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Process of Housing Damage Assessment: The 1995 Hanshin-Awaji Earthquake Disaster Case

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Abstract. Rebuilding of victims' livelihoods was a crucial issue in the restoration process in the 1995 Hanshin-Awaji Earthquake Disaster. *Housing damage assessment* influenced most of the rebuilding of the livelihood in the long term, because the Victim Certificates issued by the local governments based on the results of the *Housing damage assessment* was required to receive most of the individual assistance measures. In the process of *Housing damage assessment*, many complex problems arose, leading to extensive work on the part of the disaster responders. Consequently, a considerable number of victims were dissatisfied with the assessment and applied for a resurvey. Due to a flood of requests for resurvey, disaster responders had to work on damage assessment, leaving relief activities aside.

In order to facilitate *Housing damage assessment*, this paper discusses the following five points: (1) the processes and the problems of assessments performed in the Hanshin-Awaji Earthquake Disaster, (2) the changes in the nature of information needed by the victims, (3) the improvements over the present damage assessment, (4) the housing situation in Japan, and (5) the international situation on damage assessment.

It is obvious from the results that a poor damage assessment system and the size of the disaster produced a very large work load. Differences in appreciation among the investigators also contributed to unfair assessments and led to the victims being increasingly dissatisfied by the survey results. Finally, a design concept for a comprehensive damage assessment system, which has been derived from the above five points, is proposed for post-disaster management.

Key words: damage assessment, assessment process, assessment system, housing damage, Hanshin-Awaji Earthquake Disaster.

1. Introduction

Assessments of building damage play a vital role in the disaster relief system of Japan. The public sector carried out three large-scale damage assessments for

Figure 1. Process of rebuilding of victims' livelihood.

the disaster management of the 1995 Hanshin-Awaji Earthquake Disaster as summarized in Table I. It shows that: (1) *Initial damage estimation* was conducted to consolidate information on the disaster at an early stage, which provided disaster responders with a basis for decision-making in applying the Disaster Relief Law; (2) *Building safety evaluation* was performed to verify the safety of buildings, in cooperation with groups of volunteer architects, in order to protect human lives from further building collapses due to aftershocks; (3) *Housing damage assessment* provided a basis for issuing the Victim Certificates, which were subsequently used as a criteria for considering eligibility for most of the individual assistance measures.

Of the above elements, *Housing damage assessment* influenced most rebuilding of the livelihood in the long term. The process of rebuilding livelihoods is shown in Figure 1. In the case of the Hanshin-Awaji Earthquake Disaster, various kinds of countermeasures were launched by national and local governments for individual assistance. Most of these were available to victims in possession of Victim Certificates, which were issued by the local government based on the extent of their housing damages. Moreover, the certificate was subsequently required to receive support from the private as well as the public sector. From this viewpoint, *Housing damage* assessment can be regarded as the first step in the rebuilding of livelihoods. *Housing damage* assessment is also a key factor in the livelihood rebuilding according to a classification of countermeasures for housing damage from the viewpoint of the following four disaster management phases: response, recovery, mitigation and preparedness (Maki *et al.*, 1998).

On the other hand, the following assessments of building damages were also conducted in the private sectors: (4) building damage survey of academic interest, conducted by urban planners and structural engineers to gain an overall picture of the afflicted areas, (5) building damage survey for business, involving assessment related to life insurance and indemnity of housing or customer services by construction companies.

As mentioned above, since multiple assessments of building damages for various purposes were conducted by many organizations, they were entangled and the situation was called "assessment pollution". Therefore, the constitution of a comprehensive and consistent damage assessment system following the disaster phases should contribute in facilitating assessments of building damages including *Housing damage assessment*.

In this paper, the process of *Housing damage assessment* conducted in the Hanshin-Awaji Earthquake Disaster is revealed through ethnographic interviews with disaster responders of the local government. The relationships between the

Table I. Building damage assessments by the public sector in the 1995 Hanshin-Awaji earthquake disaster

Title	Purpose	Period	Organization
Initial damage estimation	To consolidate information on the disaster	From Jan. 17, 1995[1]	Local government (Mainly local police and fire department)
Building safety evaluation	To protect human lives from further building collapses	Jan. 23 to Feb. 9, 1995	Local government (Hyogo and Osaka Pref. in cooperation with groups of volunteer architects)
Housing damage assessment	To provide a basis for issuing the Victim Certificate	Jan. 23, 1995 to Mar. 31, 1996[2]	Local government (e.g., welfare department, financial bureau, fixed property tax division in local government)

[1] *Initial damage estimation* was conducted immediately after the earthquake by each local government, but completion date was unclear. Global image of damage could not be grasped until the evening of the day.
[2] The period was different for each local government. The case of Ashiya City is shown as an example.

problems encountered in performing the assessment and the factors causing the problems are also analyzed using a causal relation diagram. Based on this analysis, a number of requirements are established from the perspective of time and accuracy of determination in the assessment by the public sector. Finally, a design concept for a comprehensive damage assessment system is proposed, which integrates several improvements over the building damage assessment methods currently in place, respecting both the Japanese housing situation and the international situation in the assessment of damages.

2. Ethnographic Interviews

The assessments of building damages were carried out by the local government officials, for the public sector. However, in the case of the Hanshin-Awaji Earthquake Disaster, detailed information on the assessment process was not well documented. Therefore, group interviews were carried out with the local government officials in order to identify the processes and the problems of assessment of building damages, based on disaster ethnography. Disaster ethnography is one of the efficient research methods for understanding disaster processes (Hayashi and Shigekawa, 1997). The ethnographic interviews were conducted from August 16th to October 4th, 1999, that is nearly 5 years after the earthquake, with the cooperation of four cities and one town, shown in Figure 2: Kobe City, Nishinomiya City, Ashiya City, Akashi City and Hokudan Town. The figure also shows a summary of the damage data, which were human casualty and building damage data obtained by *Housing damage assessment*. The total number of human casualties is 6,432 including related deaths. According to the results of *Housing damage assessment*, 111,233 buildings suffered major damages and 137,283 buildings suffered moderate damages. The distribution of the major damage rate is also shown. The data used was calculated by the Building Research Institute of Japan (BRI, 1996), based on the results of building damage survey of academic interests conducted by the Architectural Institute of Japan (AIJ) and the City Planning Institute of Japan (CPIJ) (AIJ&CPIJ, 1995). The survey by AIJ&CPIJ was conducted widely to gain an overall picture of the afflicted area.

The interviews were carried out as part of the "Committee for Global Assessment of Earthquake Countermeasures" in Hyogo Prefectural Government, which was reported in detail (Hyogo Prefectural Government, 2000a). The interviews consisted of free discussions between the authors and the disaster responders in each local government, who were selected (approximately between 5 to 10 persons) under the following conditions:

1. A person at the front line, such as help desks, involved in *Housing damage assessment* works such as issuing Victim Certificates.
2. A person who was in effective posts of responsibility of operations related to *Housing damage assessment*, such as managers of responsible sections.

