Development of a Methodology for Participatory Evacuation Planning and Management:
Case Study of Nagata, Kobe

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Chapter 1 Introduction

1.1 Background

1.1.1 Disaster planning and management: an overview

With the rapid economic development and urbanization, the cities are growing fast. Throughout the world it is common to observe that large cities and urban agglomerations along with a wide range of opportunities also bring a variety of safety risk. Cities, as those grow bigger and bigger and become more complex, generally become increasingly vulnerable to hazard, both natural and man-made (Misra, 2004). Many cities are located on seismically active zones, near active volcanoes and on areas prone to cyclones and floods and possibilities of damage by these hazards have increased significantly. Due to the lack of proper awareness and preparedness to disasters, the number of casualties affected and economic losses caused by natural disasters have been increasing over recent decades (EM-DAT, 2004). For example, the Tangshan earthquake (July 28, 1976) in China devastated the whole municipality, and killed 242,000 people with millions of people homeless (Liu, 1985). The Indian Ocean earthquake (December 26, 2004) and subsequent tsunamis caused a total of 229,866 people lost, including 186,983 dead and 42,883 missing (United Nations, 2005). Now, most of the countries have taken various countermeasures to reduce the losses due to disasters.

Safety, risk management and disaster preparedness, are now becoming very import aspects of city management in Japan. In the wake of accelerated urban growth and emergence of strong market forces, local area needs and priorities in Japan changed and so was the perception of day to day risks and security from disasters (Misra, 2004). The structural countermeasures are effective in saving people's lives and properties especially from the small-scale low-impact disasters. While for the low-frequency high-impact disasters, these measures probably cause more losses especially when the risks level greatly exceeds the resilience capacity of infrastructure. That was exactly what happened in the Great Hanshin-Awaji earthquake (January 17, 1995) in Japan (The Asashi Simbun, 1996). The earthquake also taught people that the impact of a low-frequency high-impact disaster (catastrophic disaster) may exceed the present capacity of the public rescue and relief services. In most of the similar cases of catastrophic disasters, the local governments are found to be not able to provide the sufficient services to the citizens in the time of disaster. Though various types of national or international assistances from outside of the suffered region may be available, such as those provided by NGOs, NPOs and INGOs, that kind of external assistance is not at all sufficient, particularly for rescue, relief and recovery. So, it is needed to stress the need for community capacity building.

Both communities and local authorities should be empowered to manage and reduce disaster risk by having access to the necessary information, resources and authority to implement actions for disaster risk reduction (Hyogo Framework, 2005). If the local government is only the decision-maker in such cases, they may inevitablely be in bias due to the lack of local knowledge even with the experts' help. The local government should also learn from the local residents. On the other hand, the individual citizens and the local community should have sufficient professional advice for preparation in advance to cope up with the sudden disaster shocks (The Asashi Simbun, 1996). Often due to the lack of professional knowledge, the individual citizens and the local community fail to find their best way to get prepared for disaster risks. They also need to learn from the local government, experts, or NGO/NPOs. This kind of two-way risk communications are often called "social co-learning" (Okada, 2005).

Japan, realizing the need for promotion of 'bottom-up' planning and closer involvement of the civil society in urban development, also brought in appropriate changes in its Urban Planning Law in the 1992 and made it mandatory for the local governments to adopt participatory urban planning at the local level (Misra, 2004). After the 1995 Great Hanshin-Awaji earthquake, the local government has started to take the proactive countermeasures in collaboration with the local communities and individual citizens. Institutional changes are also under way, which gradually shifted the conventional type of top-down approach towards the bottom-up approach (multi-stakeholder participatory approach) (Okada *et al.*, 2004).

In Japan, self help ("Jijyo" in Japanese) and mutual aid ("Kyojyo" in Japanese) are now more advocated by many policy makers and frequently quoted as keywords for community-based disaster reduction, in the official documents and manuals on disaster planning and management. For example, the Disaster Planning Manual of Kagawa Prefecture (2006) emphasizes the importance of self help, and mutual aid for disaster risk management. Such self-help and mutual-aid activities can enhance the individual citizen's awareness, and enhance their internal communications with other neighboring individuals and communities. Besides the individuals and the community, disaster volunteers, such as NGOs and NPOs, are also taking more and more important roles in the community's disaster prevention planning and management.

1.1.2 Disaster evacuation planning and management

The Webster's English Dictionary defines evacuation as, "the act or process of evacuating". In the Weblio dictionary, it is mentioned that evacuation planning is the comprehensive planning of evacuation stairs, evacuation facilities, evacuation routes and smoke control equipments, etc.

The term "sheltering and evacuation planning" is frequently used in disaster management practices. Shelter planning is often viewed to be combined with or as a part of evacuation planning. Moreover, evacuation warning and evacuation directive are also viewed as important parts of evacuation (e.g., FDMA, 2007; and DHS&EM, 2005).

The Building Standard Law and the Fire Defense Law of Japan prescribe that the objectives of evacuation planning is to enable people to evacuate to (a) safe place(s) in the event of a disaster, and that it is concerned with comprehensive planning of such facilities as evacuation ladders, evacuation installations, evacuation pathways, smoke dispersal, etc. (Weblio dictionary).

Considering the above definitions, this thesis proposes a broader and more generic definition as follows: evacuation planning is defined as the planning of facilities, technologies and resources related with the overall evacuation process, including transmission of evacuation warning and directive information (used before evacuating), evacuation guidance and route (used during the process), as well as evacuation center (shelter) (used after the process). Much of this process of evacuation is to be governed at the community level (particularly concerned with evacuation from an individual house to the shelter).

With the intent to increase disaster preparedness and awareness, more and more countries such as Japan, US, UK and China have been enforcing their efforts to evacuation planning, such as setting up disaster shelters, releasing the shelter planning manuals, and carrying out disaster evacuation drills in the disaster-prone areas. However, at grass-root level, several problems arise very often, due to the lack of local knowledge and also the lack of motivation to identify such knowledge by the local government. For example, a survey was conducted by randomly taking 150 samples in front of the first shelter in Beijing by the China Seismic Information in 2006. The result showed that, 75% people still do not know that Beijing had already set up disaster shelters and 63% people do not know the function of disaster shelter (China Seismic Information, 2006). The Oklahoma and Kansas Tornado disasters in 1999 exemplified that people were killed due to the inadequate access to the designated shelters (FEMA 342, 1999). Such harsh examples are also available in the northern part of Kyoto Prefecture, Japan where a significant number of designated shelters and evacuation routes were inundated during the Typhoon No. 23 in 2004 (Typhoon Disaster Committee, 2005). These evidences indicate that the shelter planning originally developed by the local government should be reexamined and revised, if needed, by taking account for more local concerns and knowledge owned by local residents. Specifically their concerns and knowledge have to be well reflected in the locally refined shelter planning.

Therefore community's evacuation planning and management should be managed in a participatory way. Regarding disaster shelter planning (including determining shelter location, assigning residents to the shelters), there are only a few studies which have been conducted by the local government and the experts in collaboration with the individual citizens and the local community (Xu *et al.*, 2007b). On the other hand, there are abundant examples of evacuation simulation works on individuals' activities which have been carried out by researchers. However, the subject of multi-stakeholder evacuation simulation for participatory planning and management is as yet an unexplored research area (Xu *et al.*, 2007a).

