residents evacuating whose number peaks during the night. As some residents evacuated to places outside the affected area by car immediately after the earthquake, we should also plan for means of transportation for evacuation instead of privately owned cars to avoid traffic congestion.

2.As the period of evacuation stretched, more and more evacuees began to desire to live in places near their original places and lead independent lives instead of living in those temporary shelters dependent on their relatives and acquaintances outside the damaged area. Considering their desires, it is necessary to supply them with houses near their initiel residences. Besides, because to supply them with permanent houses of their own is a fundamental solution to end the evacuees status, it is necessary to private financial aids and other means to bring down the obstacles to speedy restoration.

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Tobishima Construction Co., Ltd.
Toda Corporation
Waterfront Vitalization and Environment Research Center
WESCO Inc.

CIT (TAIWAN) & NCTU (TAIWAN)

Ministry of Transportation and Communications
Ministry of Education
Council for Economic Planning and Development
National Science Council
Public Construction Commission
Bureau of Taiwan High Speed Rail, MOTC
Civil Aeronautics Administration, MOTC
Institute of Transportation, MOTC
Taiwan Area National Expressway Engineering Bureau, MOTC
Taiwan Area National Freeway Bureau, MOTC
Tourism Bureau, MOTC
Taipei City Government
Taipei Rapid Transit Corporation