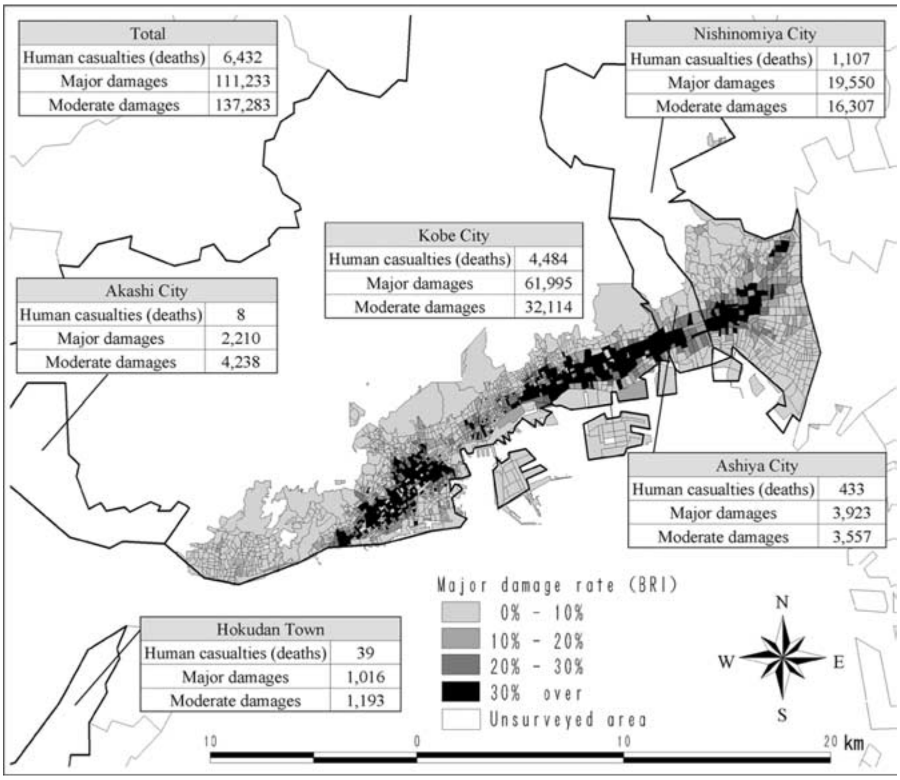

Figure 2. Location of group interviews and summary of damages (human casualty data and building damage data as of 1996).

The subjects addressed in the interviews were as follows: (1) entire flow of building damage assessment, (2) purpose of the survey, (3) target buildings for the survey, (4) organization, (5) survey criteria, (6) survey method, (7) contents of the survey form, (8) counting method of the results, (9) counting unit, (10) issuance period for the Victim Certificate, (11) organization of the issuance, (12) issuance method, (13) use of Victim Certificate, (14) period for the application for a resurvey, (15) number of request for a resurvey, (16) assignments of responders at the time, (17) problems in the assignments and (18) improvement of the assessment.

In the following section, the process and problems in the assessment of building damages are discussed base on the above interviews.

3. How was Housing Damage Assessment Conducted?

The process of assessing building damages by the public sector consists of the two phases shown in Figure 3. The period of each survey is also shown in Table I. In the first phase, *Initial damage estimation* is carried out. This was conducted immediately after the earthquake by each local government, but the completion

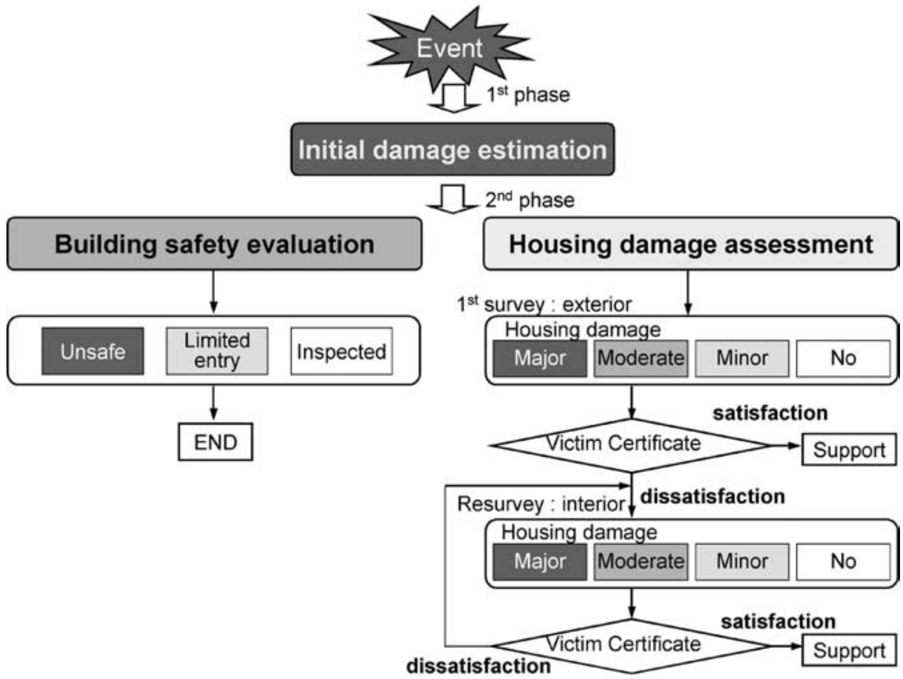

Figure 3. Process of building damage assessments by the public sector.

date is unclear. A global image of the damages could not be grasped until the evening of the first day. In the next phase, *Building safety evaluation* and *Housing damage assessment* are conducted concurrently. *Building safety evaluation* was performed from January 23rd to February 9th 1995. *Housing damage assessment* started on January 23rd and it lasted for about one year in the case of Ashiya City.

3.1. INITIAL DAMAGE ESTIMATION

Regarding *Initial damage estimation*, in Japan, in the event of a disaster causing damage, the local government must first report the damage aspects to the national government. Then, based on these reports, the national government decides whether to apply the Disaster Relief Law. The number of houses with major damage is used as one of the criteria in making this decision. In the case of the Hanshin-Awaji Earthquake Disaster, the Disaster Relief Law was applied to 10 cities and 10 towns in Hyogo Prefecture and 5 towns in Osaka Prefecture. The estimation was started immediately after the earthquake mainly by the police and the fire department. The damages were inspected on foot or from the air using a helicopter. However, the activities were hindered due to requests for rescue during inspection, road blockades by damaged roads and buildings, and damaged heliports. Therefore, the information on the disaster could not be collected smoothly. This delay in the gathering of information on the disaster led to the delay in the initial response activities. One of the reasons that caused the delay is reported in "Committee for Global Assessment of Earthquake Countermeasures" (Hyogo Prefectural Government, 2000b). It was the overflow of unnecessary information for initial response activities, i.e., information that is too accurate in the initial response period, when the exact number of damaged buildings is not necessary. It is important to provide disaster response headquarters with reasonable information, which allows the disaster scale to be envisaged and to make a decision on applying the Disaster Relief Law.

3.2. BUILDING SAFETY EVALUATION

Building safety evaluation is an emergency survey aimed at protecting human lives from further building collapses due to aftershocks. In this evaluation, damages are divided into three levels: unsafe, limited entry and inspected. The assessment forms is prepared for three structure types: wooden, steel and reinforced concrete. The criteria for judgment are similar to those defined by the Applied Technology Council (ATC-20, 1989 and ATC20-2, 1995), which consist of the following three categories: (1) overall hazards, (2) structural and ground hazards and (3) falling hazards. Each category has several items. Each item is checked against three damage levels based on safety considerations. If one or more items are judged as unsafe, the total building is judged unsafe. In the Hanshin-Awaji Earthquake Disaster, the total number of surveyed buildings was 46,610, of which 6,476 were unsafe, 9,302 were of limited entry and 30,832 were inspected. This survey was first performed in the Hanshin-Awaji Earthquake Disaster, although it had been previously conducted experimentally. The main body of this survey team was made of the local government officials assisted by groups of volunteer architects. Although this survey was scheduled to be carried out for all the buildings, the immense number of damaged buildings made a complete survey impossible. Public facilities and cooperative housing complexes were given priority. Individual houses were investigated upon request by the owners. Therefore, most housing owners had to judge for themselves whether an evacuation was needed or not.