1.2 Objective of the study

The main objective of this study is to develop a methodology for participatory evacuation planning based on field works. The research focuses on how the individual citizens and the local community can be involved in a community's shelter planning, and on how the local government can collaborate with the individual citizens and the local community in the community's evacuation planning.

The Nagata Ward of Kobe City (Japan) is taken for the case study, considering that it was heavily damaged by the Great Hanshin-Awaji earthquake disaster in 1995.

1.3 Structure of the thesis

Based on the above discussions, the structure of the thesis is designed to consist of 6 chapters as follows (Fig.1.1).

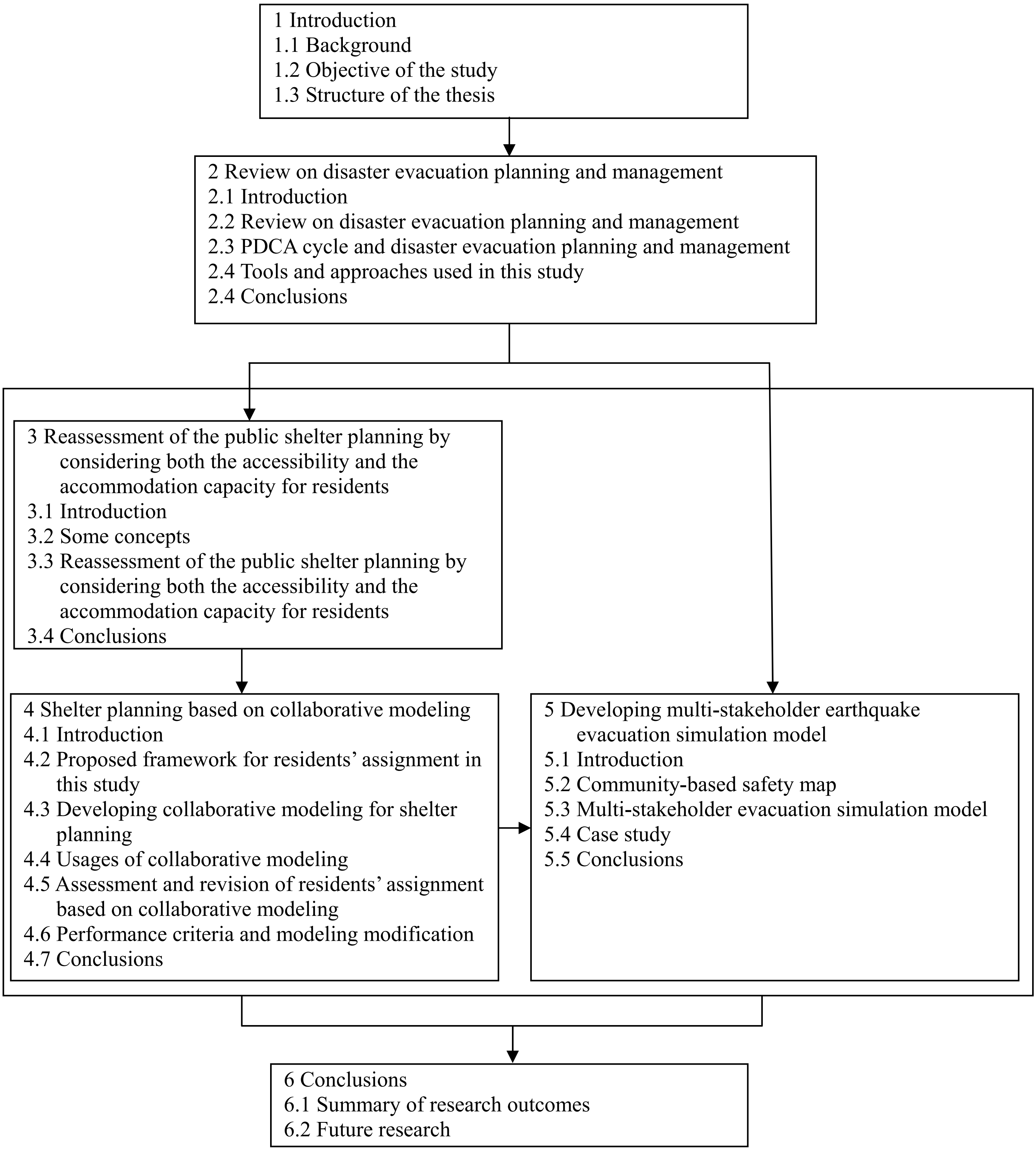

Fig.1.1: Framework of this study

Chapter 1 provides an overview of the background, objective and approaches of this study including this description of the structure of the thesis.

Chapter 2 reviews the current research works regarding the evacuation planning with a focus on Japan. It specifically underlines the need to study, and thus gives an overview of the participatory shelter planning process in reference with the PDCA cycle (Aguayo, 1991). To account for such a cyclic process of which planning is a part, this thesis uses the term "evacuation planning and management", instead of simply "evacuation planning". However if there is no possibility of confusion, the term "evacuation planning" is used to mean the evacuation planning and management. The focused evacuation planning (and management) in this thesis is supported by a spatial-temporal GIS called DiMSIS (Kakumoto *et al.*, 1997), and the framework of the "Communicative Survey" (proposed by Takeuchi *et al.*, 2007) combined with the PDCA cycle are proposed to systematically carry out community-based participatory approach for disaster evacuation planning.

Chapter 3 defines the concept of disaster shelter and discusses the spatial level of shelter planning. The performance criteria for shelter planning are addressed from the viewpoint of the Vitae System (Okada, 2005). The accessibility and accommodation capacity of the shelters in the Nagata Ward is examined.

Chapter 4 develops a collaborative modeling for shelter planning (shelter location planning and residents' assignment planning) based on questionnaire survey with a focus on earthquake disaster in the Nagata Elementary School Community. The current residents' assignment is analyzed based on the collaborative modeling. To check the revision result, workshops and Crossroad Game (Kikkawa e*t al.*, 2004) involving local residents are also organized, and assessment is made of the usability and limit of the proposed approach.

Chapter 5 develops a complementary approach to the one shown in Chapter 4. This approach is to develop a community safety map and a multi-stakeholder evacuation simulation model by using DiMSIS in the Nagata Elementary School Community. The usability of this approach is tested through a series of organized "town-watch walks" by residents and non-residents. How to overcome its limitations is also discussed.

Chapter 6 summarizes the main contributions of the study and discusses the needs for further extensions of this research.

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Chapter 2 Review on Disaster Evacuation Planning and Management

2.1 Introduction

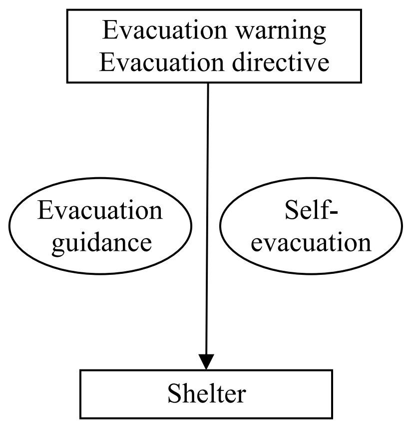
As mentioned in Chapter 1, there has been increasing need for community's evacuation planning to be managed in a participatory way. Both the local community and individual citizens should be involved in the community's evacuation planning. This chapter places a focus on the review on the status quo of the disaster evacuation planning and management, particularly in Japan.