3.3. HOUSING DAMAGE ASSESSMENT

Housing damage assessment was generally conducted in two stages, i.e., the first survey and the resurvey. The first survey involved the inspection of the building's exterior only, and was conducted by disaster responders of the local government who lacked expertise in the field of buildings. Then, Victim Certificates were issued based on the results of the assessment, which were divided into four levels: major damage, moderate damage, minor damage and no damage. The assessment criteria are shown in Table II. There were no other detailed criteria. Minor damages and no damages had no criteria. In the Hanshin-Awaji Earthquake Disaster, many houses were judged as having minor damage even if they had no damage. If the

Table II. Criteria for housing damage assessment (1968)*

Damage level	Description
Major	Houses which have been destroyed specifically, cases where the area of the section of the dwelling that collapsed, burned down or washed away is at least 70% of the dwelling, or where the amount of damage to the main structural part of the dwelling is at least 50% of the market value of the dwelling.
Moderate	Damage to the houses is considerable, but if repaired it can be used again as it was originally. Specifically, where the area of the section ranges from 20% to less than 70% of the dwelling, or if the amount of damage to the main structural part of the dwelling is at least 20% but less than 50% of the market value of the dwelling.

*Minor damages and no damages had no criteria.

victims were satisfied with the first result, they could receive the corresponding level of support. However, a considerable number of victims were dissatisfied and applied for resurvey. Disaster responders had to repeat more than 30% of these surveys to reach an agreement with the victims. Resurveys included the inspection of the building's interior and were conducted by disaster responders accompanied by building construction experts. Even then, if the victims were still dissatisfied, the resurvey was repeated. As a result, the dissatisfaction of the victims made the *Housing damage assessment* very time-consuming, such that it could take about one year until an agreement could be reached on the assessment.

4. Why was Housing Damage Assessment Difficult?

4.1. CAUSAL RELATION DIAGRAM

The problems encountered in *Housing damage assessment* were the most complicated and the most difficult to include in rebuilding the victims' livelihood. A causal relation diagram, as shown in Figure 4, was prepared based on the results of the ethnographic interviews, to analyze why *Housing damage assessment* were difficult. A number of problems associated with *Housing damage assessment* were pointed out in the interviews. This diagram shows the relation between the problems and the factors causing the problems. The highlighted contents in the figure indicate problems taken up by all local governments and the other contents show those pointed out by two or more governments. It was found that these problems were interrelated in a complex manner; however, they could be classified into 10 categories: (a) disaster scale, (b) purpose, (c) legal criteria, (d) method, (e) accuracy, (f) human resources, (g) timing, (h) information management, (i) emotion of victims, and (j) contact.

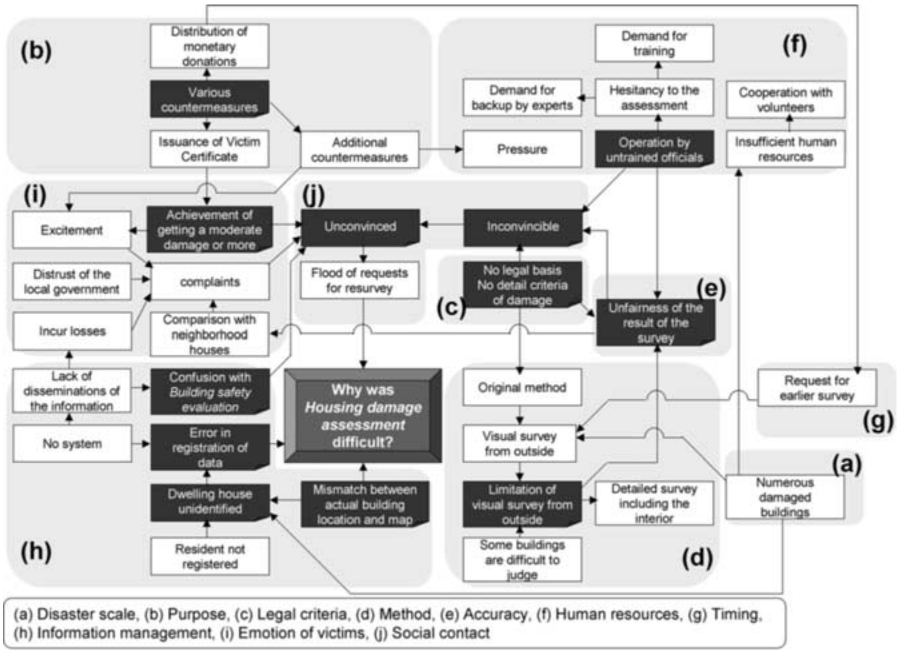

Figure 4. Causal relation diagram among problems in *Housing damage assessment.*

4.2. ANALYSIS OF THE PROBLEMS

As explained in the previous section, one of the serious problems was a flood of requests for resurvey. The primary cause of this problem was that reaching an agreement with the victims was difficult, as shown with the contact, category (j), of the above causal relation diagram. Namely, requests for resurvey would not be required if the victims were satisfied with the results of the *Housing damage assessment*. The reasons why reaching a consensus with the victims was difficult are analyzed in detail on the basis of categories in the diagram shown in Figure 4.

4.2.1. *Disaster Scale*

The Hanshin-Awaji Earthquake Disaster was one of most disastrous earthquakes recorded in Japan. Table III shows the damages of recent earthquake, which caused over 10 fatalities in Japan after the establishment of the present Building Standard Law in 1950. In the Hanshin-Awaji Earthquake Disaster, the total number of major and moderate damaged buildings was about 240,000 buildings. This situation created difficult circumstances, such as shortage of manpower, and *Housing damage assessment* had to be conducted initially with the inspection of the building exterior only. Moreover, it affected information management, such that no confirmation was given on which buildings were the subjects of assessment. *Housing damage assessment* was conducted following other earthquakes, which happened before the Hanshin-Awaji Earthquake Disaster. The associated problems, however, have re-

Table III. Damage statistics in recent earthquakes in Japan

Earthquake	Year	Number of buildings		Number of human casualties	
		Major damage	Moderate damage	Death	Injury
Tokachi-oki Earthquake	1952	815	1,324	28	–
Niigata Earthquake	1964	1,960	6,640	26	447
Tokachi-oki Earthquake	1968	673	3,004	52	330
Izu-Hanto-oki Earthquake	1974	134	240	30	102
Izu Ohshima Kinkai Earthquake	1978	96	616	25	211
Miyagi-ken-oki Earthquake	1978	1,183	5,574	28	1,325
Nihonkai Chubu Earthquake	1983	934	2,115	104	163
Nagano-ken Seibu Earthquake	1984	14	73	29	10
Hokkai-do Nansei-oki Earthquake	1993	601	408	202	323
Hyogo-ken Nanbu Earthquake (Hanshin-Awaji Earthquake Disaster)	1995	111,233	137,283	6,432	43,792

mained dormant since the number of damaged buildings was comparatively fewer in the former. It goes without saying that smaller numbers of damaged buildings facilitates assessment.