2.2 Review on disaster evacuation planning and management

2.2.1 Disaster evacuation planning

In Japan, generally all the prefectural offices have published their evacuation planning and management manuals (FDMA, 2007). All these manuals have three basic and common contents, namely evacuation warning and directive, evacuation guidance, and shelter planning and management. Also, the governmental offices of some prefectures or cities will tend to focus more on risk area setting, evacuation route planning and vulnerable people caring in the evacuation planning. Table 2.1 lists the contents of evacuation planning for earthquake disaster in some cities in Japan.

Table 2.1: Contents of evacuation planning in some cities in Japan

City	Contents of evacuation planning	Evacuation process
Kobe, 2006	Evacuation warning and directive Evacuation guidance Shelter planning and management	
Tokyo , 2007	Evacuation warning and directive Evacuation guidance Evacuation route planning Shelter planning and management	
Osaka, 2006	Evacuation warning and directive Evacuation guidance Shelter planning and management Countermeasures to vulnerable refugees	
Yokohama, 2005	Evacuation warning and directive Evacuation guidance Shelter planning and management	
Fukuoka, 2007	Risk area setting Evacuation warning and directive Evacuation guidance Shelter planning and management	

In order to specify areas at disaster risk, and to examine when and where to evacuate, how to evacuate, and, how evacuees may find about the conditions of their shelters, besides governmental efforts, local residents, NGOs/NPOs and/or experts should also be involved to make decision (not only in terms of collaboration but also active participation). Community members, the source of expert knowledge about communities' strengths, weaknesses, needs, and preferences are indispensable if their experiential expertise is intended to be effectively shared (Thompson *et al.*, 2002). Such kind of evacuation planning with the involvement of individual citizens and local community is called participatory evacuation planning.

2.2.2 Participatory evacuation planning and collaborative modeling

Generally, participatory approach can be defined as a process through which members of a community identify a problem, collect and analyze information, and act upon the problem to find solutions and to promote social and political transformations (Selener, 1997). A combination of both systems methodology and participatory research can theoretically facilitate the integration of various disciplines and different types of knowledge (Purnomo *et al.*, 2003). Participation in this study will be defined after Patrick *et al.* (2002) as expectation that citizens have a voice in policy choices.

A collaborative modeling process combines simulation, soft systems methodology, participatory research and process agreements among the stakeholders (Purnomo, 2003). In the context of disaster risk management, the initial practice of "collaborative modeling" is a prototype version of a particular model which requires a certain level of expertise and professional knowledge. The model is used, tested and evolved through a participatory process involving by participants from administrators and disaster professionals on a voluntary basis most probably on the metropolitan or municipality level. However, on the community level disaster risk management, "collaborative modeling" commonly means continued modeling activities of the socially tested and evolving process of participation for "small but steady" implementation (Okada *et al.*, 2004).

So far, some attempts have been made to carry out research works on collaborative disaster planning, and different collaborative models have been developed in this area (e.g., Silver, 1992; Allen *et al.*, 2002; Fuhrmann, 2003; Siebra, 2006; and Microsoft, 2006). "Multi-agent based collaborative modeling for disaster evacuation simulation" is a typical case of developing collaborative modeling for disaster planning on the community level (e.g., Peng *et al.*, 2006; and Liu *et al.*, 2007). However, most of the models are very conceptual and the performance criteria or indices (parameter) are not explicitly discussed.

Okada *et al.* (2004) used the term "ima-simulation" to mean a broadened notion of simulation which allows users to obtain virtual experiences and active imagination about what otherwise would not be lively felt about. This way, local residents participating in the series of workshops are expected to acquire, for example, the skill of fixing their "risky furniture" rigidly and securely to the wall or floor. This approach is expected to help people implement it by way of letting the participants practice the skill with the help of some experts attending. Collaborative modeling is considered also as a process-oriented approach. This means that the process of developing the model is accompanied by the enhancement of the quality of risk communication on both ends, modelers on one hand, and residents on the other (Okada *et al.*, 2004).

2. 3 PDCA cycle and disaster evacuation planning and management

The PDCA cycle was advocated by Shewhart and Deming after the World War II (Aguayo, 1991). It is the continuous improvement cycle of "*P*lan", "*D*o", "*C*heck" and "*A*ct", and used for production management and quality control in the industry.

This cycle fits in well with the evolving perspective of participatory disaster planning and management. But, the conventional practice of government-led disaster planning and management is not accommodating this cycle. That is, in the conventional government-led disaster planning and management, the government is practically the only stakeholder who is engaged in the process, whereby the objectives and problems to be solved are confined to be well-defined or determined. Moreover, the entire process is not participated by a whole set of governmental sections or organs which are responsible for their each piece of administrative duties. For instance, "*Plan*" can be the first stage of the process which is handled by a particular administrative unit, and the following stage to "*Do*" the plan was isolated and exercised by another responsible unit.

However, in the cases of participatory community' planning, all the stakeholders (local government, local people, NGOs/NPOs and/or experts) need to share the current status (status quo) and their information and knowledge in the community before they are going to start planning. Therefore, the process should be started with the stage of "*Check*" instead of "Plan", and then it goes to complete as the CAPD cycle ("*Check-Action-Plan-Do*") (Matsuda *et al.*, 2006). Okada (2002) introduced this CAPD cycle into the urban risk management tasks, which is called "urban diagnosis", and it emphasizes the diagnosis of the status quo based on the practice of "*Check*" and "*Act*" before "*Plan*". This management method is also suggested to help participating agents to share the current condition and to provide a communication platform for disaster preparedness policy making. To account for such a cyclic process of which planning is a part, this thesis uses the term "evacuation planning and management", instead of simply "evacuation planning".

To develop collaborative modeling, some tools and approaches are discussed as below.

2.4 Tools and approaches used in this study

2.4.1 DiMSIS

DiMSIS, the Disaster Management Spatial Information System, was first developed based on the idea of disaster management cycle by Kakumoto *et al.* (1997) for the purpose of risk-adaptive regional management. DiMSIS has the functions of both spatial analysis and temporal analysis. Based on the advantages for disaster risk management, various types of implementations for community disaster management have been carried out. Table 2.2 summarizes some typical implementations for earthquake disaster risk management in different phases of disaster cycle (Alexander, 2002).

Besides earthquake, DiMSIS can also be used for the management of other disasters and diseases etc., such as for flood risk communication and evacuation (Kawashima *et al.*, 2006), for bird influenza control (Kakumoto *et al.*, 2007), and for fixed assets and agricultural information management (Hitachi Information Systems, 2007).

Earthquake evacuation simulation, which offers as a reference and important database for earthquake evacuation planning, can be more effectively modeled by using DiMSIS with the spatial-temporal analysis function. Participatory (multi-stakeholder) shelter planning can be better managed by use of the local residents owning their local knowledge.

Therefore, besides the basic spatial analysis functions used for shelter planning in Chapters 3 and 4, the thesis presents two types of field studies on community disaster management in the Nagata Elementary School Community. They are: (i) Community disaster management system, which is used for community disaster management by the leader of "Bousai Fukushi Community" (meaning "self-organized community association for disaster reduction and social care"); (ii) Multi-stakeholder evacuation simulation system, in which the activities of individual citizens, local community and fire station are considered. These two field studies will be presented in Chapter 5.

Table 2.2: Typical implementations of DiMSIS for earthquake disaster management

Phase	Author(s), year	Implementations
Mitigation and preparedness	Xu *et al.*, 2005	Community safety map
Response	Hatayama *et al.*, 1999	Rescue support system for disaster drill
	Kajitani *et al.*, 2003	Search and rescue simulator for disaster rescue
Recovery	Kakumoto *et al.*, 1997	Recovery process (Kobe, Japan)
	Kakumoto *et al.*, 2004	Recovery process (Duzce city, Istanbul)
	Kakumoto, 2005	Recovery process (Niigata, Japan)

2.4.2 Crossroad Game

Gaming is a participatory approach to problem solving that engages a real-life situation compressed in time so that the essential characteristics of the problem are open to dynamic environment requiring periodic decision. The use of games by groups to explore values, ideas, and behaviors as communication function gives participants a better understanding of themselves and others (Sanoff, 2000). The original game, "Crossroad", is designed to increase the awareness of interpersonal and intrapersonal conflicts (Kikkawa *et al.*, 2004). Kikkawa *et al.* (2004) modified it to include disaster preparedness and response training elements. They use the word "Cross: Kobe", which is designed for the general public and for disaster response personnel in national and local government or non-governmental organizations, for the purpose of increasing their awareness of the problems faced in disaster situations. Disaster response requires a series of decisions to be taken with respect to serious problems or dilemmas. Responses to complicated decision, which are usually difficult to convey and explain within a normal, lecture-style educational context, can be facilitated with a game situation, especially since players (stakeholder) share their perspectives with other players during the game. The detailed procedure of the "Crossroad Game" is explained by Kikkawa *et al.* (2004).

In this study, this game is used to determine the shelter planning criteria and the necessity for setting up a secondary shelter for the Nagata Elementary School Community (see Chapter 4). It is also expected that this kind of participatory brain storming game will activate livelily discussions among participatory residents related to their local concerns and knowledge.

Besides these, in this study, interview, workshop and town-watch walks are also used as communication tools to develop the collaborative modeling.

2.4.3 Communicative Survey

Takeuchi *et al.* (2007) presented the concept of "Communicative Survey" and discussed its characteristics as a risk communication technique within which social survey methods are incorporated (Fig.2.1). The needs and concerns of the community are extracted by questionnaire survey or communication through interview or meeting, and then the risk information is provided and shared by using questionnaire sheets and organizing workshop. Such information sharing mechanism is called the "Communicative Survey technique". Different from the general deliberative disaster risk commutation (Kikkawa, 1999), the manner, which is actually designed and operated the framework of the "Communicative Survey" in this study, is characterized as follows:

i) The members (especially the leaders) of the autonomous council ("Jichi-kai" in Japanese) or autonomous disaster prevention organization ("Jisyu-bousai-kai" in Japanese) etc. are identified as the key persons who serve as the bridges for risk communication between the risk management specialists and the local residents.

ii) Through continuous surveys, feedbacks and risk communications in a certain long process, the specialist and local residents are expected to mutually share, and eventually reach the common understanding of the community's needs.

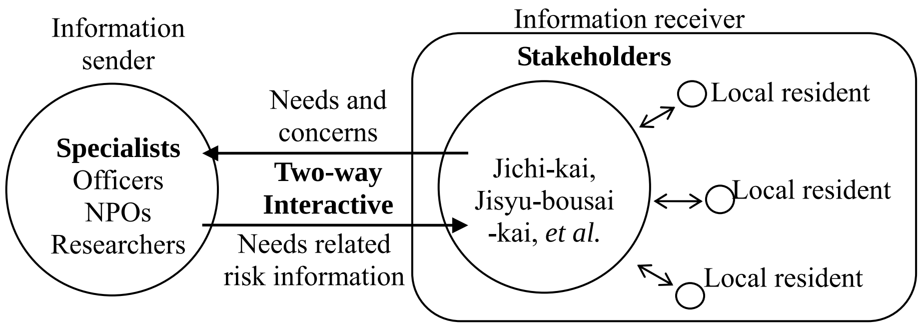


Fig.2.1: Communicative Survey technique
(Takeuchi *et al.*, 2007)

The process of communicative survey for the evacuation planning in this study is designed as shown in Fig.2.2.

2.5 Conclusions

The status quo of the practice and research on evacuation planning has been reviewed with a focus on Japan, and an overview of the participatory shelter planning process in reference with the PDCA cycle has been provided. An integrated framework of the "Communicative Survey" combined with the PDCA cycle by using DiMSIS has been proposed. The following chapters will be addressed the selected field-work-based research achievements on evacuation planning (and management).

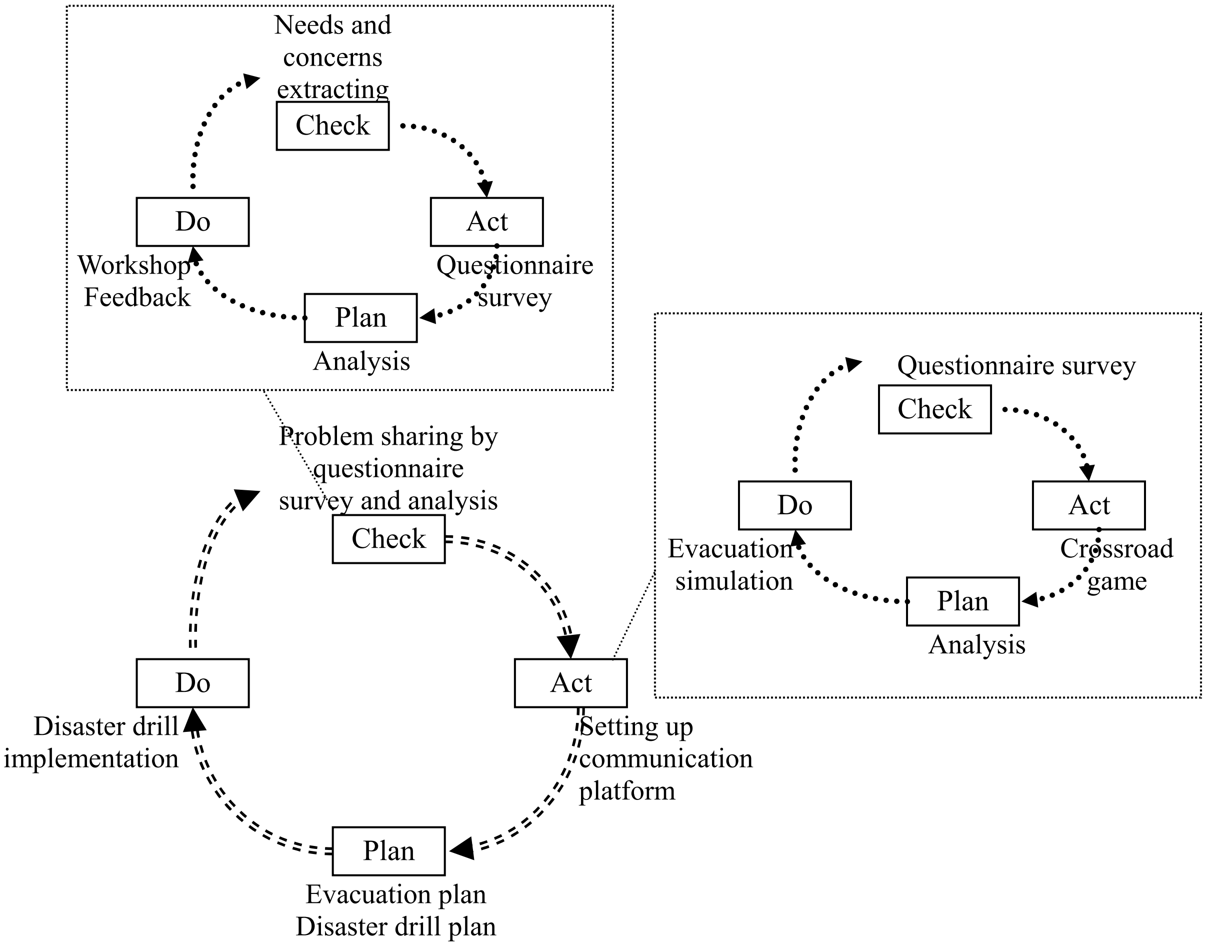


Fig.2.2: Process of the Communicative Survey for evacuation planning in this thesis

*The activities of "Evacuation planning and disaster drill planning" and "Disaster drill implementation" have not been carried out.