4.2.2. *Purpose of the Damage Assessment*

The purpose of *Housing damage assessment* was unclear. Not only disaster responders but also the victims did not completely understand the purpose of damage assessment when it was initiated. Although the Victim Certificate was ultimately used to allot various forms of support, the reasons for initiating *Housing damage assessment* differed in each local government. For example, one local government began *Housing damage assessment* for distributing monetary donations, another for disaster assistance loans. One disaster responder at the interview said that he never imagined that the results of *Housing damage assessment* would be used for the future allocation of various forms of support which were launched one after another. The victims were also unaware of what the Victim Certificate would be used for. It is important to clarify the purpose and enhance the awareness of building damage assessments.

4.2.3. *Legal Criteria, Method and Accuracy*

Housing damage assessment requires the highest accuracy because it affects rebuilding of victims' livelihoods in the long term. The Victim Certificate, which was issued by local governments based on the result of *Housing damage assessment*,

Table IV. Uses of the Victim Certificate

Sectors		Supports
Public	(a)	Distribution of monetary donation
	(b)	Reduction and exemption of taxes
	(c)	Reduction and exemption of school expenses
	(d)	Demolition of buildings at government expenses
	(e)	Moving to temporary housing
	(f)	Permanent restoration of housings
	(g)	Subsidies for individual recovery
	(h)	Loans for the restoration of housing
	(i)	Disaster support funds
	(j)	Money to support rebuilding of victims' livelihood by law
Private	(a)	Certification for life insurance and indemnity of housing
	(b)	Certification for bank loans

Photograph 1. Actual example of results in *Housing damage assessment.*

was required in order to receive various forms of support not only from the public sector, but also the private sector, as shown in Table IV. In addition to this, a serious problem was the lack of a clear threshold between moderate and minor damage, since most of the support for recovery and reconstruction was limited to victims with certificates citing major or moderate building damage. Although the victims asked for a fair assessment, the results varied among each local government or among inspectors. Photograph 1 shows an actual example of results in *Housing damage assessment*. To gain the victim's assent, differences in results must be explained.

Three factors made the assessment inaccurate. First, there were no detailed criteria other than the descriptions shown in Table II. Second, there was no systematic method. Each local government developed their own detailed method for damage inspection independently since the criteria could be applied, for example, to damage of the ground, foundations, equipment or lifeline facilities. The third factor was the competence of the inspector. Since there were only few experts in local governments for housing damage inspections, the inspections were conducted by untrained officials. These factors contributed to the dissatisfaction of victims and the need to repeat surveys. It is necessary to improve *Housing damage assessment* and make it easier in order to allow for a fair assessment even when it is carried out by non-experts. Training the officials to enhance their awareness and skills is also important.

4.2.4. *Human Resources*

The allocation of human resources was inefficient. In particular, *Building safety evaluation* and *Housing damage assessment* were conducted concurrently, therefore, human resources were divided. Experts such as architects investigated building safety as part of a volunteer group. Nevertheless, *Building safety evaluation* could not be conducted for all the buildings because experts were few in comparison with the excessive number of buildings. In the case of the Hanshin-Awaji Earthquake Disaster, individual wooden houses constituted the major portion of all damaged buildings; therefore, sufficient information on the safety of their own buildings could not be provided to the victims. In addition, *Housing damage assessment* was performed by local government officials, who did not have the expertise in the field of architecture. They hesitated to assess engineered buildings, which are large-scale and complicated structures. Therefore, the development of an expert backup system to assist the officials is necessary. The number of registered experts for *Building safety evaluation* has been increasing since the earthquake, as described later, and it is important to properly take advantage of such experts' competence for *Housing damage assessment*.

4.2.5. *Timing*

One of reasons why the *Housing damage assessment* had to be carried out early was the distribution of monetary donation. Monetary donations provide rapid assistance for daily life. In the interviews, the opinion was expressed that it should not be connected with the Victim Certificate. It is possible that the assessment would be conducted more thoroughly, if the monetary donation is separated from the Victim Certificates.

4.2.6. *Information Management*

Information management was poor. There are two major factors: (1) geographic information and (2) information system. Regarding geographic information, in the field, investigators could not confirm the target building on the map because the map they were using was different from the actual field situation and the appearance of the town had changed completely. The information system was not single and centralized: each department in the local government developed their own information system independently, i.e., the system for recording the damage data and the system for issuing the Victim Certificates were separated. Therefore, the problem of damage data mismatches between each of the systems appeared. Another problem was that most of the victims also confused *Building safety evaluation* and *Housing damage assessment* for similar surveys. Information concerning which survey was conducted was not well communicated to the victims. It is necessary to provide the victims with the proper information in advance.

4.2.7. *Victim's Emotion and Contact*

One of the matters taken up frequently in the group interview was the emotion of the victims. The victims wanted a judgment of moderate damage or more as the effects of the Victim Certificate were extensive. In addition, unfair judgments and the lack of credibility of the local government helped increase dissatisfaction. Additional countermeasures, which meant that public support was provided one by one without immediate presentation after the earthquake according to the situation of the survivors, also contributed to the victims' irritation. However, they were satisfied with the result once they requested a resurvey. According to the disaster responders, the point of having contact with the victims was to listen to their thoughts and emotions. Reaching a consensus with the victims was the most important aspect.

The above analysis revealed the problems in *Housing damage assessment*. An additional problem was the relation between the *Building safety evaluation* and *Housing damage assessment*: human resources were not effectively utilized and these surveys were confusing. Therefore, the development of a comprehensive damage assessment is necessary, which includes *Initial damage estimation*, *Building safety evaluation* and *Housing damage assessment*. In the next section, the relationships between the three purposes of assessment by the public sector are shown from the perspective of a number of requirements for each assessment of building damages, in order to develop a consistent system for the assessment of building damages.

5. Requirements for the Assessment of Building Damages

Based on a questionnaire concerning livability and housing repair, two timings appeared prominent with respect to the victims asking for information on housing options: within the first week after the Hanshin-Awaji Earthquake, the victims inquired about the safety of their housing; within one month, they inquired about the recovery of their housing (Kimura *et al.*, 2000). However, *Building safety evaluation* was conducted 6 days after the earthquake and *Housing damage assessment* lasted for one year or more in cases necessitating resurveys. Therefore, the information was not available at the victims' request.

Based on the results of ethnographic interviews and the above-mentioned shift in the inquiry on the part of the victims, a number of requirements have been established, from the perspective of time and accuracy of determination in the

Table V. Requirements for building damage assessments by the public sector

Title	Influence on victims	Time	Accuracy	Victim's needs
Initial damage estimation	The basis for applying Disaster Relief Law and the key for the disaster relief system	Immediate	Reasonable	***
Building safety evaluation	Information for temporary evacuation	Rapid	Moderate	Within a week
Housing damage assessment	Most influential on individual life recovery	Long term	High	Within a month

damage assessments to be performed by the public sector. These requirements are summarized in Table V.

Initial damage estimation necessitates an immediate survey to provide disaster responders with information on the disaster. Therefore, *Initial damage estimation* is a key, which sets in motion the disaster relief system. As explained in Section 3.1, the high accuracy in the assessment result is not required in the initial response period. It is unnecessary to clarify the exact extent of the damages to each building. Reasonable information on disaster is required to allow administrators to make a decision, i.e., it is necessary to estimate a distribution of damage rate for each area.

On the other hand, *Housing damage assessment* requires accuracy as high as possible, since it mostly influences individual rebuilding of the victims' livelihood. However, operating a detailed survey of all housing including the inspection of the building interior may take a long time. If the investigator can easily make a judgment based on the exterior appearance, such as completely collapsed housing, *Housing damage assessment* should be conducted rapidly within a month because victims who live in such houses will require early support. However, if the judgment is difficult, it should be conducted thoroughly until the victims assent. On that account, early countermeasures such as the distribution of monetary donations should be unrelated to the Victim Certificate.

Building safety evaluation must be conducted within a week. In addition, it requires some degree of accuracy from the perspective of safety. However, an exact judgment is not needed. If the investigator hesitates to evaluate whether the building is safe, the building should be evaluated as unsafe to be the safe side.

6. Improvements Over Current Damage Assessments

The significance of damage assessment gained a new meaning in the lessons learned from the Hanshin-Awaji Earthquake Disaster. Improvements have been proposed for each damage assessment.

Regarding *Initial damage estimation*, emergency responses were delayed in the Hanshin-Awaji Earthquake Disaster owing to difficulties in obtaining early information on the aspects of the damage. Therefore, methods for performing early estimation were proposed, such as the estimation of damage based on the distribution of seismic motions measured by seismometers, or application of remote sensing technology, to this end. These methods would give access to information during the information blank period immediately following an earthquake.

The manuals describing *Building safety evaluation* were revised in 1998. Improvement of the organization for the surveys has progressed and the number of registered experts for *Building safety evaluation* has been increasing since the Hanshin-Awaji Earthquake Disaster: They are about 90,000 in 1999.

Murao and Yamazaki (1999) pointed out that *Housing damage assessment* requires objective and uniform criteria. They also proposed an assessment form based on the actual cost of construction.

An effective process for *Housing damage assessment* was also proposed, which consists of both visual survey based on damage patterns of buildings for prompt service, and resurvey, to gain the assent of victims on the assessed damage (Kohiyama *et al.*, 2000).

Okada and Takai (2000) classified building damage patterns using photographs of building damages taken in Hokudan Town, Awaji Island, in the Hanshin-Awaji Earthquake Disaster, and proposed a damage pattern chart for wooden-housing superstructures. A damage chart for wooden-housing affected by liquefaction was also developed based on the analysis of damaged buildings in the Tukiji area, Amagasaki City (Horie *et al.*, 2000a). These damage pattern charts are illustrated by the schematics of building damages as shown in Figure 5. They are expected to facilitate damage assessment and reduce the error in judgment due to differences in the viewpoints among investigators.

The items which are essential in each of the surveys were clarified in the case of wooden structures, based on the analysis of a set of items collected from 12 building assessments, using the quantification method III and the correlation t-test (Horie *et al.*, 2000b). The items that are typical and common to *Building safety evaluation* and *Housing damage assessment* were detected. Common items were: (1) overall damage including tilt of building, (2) exterior walls, (3) roof, (4) tiles of roof, (5) columns and (6) fixtures. Typical items were: (1) ground and (2) falling hazard such as chimney and balcony for *Building safety evaluation*, and (1) foundation, (2) interior columns and (3) stairs for *Housing damage assessment*.

The above-mentioned individual improvements should enhance efficiency in damage assessment. Moreover, the institution of a comprehensive and consistent system for damage assessment, which includes *Initial damage estimation*, *Building safety evaluation* and *Housing damage assessment* will be more effective by adapting the above improvements in an integrated manner.

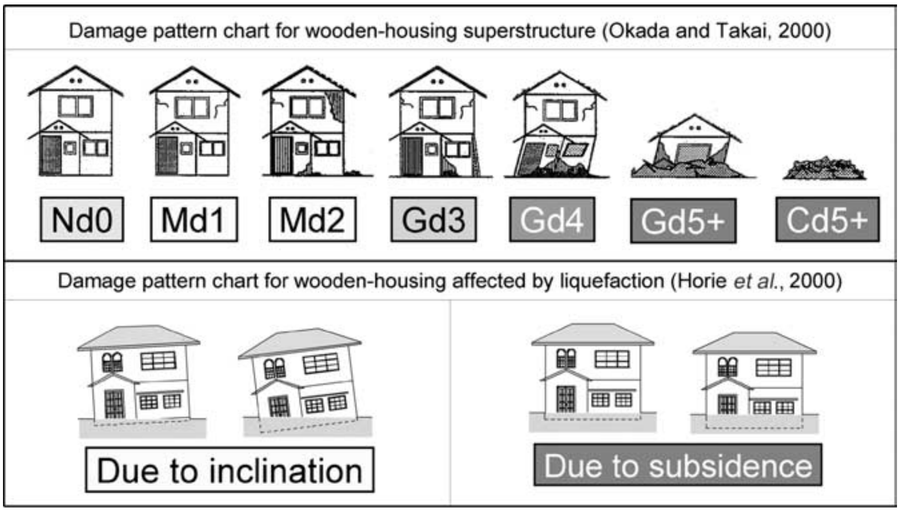

Figure 5. Example of building damage charts.

7. Housing Situation in Japan

Until the Hanshin-Awaji Earthquake Disaster, the main countermeasure against an earthquake disaster was the prevention of damage, and focused on raising seismic resistance of structures. Japan's high seismic resistance is well recognized in the world. However, a gigantic number of buildings suffered damage in the Hanshin-Awaji Earthquake Disaster. Especially, the rate of damage for wooden structures was higher than for non-wooden structures. Why were such a great number of the wooden structures damaged? In this section, the construction system in Japan is addressed. Engineered buildings and non-engineered buildings are classified from the perspective of the inspection system, structural design system and construction management. Next, buildings that are the target of assessment of building damages are studied based on housing statistics standpoint to construct an effective system for assessing damages.

7.1. ENGINEERED BUILDINGS AND NON-ENGINEERED BUILDINGS

An engineered building has considerable structural safety against the dead load, live load, snow load, wind pressure, earthquake load, other loads and external forces. To evaluate structural safety, the following items are essential:

1. Building codes for structural safety such as the Building Standard Law.
2. A design by experts based on the building codes.
3. A verification system for the design by an authorized sector.
4. A system for the management of construction to ensure the design.
5. An inspection system after completion of the construction.

Although buildings that fulfills the above five items may be called engineered buildings, there are buildings that are not checked for structural safety in a inspection system and which do not require experts for structural design and construction management.

The inspection system in Japan mainly consists of the following three processes: (1) submission of application form for building confirmation, (2) verification of building design, (3) inspection of building after construction. However, the application form for building confirmation was not submitted for all the buildings. There are buildings that do not require inspection in the Building Standard Law. Moreover, in the buildings which need the inspection, there are buildings for which the verification of structural safety have been omitted. The necessity for inspection is determined based on six points: (1) uses of building, (2) building story, (3) total floor area, (4) building height, (5) height of eave, (6) location for construction.

Regarding structural design and construction management, there are two types of buildings in the Architect Law related to the structural design and the construction management: one requires structural design and construction management by experts such as architects; the other does not. The determination of the requirements for experts is based on four points: (1) building story, (2) total floor area, (3) building height, (4) height of eave.

The relationship between the building properties (structure type, building story, total floor area, building height, height of eave) and the items are shown in Table VI. Consequently, in the case of wooden structures, the buildings (1 or 2-stories, the total floor area is under 500 [m^2], the building height is under 13 [m], and the height of eave is under 9 [m]) cannot assure structural safety credibly. In the case of non-wooden structures, the buildings (1-story, the total floor area is under 200 [m^2], the building height is under 13 [m], and the height of eave is under 9 [m]) cannot be assured. These buildings should be non-engineered building and they have a high possibility of suffering damage. Among these buildings, however, prefabricated houses and wood framed houses have their own building codes for structural safety, and such houses are engineered buildings. Actually, the number of damaged houses of these types was comparatively few in the case of Hanshin-Awaji Earthquake Disaster.