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Chapter 3 Reassessment of the Public Shelter Planning by Considering both the Accessibility and the Accommodation Capacity for Residents

As mentioned in Chapters 1 and 2, shelter planning is one of the most important parts of evacuation planning. In Chapters 3 and 4, residents' assignment planning to shelters is analyzed based on designated shelter locations as one of important parts of evacuation planning and management.

In this chapter, the definition, spatial levels and performance criteria for shelter planning are discussed. Then the need for reassessing the public shelter plan which has been completed exclusively by the respective local administrative body is addressed. With a case study in the Nagata Ward of Kobe City, Japan, reassessment is made by considering residents' accessibility to the nearby shelter and also its accommodation capacity with designated shelter locations[1].

3.1 Introduction

Due to increasing awareness of disasters more and more countries have started to set up the disaster shelters. In Japan, the salvation hut ("Osukui Goya" in Japanese) in the Edo Period appeared as the rudiment of disaster shelter). Now more than 1,000 cities or wards have set up shelters, and many cities and wards have formulated shelter management manuals (ANICE, 2005). After the tornadoes (56 tornadoes struck Arkadelphia, Arkansan on January 21, 1999 and 68 tornadoes struck Oklahoma and Kansan on May 3, 1999) in USA, tornadoes and hurricane shelters were set up in lots of states, and several national guide documents such as FEMA 320 (FEMA, 1998), FEMA 361 (FEMA, 2000) and ARC 4496 (American Red Cross, 2002), as well as some local guide documents (ACOAEMO, 2003) were published as the disaster shelter planning standards. Developing countries have also started to set up disaster shelters. For example, China set up the first shelter in Beijing in 2003, and another 18 shelters will be built there by the end of 2007 (Rednet, 2004).

In this chapter, with a focus on Kobe, the lesson learned from the Great Hanshin-Awaji earthquake in Japan in 1995 are intended to be used as a reference case to analyze and solve the shelter planning performance criteria and residents' assignment problem. In Kobe city, since long the city government has designated the shelter locations and residents' assignment to these evacuation centers based on the jurisdictionary areas of elementary schools ("Shogakko-ku" in Japanese). Therefore this chapter attempts to develop a systematic approach to examine this type of shelter planning problem. The public shelter planning is reassessed by considering both the accessibility and the accommodation capacity for residents in the Nagata Ward of Kobe City.

3.2 Some concepts

3.2.1 Definition of disaster shelter

The concepts of disaster shelters in different countries are not always same since they have

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[1] The work in this chapter is mainly based on Xu *et al.* (2006, 2007).

their own characteristics.

In Japan, basically there are four kinds of shelters, namely wide area shelter ("Kouiki Hinanjyo" or "Kouiki Hinan Basyo" in Japanese), temporary shelter ("Ittoki Hinanjyo" in Japanese), general accommodation shelter ("Syuyo Hinanjyo" in Japanese) and special accommodation shelter for people who need support (such as the handicapped) ("Saigai Jakusya Hinanjyo" in Japanese) during the disaster period (ANICR, 2005). For the wide area shelter and temporary shelter, outdoor spaces are commonly used, such as parks and playgrounds where living condition is not offered. These shelters serve the purpose of temporary stay for the potential victims. Often, these shelters are called the "primary shelters". Both the general accommodation shelter and special accommodation shelter basically serve the purpose of long term stay for the refugees. Obviously both are accommodation shelters, and the latter one is built exclusively for special groups of people, like the old, the pregnant, the handicapped or people who have a physical, medical or mental disadvantage.

In USA, there are two kinds of shelters, viz. emergency shelter and temporary shelter (Quarantelli, 1995). In their definitions, the emergency shelter in USA is similar to the temporary shelter in Japan, while temporary shelter in USA almost has the same meaning and function as the accommodation shelter in Japan.

In China, there is only one kind of shelter, namely emergency shelter, which is used as temporary shelter in general (Yang *et al.*, 2004). However in these shelters, lifeline maintenance facilities are prepared, which is not same as the ones in Japan and USA.

Thus, it is proposed to classify disaster shelters into two types according to their functions, namely primary shelter (or temporary shelter) and accommodation shelter (or secondary shelter). The former one basically serves the purpose of temporary stay for the refugees, the latter one serve the purpose of long term stay if the disaster lasts or extents over time.

3.2.2 Area levels (spatial scales) of shelter planning

Shelter planning can be classified into four different levels (Fig.3.1) according to the existing plans in some counties.

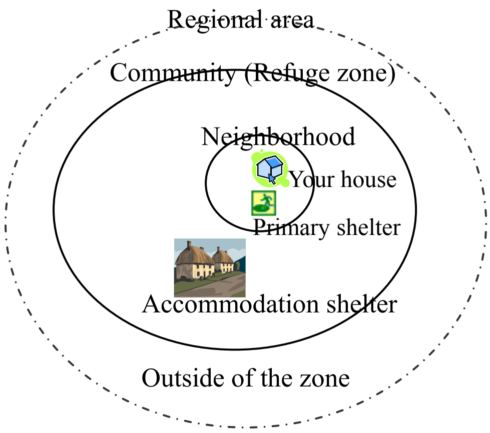


Fig.3.1: Area levels of shelter planning

(1) Household level

A shelter, or a safe room, built into the house can help the victim protect him/her and his/her family from injury or death caused by the dangerous forces of extreme hazards, such as tornado and hurricane. The shelter at this level is often a primary shelter. FEMA 320 (FEMA, 1998) is a typical guideline of setting up a household level shelter.

(2) Neighborhood level

A shelter in the neighborhood area can offer the victim a place to take refuge temporarily during a disaster relief and rescue period, when it is impossible to evacuate to an accommodation shelter because of the limited time. People in the neighborhood will often evacuate to a park or an open space primarily when an earthquake, a tsunami or fire happens. Often the shelter at this level is also a primary shelter or a temporary shelter. Planning a safe place near one's home, such as a garden and parking lots where one can evacuate immediate when a disaster happens, is typical of neighborhood level shelter planning. In Japan, Almost all of the temporary shelters planning belong to this level.

(3) Community level (Refuge zone level)

An accommodation shelter in the community can provide a place (temporary house) for refugees whose houses are damaged or destroyed because of the disaster, and the shelter can help the victim tide over a difficulty during a disaster recovery and restoration period. FEMA 361 (FEMA, 2000) is a typical guideline for setting up a community level shelter. In Japan, most of the guidelines or manuals of disaster accommodation shelters belong to this level.