On the other hand, in the engineered buildings, questions about seismic resistance exist by two reasons: (1) operation of inspection system in the Building Standard Law, (2) existing non-conformed buildings. A major revision of the Building Standard Law took place in Japan in 1998. Maki and Hayashi (2000) reported differences of application before and after the amendment. According to this, it was pointed out that the inspection system in the Building Standard Law did not function well before the amendment. Therefore, an interim inspection is added, and the private sectors are authorized to arrange the inspections after the amendment. Moreover, buildings that do not comply with current Building Standard Law also exist since the Law does not apply to pre-existing building. These buildings also have a high possibility of suffering damages.

Table VI. Relationship between the building properties and essential items for engineered building (shaded cells are defined non-engineered buildings)

(a) Wooden structure

Building scale				
– story: S	$S \Leftarrow 2$ and $H \Leftarrow 13$ and $HE \Leftarrow 9$			Others
– total floor area: A[m^2]				
– height: H[m]	$A \Leftarrow 100$	$100 < A \Leftarrow 500$	$500 < A$	
– height of eave: HE[m]				
Building Codes	OK?[1]	OK?[1]	OK?[1]	OK
Structure design	NG	OK	OK	OK
Design check	NG	NG	OK	OK
Construction management	NG	OK	OK	OK
Inspection after construction	NG	NG	OK	OK

[1]Fundamentally, only the quantity of seismic resistance wall is checked.

Building scale				
– story: S	$S \Leftarrow 1$ and $H \Leftarrow 13$ and $HE \Leftarrow 9$			Others
– total floor area: A[m^2]				
– height: H[m]	$A \Leftarrow 30$	$30 < A \Leftarrow 200$	$200 < A$	
– height of eave: HE[m]				
Building Codes	OK	OK	OK	OK
Structure design	NG	OK	OK	OK
Design check	NG	NG	OK	OK
Construction management	NG	OK	OK	OK
Inspection after construction	MG	NG	OK	OK

7.2. HOUSING SITUATION ON THE STATISTICS IN JAPAN

According to statistics about housing in 1998, the total number of houses was 50,246,000 in Japan, of which 43,922,100 (87.4%) were with occupants, 393,600 (0.8%) were with temporary occupants, and 5,930,300 (11.8%) were vacant or under construction. In the houses with occupants, 41,744,200 were for private use, 123,800 were for combined use with agriculture, forestry or fisheries, and 2,054,100 were for combined use with store. Figure 6 shows a cross-counting analysis of building structure type and housing type, in the houses with occupants. The structure type and the housing type are divided into four types, respectively. The rate of individual housings was 57.5%, the rate of row housings, which are Japanese traditional tenement housings, was 4.2%, the rate of apartment and condominium was 37.8%, other housings was 0.5%. Two prominent groups appeared. One is the individual wooden house with one or two stories. This group amounted for 91.8% of the individual houses, and 52.8% of the total houses. Most of these houses should be classified as non-engineered buildings, according to the definition

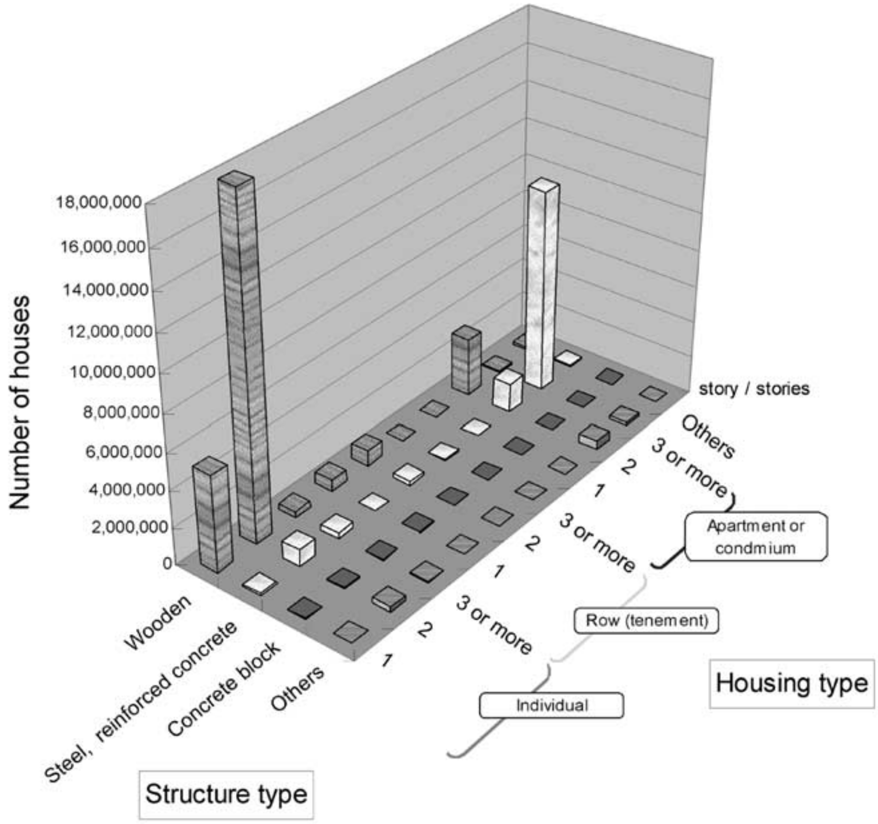

Figure 6. Cross-counting analysis of building structure type and housing type.

in the previous section. Another group was steel or reinforced concrete structures, with two stories or more in apartments or condominiums. This group amounted for 76.3% of the type of apartments or condominiums, 67.9% of the houses excluding individual houses and 28.8% of the total houses. These houses should be classified as engineered buildings. These two groups amounted to 81.7% of the total houses. The proportion of non-wooden structures with one story, which should be non-engineered buildings, was low (0.6%).

7.3. ESTABLISHMENT OF TARGET BUILDINGS FOR EFFECTIVE BUILDING DAMAGE ASSESSMENT SYSTEM

An efficient allocation of experts is necessary for the development of an effective damage assessment system. From the perspective of assessment of building damage, buildings that are the targets of assessments can be divided into two categories: individual houses and others. Assessments of individual houses do not require experts because they are small-scale and simple structures. Other houses require the involvement of experts because these buildings are large-scale and complicated structures, such as multi-story houses. They amount to 57.5% and 42.5%, respectively.

Table VII shows the characteristics in each category obtained from housing statistics. Individual wooden houses with one or two stories amounted to 91.8% of the individual houses. Therefore, this category consists mostly of non-engineered buildings. Strictly, this category includes non-wooden houses and wooden-houses with three or more stories. Moreover, there are prefabricated houses and wood framed houses, which are engineered buildings. Another category is occupied by steel or reinforced concrete structures with two stories or more in apartments or condominiums (67.9%). In this category, the rate of wooden row (tenement) houses is 7.7% (one or two stories: 7.6%; three or more stories: 0.1%) and the rate of apartments and condominiums is 17.4% (one or two stories: 16.9%; three or more stories: 0.5%). These houses cannot be distinguished as engineered buildings and non-engineered buildings since the building scale is not clear, e.g., building height or total floor area. Another issue is the existence of buildings that do not comply with the current Building Standard Law. Especially, many row (tenement) housings were damaged and caused a considerable number of casualties in the Hanshin-Awaji Earthquake Disaster since most of these constructions were old, and occupied by many elderly people. These characteristics of housing should be taken into account for constructing future building damage assessment systems.

8. International Situation

This section addresses the damage assessment system in California, USA and in New Zealand, in order to construct an effective damage assessment system in Japan. Some of the problems encountered during the assessment of building damages conducted in recent earthquake disasters are also summarized.