(4) Regional or wider level

A shelter planning at regional level focuses more on the relation between different accommodation shelters. The shelter planning at this level is often developed by a local or the central government, who are primarily concerned about the whole region. In Japan, the accommodation shelter locations are designated, and potential victims to each shelter are assigned by the local government in a region. This kind of planning is a typical case of shelter planning at regional level. In USA, the shelter planning, such as setting up shelters in elementary or middle schools is conducted by a local government belongs to this level.

3.2.3 Performance criteria for shelter planning from the viewpoint of the Vitae System

Shelter planning should appropriately link up post-disaster processes to pre-disaster processes. To systematically combine such retroactive event and proactive event some performance criteria are necessary.

For the current shelter planning, often shelter location, structure, facility, shelter scale and capacity, evacuation route, tool and distance are focused on. For further analysis, it is found that at the same level and for the same hazard type, their performance criteria are not completely same in different countries, even if they vary from region to region in the same country.

Based on the Vitae System (Okada, 2005), different performance criteria are considered and integrated for shelter planning (Table 3.1, Table 3.2).

Table 3.1: Function check phases of the Vitae System for shelter planning

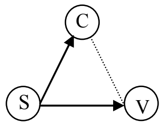
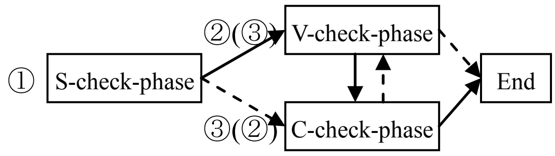
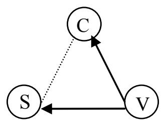
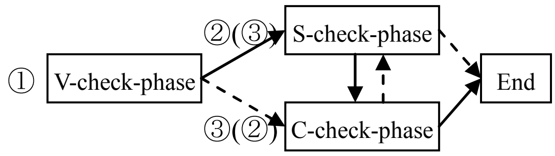
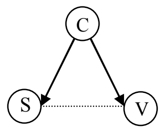
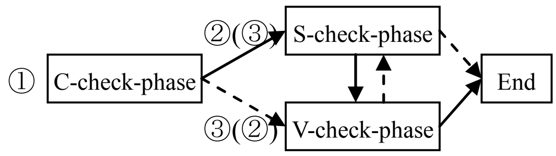
Approach	Phase	Remarks
 S-front integration approach		Start with S followed up by V and C to be integrated
 V-front integration approach		Start with V followed up by S and C to be integrated
 C-front integration approach		Start with C followed up by S and V to be integrated

Table 3.2: Performance criteria of each function of the Vitae System for shelter planning

Function	Criterion	Indicator (example)
S	Security from disaster risks	Location, structure
	Sustainability of lifeline services	Food and water supply
V	Accommodation capacity	Area, capacity
	Comfortability	Private space, noise prevention
	Mutual assistance capacity	Inter-assistance between neighboring shelters
	Vital life support services	Improving privacy, spaces for relaxation
C	Accessibility to shelter	Evacuation route, time
	Connectivity (accessibility) to external resources and information	Evacuate to neighboring shelter
	Connectivity (accessibility) to voluntary assistance and rescue	Voluntary agency
	Telecommunication capacity, and social network capacity	TV, telephone

From the viewpoint of the Vitae System, the performance criteria for shelter planning can be first classified into three basic types, and then overall assessment should be made to integrate three of them. Any shelter as an adaptive capacity to changing environment should have a dynamic balance among three cardinal functions, that is, "Survivability (to live through or become alive)", "Vitality (to live livelily)" and "Conviviality (to live together or communicate)". More specifically the following procedure is proposed. The existing public shelter planning is examined and reassessed in terms of each of the three basic functions and then later it needs to be reexamined with reference to the remaining ones in an integrated manner. The three prospective approaches staring with one of the three basic functions are represented by the symbol S→V & C type, V→S & C type and C→S & V type, respectively (Table 3.1). The performance criteria may vary for different hazards and regions, but the proposed approaches are expected to apply to any case with specifics to be developed case by case.

In the following section, an illustration will be made to apply this idea with a focus on the S-front integration approach (Table 3.1). It will be explained that by assuming that shelters are already located and designated as official shelters in the already publicized administrative shelter planning, which means that S-check-phase has already been performed by the local government, the author will move to C-check-phase, then finally to V-check-phase. As a C-check-phase, the accessibility to shelter as one of the respective criteria will be used to examine residents' assignment planning alternatives. Likewise, "accommodation capacity" will be used to carry out the V-check-phase. Thus overall assessment will be made based on the results obtained through this integration process.

3.3 Reassessment of the public shelter planning by considering both the accessibility and the accommodation capacity for residents

3.3.1 Introduction

As for shelter location planning, for different hazard types and shelter types, different countries have different criteria, including location, security, route condition, service distance (or evacuation distance), and accommodation capacity (e.g., FEMA, 1998, 2000; TGM, 2000; Aichi, 2005; and Beijing, 2004).

Many researchers have discussed to decide shelter locations and their services areas in different methods, such as the Voronoi Diagram (e.g., Kashiwabara *et al.*, 1998; Kamiya *et al.*, 2000; Hasobe, 2005; and Morita *et al.*, 2004a), and evacuation simulation methods (e.g., Inoue, 2002; Morita *et al.*, 2004b). Some researchers also discussed the accommodation capacity when determining the shelter location (e.g., Yamada *et al.*, 2004).

In Japan, most of evacuation shelters designated by the local government are expected to be used for temporary relief for life security as well as for the use of long stay refugee. A point is made that the above mentioned designated shelters tend to be determined without considering such multiple functions of shelters required in the event of a disaster. For instance, with distance to shelters considered, its capacity to accommodate potential refugees should also be systematically taken into account. Such examinations of multiple functionalities need to be addressed systematically in actual administrative shelter planning processes.

By assuming that shelters are already located and designated as official shelters in the already publicized administrative shelter planning, the problem is to assign the potential victims (residents) from various neighborhood communities to the designated shelters which have their own conditions such as accommodation capacity as mentioned above. This assignment problem is to find out the most appropriate assignment of residents (potential refugees) to their shelter facilities. Besides the accommodation capacity, the evacuation time should also be considered for residents' assignment planning. This is because most of the evacuation shelters designated by the local government are expected to be used for temporary relief for life security as well as for the use of long stay refugee for recovery.

This study is based on the evidences of the Hanshin-Awaji earthquake in Japan in 1995, which is used as a reference case to compute and analyze the assignment planning problem. The Nagata Ward (Fig.3.2) of Kobe City, Hyogo Prefecture, Japan, which was heavily damaged during the Hanshin-Awaji earthquake, is composed of 94 Chos (403 Cho-Chomes) and has a population of 103,681 (January 1, 2006) (Nagata Ward, 2006). During the Hanshin-Awaji earthquake, there were about 70 accommodation shelters in the Nagata Ward, while now (as of 2005) there remain only 25 designated accommodation shelters (Nagata Ward, 2005a) (Fig.3.3). The residents who are supposed to evacuate from each Cho-Chome to designated shelters are also determined nominally by the local government basically based on the elementary school area (Nagata Ward, 2005b). In this study it intends to present a prototype tool with which to evaluate the existing residents' assignment to the designated disaster shelters in their officially approved evacuation and shelter planning. For this purpose the evacuation time and accommodation capacity of each designated shelter in the Nagata Ward is examined.

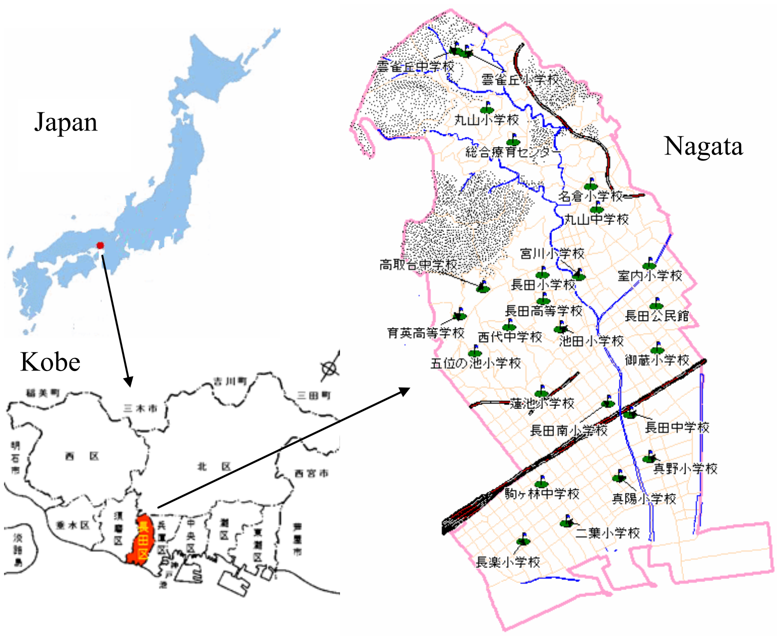


Fig.3.2: Location of the Nagata Ward

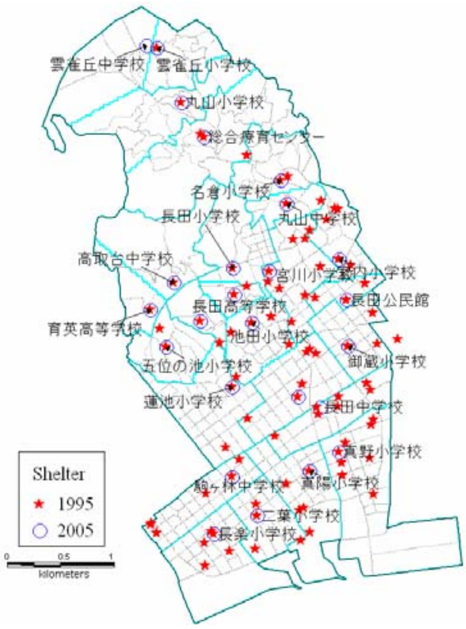


Fig.3.3: Accommodation shelters in the Nagata Ward in 1995 and 2005

3.3.2 Analysis of the plan of residents' assignment to the designated shelter in the Nagata ward

(1) Evacuation time analysis

Evacuation time, which is defined and calculated by dividing the evacuation distance by evacuation velocity, is one of the most important indicators to evaluate the performance level of a resident taking refuge immediately after a disaster happens.

Evacuation means (evacuation mode) is one of the main factors that affect the evacuation velocity. During the Hanshin-Awaji earthquake in 1995, about 73% refugees evacuated to shelters by walking (Kashiwabara *et al.*, 1998) which is also designated as the main evacuation means in many cities and wards in Japan. Evacuation speed varies due to evacuation route status (conditions such as road width, road surface, slope, or barrier), refugees (gender, age, or physical status), weather, etc.

As for road conditions, the Ministry of Construction Government of Japan (1997) set a standard that roads which are narrower than 4 meters are considered not appropriate as an evacuation route, and the National Institute of Occupational Safety and Health, Japan (2002) specified the evacuation speed of people for different road surfaces and slopes by experiments.

Accordingly, here it assumes:

- Roads wider than 4 meters are used to constitute evacuation routes and there is no traffic congestion.
- The evacuation velocity is 1.10m/s for children (age<10) and old people(age≥ 65), and 1.30m/s for the young when the slope of evacuation route is flatter than 10 degree; and

0.80m/s and 1.10 m/s respectively when the slope is steeper than 10 degree.

Based on the above assumptions, the evacuation time of each household to the designated shelter is calculated, in accordance with the designated assignment plan developed by the Nagata Ward, Kobe City. For comparison, the evacuation time map of households in each Cho-Chome (Fig.3.4) based on the designated shelter planning (2005) and the population density map based on Cho-Chome (Fig.3.5) are developed with the help of DiMSIS in this area.

In the Nagata Ward, the evacuation time of households in 155 (38%) Cho-Chomes is estimated to be less than 5 minutes (bright areas), in 184 (46%) Cho-Chomes it ranges between 5 minutes and 10 minutes, and in 16 (4%) Cho-Chomes it takes longer than 15 minutes (dark areas) (Fig.3.4). Those households with shorter evacuation time are found to be mainly concentrated in the middle area of the ward (called "middle zone"). The reasons are analyzed as follows.

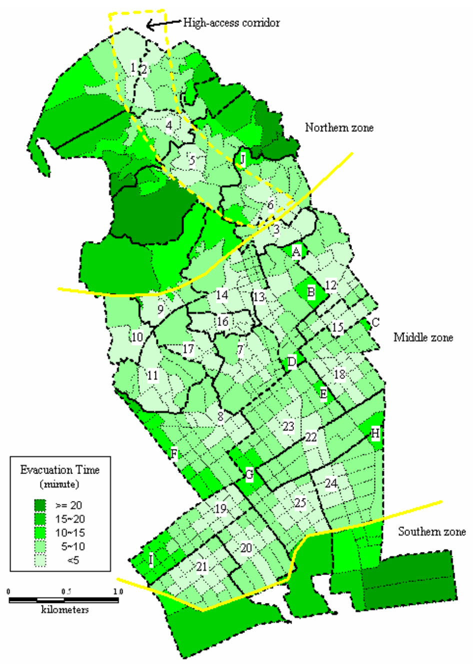


Fig.3.4: Evacuation time of household in each Cho-Chome according to the designated shelter planning in the Nagata Ward in 2005

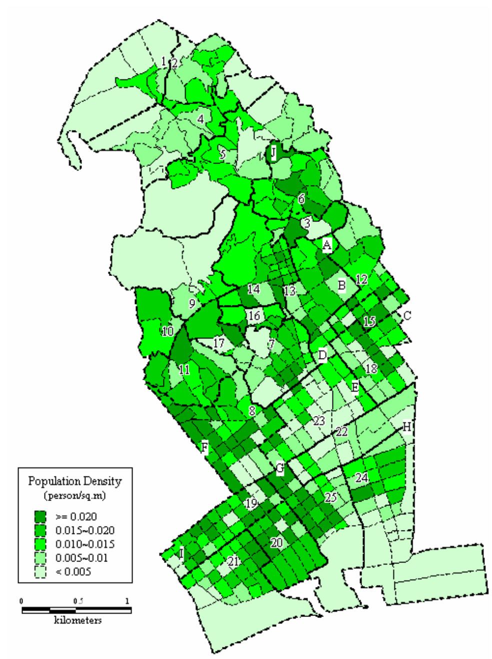


Fig.3.5: Population density of each Cho-Chome of the Nagata Ward in 2005

In the middle zone, the evacuation time of 90% households is less than 10 minutes, and the dark areas with evacuation time longer than 10 minutes are found to be distributed mostly over the areas of A, B, C, D, E, F, G, H and I (Fig.3.4). In the area of B where Hyogo Prefectural Minatogawa High School is located, and in the area of H which is an open area, the population density is very low (almost no people live there at night). A school or an open area can be used as an official shelter during a disaster emergency situation, so it is not necessary to design new shelters around these areas. Though in the areas of A, C, D, E and G, the population density is moderate or low (Fig.3.5), the households in these areas have longer time, which implies that the performance level of evacuation for life security is found unduly low, The necessity of assigning new shelters around or changing the existing residents' assignment as nominally assumed by the local government is rightly argued. Actually during the Hanshin-Awaji earthquake, other shelters were used in or close to these areas. The areas of F and I in the middle zone have high population density (Fig.3.5) and relatively a long evacuation time (Fig.3.4) for households. Therefore, it is appropriate to claim that additional shelters are needed here, and that the existing residents' assignment plan should be changed.