8.1. CALIFORNIA, USA

Building safety evaluation and *Housing damage* assessment were conducted in parallel in Japan. On the contrary, in the case of the 1994 Northridge Earthquake, only one *safety evaluation of buildings* was carried out in California. The result of this evaluation was used as the criteria for both safety and support for individual recovery. The survey applied the ATC 20 method. The evaluation process is shown in Figure 7. There were three phases in the process: (1) rapid evaluation, (2) detailed evaluation and (3) engineering evaluation. The detailed survey was carried out gradually. The rapid evaluation was conducted by officials and experts. In the Detailed evaluation, inspectors with structure expertise judged the extent of building damage. The evaluation result was firstly divided into three levels: unsafe, restricted use and inspected. Finally, the results were classified into two levels, unsafe and inspected. In addition to these results, the dangerous area was judged as

Table VII. Characteristics for each individual housing and the others

Individual housing (57.5%)	Others (42.5%)
Wooden housing with one or two stories (91.8%)	Wooden row (tenement) housing (7.7%): (NE?)
– conventional framework housing: (NE)	Wooden apartment and condominium (17.4%): (NE?)
– prefabricated housing: (E)	Non-wooden row (tenement) housing (2.1%): (E)
– wood framed housing: (E)	Non-wooden apartment and condominium (71.6%)
Others (8.2%)	– steel or RC frame with two or more story (67.9%): (E)
– wooden housing with three or more stories (1.2%): (E)	– others (3.7%): (E)
– non-wooden housing (7.0%): (E)	

Shaded cell is dominant housing type in each category.
(NE): Non-engineered buildings, (E): Engineered buildings, (NE?): Possible Non-engineered buildings for existing non-conformed buildings.

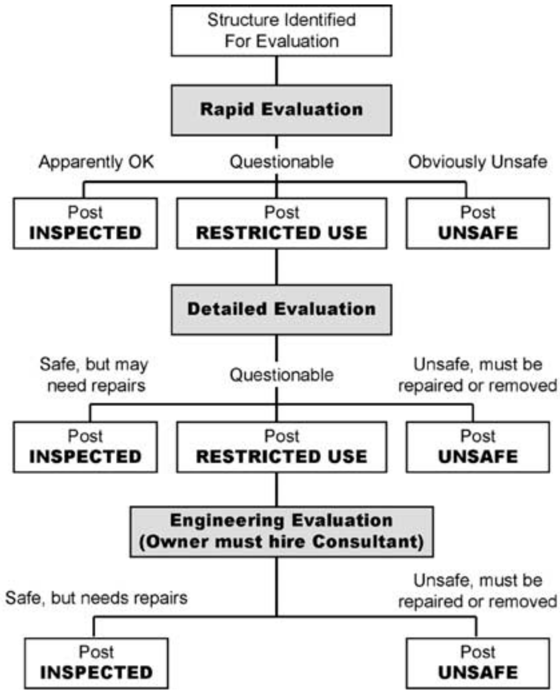

Figure 7. Evaluation process in ATC 20 and ATC 20-2.

an unsafe area. In the Hanshin-Awaji Earthquake, people walked beside damaged electric poles. It is important to restrict the approach to a dangerous area and to make sure that the safety of the buildings was inspected. Another difference is that the aftershocks were considered in ATC 20. In the case of further building damages due to aftershocks, the evaluation was re-conducted. The handbook for field survey and tools for training were also developed (ATC 20-1, 1994 and ATC 20-T, 1993). Safety of inspectors was also considered in these materials.

8.2. NEW ZEALAND

The building damage assessment system in New Zealand is described in *Post-Earthquake Building Safety Evaluation Procedures* (New Zealand National Society for Earthquake Engineering, 1998). This procedure was derived from the ATC 20 and ATC 20-2. The evaluation conducted after an earthquake has five types as shown in Table VIII. The evaluation timing, purpose and organization were established clearly in each evaluation. The assessment process is shown in Figure 8. Although it was similar to ATC, the result of evaluation was divided into four levels: unsafe, short period entry, restricted use and inspected. As characteristics in the process, buildings might be inspected exterior only in a rapid evaluation. Critical facilities were given priority, and a detailed evaluation was first conducted. In the case of New Zealand, measures for aftershocks and safety of inspectors were

Table VIII. Summary of post-earthquake building inspections in New Zealand (New Zealand National Society for Earthquake Engineering, 1998)

Title	Timing*	Initiated by	Purpose	Conducted by	Comment
Initial (drive by/ windscreen)	Within hours after event	CD staff, emergency service action plans	Assess aggregate damage for affected area	Emergency services, TA staff, CD volunteers	No entry of premises, no formal records, emphasis on total numbers of collapses, identify rescue tasks etc.
Entry	Within first day	NZ Fire Service, Police, rescuers	Ascertain safety needs of searchers/rescuers, record search results, priorities rescues (triage)	NZ Fire Service, other emergency groups, rescue teams; engineers may be asked to advise	Short-term assessment focused on likely hazard to victims or rescue workers, shorthand marks made on buildings as hazard and evacuation reference
Rapid (safety)	1 to 14 days	Building Evaluation Manager (BEM)	Ascertain extent of damage and hazards; assess appropriate level of occupancy; note security and shoring requirements	Personnel from the building industry, architects	Formal system, placards posted on buildings, central record maintained, note made of sites needing further (detailed) inspections, unsafe areas cordoned off
Detailed	2 to 21 days	BEM	further inspection as identified by Rapid Evaluations or subsequent requests, dealing with complex or critical facilities	Structural engineers, building services and geotechnical engineers	Formal system, revised placards posted on buildings, central record updated, unsafe areas cordoned off
Engineering	Longer-term	Owners, insurance companies	Establish long-term future of buildings, establish losses for insurance purposes	Engineers, architects and loss adjusters	Meets insurance and restoration requirements under the Building Act

*All timings are estimates only.

also considered. Moreover, construction of database for evaluation using GIS, and establishing a "call center" to receive requests for inspection are described.

8.3. BUILDING DAMAGE ASSESSMENT IN RECENT EARTHQUAKE DISASTERS

Earthquake disasters have occurred in various places in the world in recent years. This paper collects some problems encountered in the assessment of building damages conducted in the 1999 Turkey Earthquake and the 1999 Chi-Chi, Taiwan Earthquake. The problems in Turkey, was that information concerning building safety was not properly provided to the victims. As a result, it was pointed out that many people lived in the tents set in front of their original houses without damage,

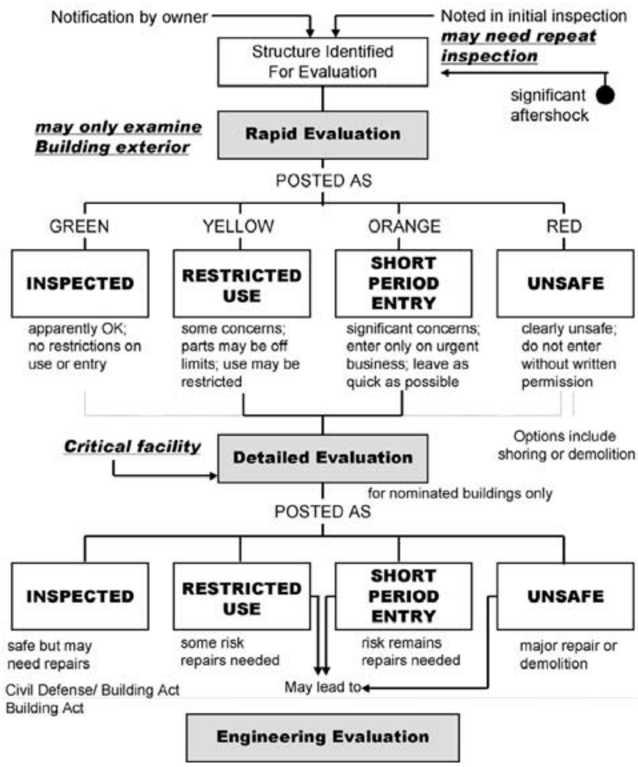

Figure 8. Process of Post-earthquake building inspections in New Zealand.

and the anxiety about the safety of housing was the key factor for evacuation (EDM, 2000a). It is important to provide information about building safety rapidly for both the victims and for the disaster management. In the case of the Chi-Chi (Taiwan) Earthquake, It was reported that the countermeasures for individual assistance were launched in an earlier stage compared to the Hanshin-Awaji Earthquake Disaster (EDM, 2000b). In the Hanshin-Awaji Earthquake, various supports were provided one by one without immediate presentation and constituted a factor that caused problems. The procedure to receive these countermeasures was conducted in a one-stop center in the case of the Taiwan Earthquake. The extent of building damages was used as criteria for receiving public support, as in the case of the Hanshin-Awaji Earthquake Disaster. However, dissatisfaction of victims against the result of assessment made the survey difficult. It is necessary to establish a procedure to reach an agreement with the victims.

9. Proposal for Comprehensive Building Damage Assessment System

It was obvious that a poor damage assessment system and the size of the disaster produced a very large work load. Differences in the appreciation among investigators also contributed to unfair assessments and led to the victims being increasingly dissatisfied by the survey results. Therefore, the constitution of an effective damage assessment system is essential for post-earthquake disaster management. A design concept for a comprehensive damage assessment system is proposed as shown in Table IX. This design concept is derived from the following five points: (1) the analysis of problems in the Hanshin-Awaji Earthquake Disaster, (2) the changes in the nature of information needed by the victims, (3) the integration of the improvements over the present damage assessment, (4) the housing situation in Japan, and (5) the international situation on damage assessment. This concept has been designed based on the time phase-target buildings matrix. There are three time phases, which are set so as to clarify the purpose of each assessment and to respect the changes in the nature of information needed by the victims: (1) *Initial damage estimation* for providing information on the disaster and applying the Disaster Relief Law, (2) *Building safety evaluation* for protecting human lives and (3) *Housing damage assessment* for rebuilding individual livelihoods. Target buildings can be divided into two categories: individual houses and others. Based on the matrix, this assessment system consists of the following five elements.

(a) Element-1 consists in counting the number of damaged buildings. It must be conducted in the initial stage with a reasonable accuracy to allow administrators to make the decision of whether to apply the Disaster Relief Law. The results are also used for planning the next assessment.

(b) Element-2 and (c) Element-3 aim at protecting human lives. They require moderate accuracy from the perspective of safety but the presence of officials is not necessary. Element-2 is to be performed on individual housings. Element-3 is to be conducted on other houses. Element-2 is carried out by individual building owners for non-engineered buildings. Actually, the building owner should be responsible for the building safety. In the Hanshin-Awaji Earthquake Disaster, local government officials carried out evaluations because building owners could not evaluate the safety of their own buildings. However, *Building safety evaluation* was not conducted for all buildings. In addition, in the Tottori-ken Seibu Earthquake, which occurred on 6th October 2000, it was not carried out for all the buildings in spite of a smaller disaster compared to the Hanshin-Awaji Earthquake Disaster. The buildings were investigated upon request by the victims, except for clearly unsafe ones. The first judgment of building safety was conducted by the building owner. Therefore, Element-2 should be helpful for this situation. The support system for Element-2 is also provided for people who are most vulnerable, or in the case of difficult assessment. If tools for facilitating the survey such as damage pattern charts are developed, individual building owners will be able to easily evaluate the safety of their building using the tools. It aims at enhancing public awareness and providing information on the safety of buildings. Damage pattern charts were developed from the perspective of structural safety and building serviceability. In the future, it will be necessary to clarify the relationship between building damage pattern and reparability. It will be also available for comparison with the results

Table IX. Design concept for effective building damage assessment system

Use		Housing		Facility		
Type		Individual	Multi-story apartment or condominium	School, hospital, etc.	Office, store, factory etc.	Officials
Owner	Private	Public	Private Public	Private		
Characteristics of structure		Non-engineered building (wooden, small scale)	Engineered building (non-wooden, large scale)			
Possible inspectors		Non-experts	Experts			
Initial damage estimation	Immediate	For information on the disaster and applying the Disaster Relief Law (a) Element-1: by officials				Required
Building safety evaluation	Rapid (within a week)	For protecting human life (b) Element-2: by individuals	(c) Element-3: by experts			Not necessarily needed
Housing damage assessment	Long term (within a month)	For individual livelihood rebuilding (d) Element-4: by officials	(e) Element-5: by officials + experts			Required

Photograph 2. Example of possible building assessed by visual inspection from outside.

obtained with Element-5. This allows the victims to have approximate ideas of the extent of the damages and the costs for repairing their housing at an early stage.

(d) Element-4 and (e) Element-5 are involved in the issuance of the Victim Certificate. Element-4 is for individual houses, and Element-5 is for other buildings. They require as high an accuracy as possible. However, in reality, it is difficult to conduct a detailed survey of all the buildings in the event of a large-scale disaster. For this reason, such a survey is conducted in two stages: the first stage involves a survey by visual inspection from the outside using damage pattern charts; the second stage involves a detailed survey including the interiors. Such a building shown in Photograph 2, which was clearly damaged, can be assessed easily from outside by visual inspection. In addition, apparently, undamaged buildings also can be assessed easily. In the process of building evaluation, in the case of ATC 20 and New Zealand, an immediate decision is made regarding this kind of damaged building. As an exception, the building in Photograph 3 seems to have no damage. However, the result of assessment by local government was major damage. This underscores the fact that limitations to visual inspection also exist.

In the future, the procedure for proposed assessment system will be developed based on the design concept. In this procedure, the following topics should be established: (1) assessment flow, (2) purpose of assessment, (3) criteria, (4) method, (5) timing, (6) target buildings, (7) organization, (8) safety for inspectors, (9) survey tools, (10) information management, (11) social contact, and (12) training system.

Photograph 3. Example of limitation of visual inspection from outside (result of assessment for Victim Certificate: Major damage).

10. Conclusions

It is clear that reaching a consensus with the victims is important to allow facilitation of the *Housing damage assessment*, as revealed by the analysis of problems in the process of *Housing damage assessment* in the Hanshin-Awaji Earthquake Disaster. Therefore, the following improvements are necessary: (1) reduction of damaged buildings, (2) clarification of the purpose and criteria, (3) development of a method for a fair judgment, (4) effective utilization of human resources, (5) appropriate timing of surveys, (6) construction of an information system and (7) establishment of effective social interface.

Consequently, a design concept for a comprehensive damage assessment system is proposed based on the time phase-target buildings matrix. This design concept is derived from the following five points: (1) analysis of problems in the Hanshin-Awaji Earthquake Disaster, (2) changes in the nature of information needed by the victims and (3) integration of the improvements over the present damage assessment, (4) housing situation in Japan, and (5) international damage assessment methods.

In the future, a building damage assessment system and training system for its use will be developed based on this design concept for post-disaster management.

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