In the southern part of the ward (southern zone), almost all of the Cho-Chomes are found to be situated far away from shelters, and the evacuation time of households in this area is very long. However this area is a port area with low population density. Maybe for this reason, there is no designated shelter located around, even during the Hanshin-Awaji earthquake disaster. Therefore it may be appropriate to leave it as it is, given that no substantial increase in population will occur there in the near future.

In the northern part of the ward (northern zone), a "high-access (blank) corridor" is formed by those households with short evacuation time. They are located near the shelters No. 1, 2, 4, 5, 6, and 3 (Fig.3.4), and households with long evacuation time are located on both sides of the corridor. The dark color areas are all hilly areas with lower population density except the area of J, and there are no shelters found in their vicinity. It may be appropriate to leave it as such since there is almost no expected increase in population.

According to the above analysis, it can be interpreted that the areas of F and I have high population density and relatively long evacuation time for households, and thus all are found to assume high-risk for evacuation (access risk, the long distance potentially compounded by the high population density). In these areas it is proposed to add new shelters and to revise residents' assignments to shelters. In the areas of A, C, D, E and G, revision of residents' assignment is also necessary in order to reduce the access risk.

(2) Shelter accommodation capacity analysis

Shelter accommodation capacity is another important factor to be considered to develop an appropriate shelter planning. The accommodation capacity of a shelter can be measured by the maximum acceptable number of refugees, which are considered to be determined primarily by the total area of the "affordable living spaces" and the variety in type of lifeline facilities installed in the shelter. Generally the acceptable number of refugees for a shelter is calculated by dividing the affordable living area by the necessary living area per capita. So far, there is no internationally or even domestically accepted norm of the necessary living area per capita. For the purpose of illustration, here it gives some examples of the existing norms and standards of the following cities, 1.65m^2/person in Higashiyamato City (2005) of Tokyo, Japan and Takatsuki City (2003) of Osaka, Japan, 2m^2/person in Hinode Cho (2005) of Tokyo, Japan and Sendai City (2004) of Miyagi Prefecture, Japan, 2.5 m^2/person in Nihonmastu City (2006) of Fukushima Prefecture, Japan, and 1.86m^2/person for hurricane in USA (FEMA, 2000). In the following analysis, the standard of living area per capita of Higashiyamato City of Tokyo, Japan (1.65m^2/person) is used to calculate the maximum acceptable numbers of refugees. Here another three capacities is used for comparison in the Nagata Ward. They are:

- 2005-base-year estimated accommodation capacity of shelter — measured by the number of designated residents in 2005 multiplied by 40%[2] according to the designated residents' assignment in 2005 in the Nagata Ward, and it is denoted as C_1.
- 1995-base-year official record accommodation capacity of shelter — estimated by the numbers of refugees accommodated to each shelter on February 1, 1995 (Kashiwabara *et al.*, 1998). It is the minimum of the already experienced accommodation capacity, and it is denoted as C_2.
- Affordable area-based accommodation capacity of shelter — measured by the estimated acceptable number of refugees, which is calculated by dividing the affordable living area of each shelter by necessary living area per capita (1.65 m^2/person, about one "Tatami" area per capita), and it is denoted as C_3.
- 1995-base-year official/non-official record accommodation capacity of shelter — measured by the total number of refugees in refuge zone[3] including non-designated informal shelters used in 1995. It is the maximum of the already experienced accommodation capacity, and it is denoted as C_4.

In this study, the already experienced capacity and the affordable area-based capacity are used for the standards of shelter accommodation capacity of the Nagata Ward. Based on the above four types of shelter accommodation capacity indices, the following four types of shelter accommodation capacity risks are proposed (Table 3.3).

Table 3.3: Shelter accommodation capacity risk in the Nagata Ward

Type	Characteristic	Accommodation capacity risk	Counter-measures
I	$C_1>C_3>C_4>C_2$ $C_1>C_4>C_2>C_3$ $C_1>C_4>C_3>C_2$	High	To add new shelter and extend capacity
II	$C_4>C_1>C_2>C_3$ $C_4>C_1>C_3>C_2$	High-Moderate	To extend capacity or add new shelter
III	$C_3>C_1>C_4>C_2$ $C_3>C_4>C_1>C_2$ $C_4>C_2>C_1>C_3$ $C_4>C_3>C_1>C_2$	Moderate	To extend capacity or add new shelter
IV	$C_3>C_4>C_2>C_1$ $C_4>C_2>C_3>C_1$ $C_4>C_3>C_2>C_1$	Low	To maintain the status quo

*Here only the situation of "bigger than" is listed. If it is "equal to" and the inequality can be attached to two types, that is defined to belong to the lower capacity risk category, for example, $C_1=C_3>C_4>C_2$ can be attached to type I and III, and it is taken for type III.

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2 40%, the percentage of population that took refuge during Hanshin-Awaji earthquake in 1995 in Nagata Ward. Numbers of refugees are 55641 at peak time (available: http://www.city.kobe.jp/cityoffice/09010/shiryokan /earthquake/earthquake 04.html), and total population is 129,978 (available: http://www.city.kobe.jp/cityoffice /06/013/toukei/contents/tyoubetsujinkou.html). And here, it is assumed that residents will only evacuate to their designated shelters.

3 The whole area where all residents locate should evacuate to the designated shelter set by local government in 2005

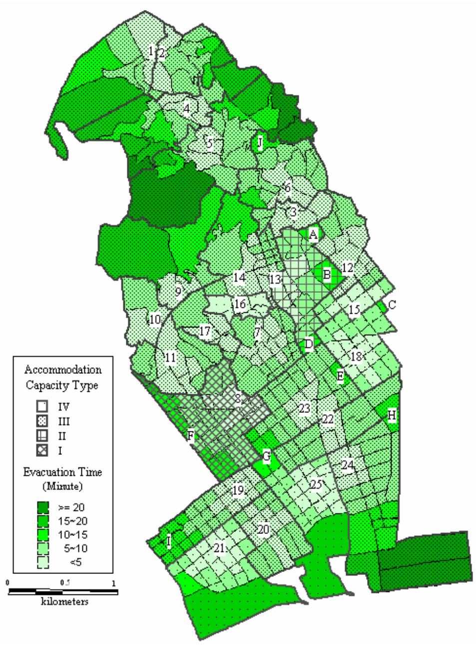

Fig.3.6: Shelter accommodation capacity type and evacuation time of household in each Cho-Chome in the Nagata Ward in 2005

Type I — the 2005-base-year estimated accommodation capacity is found to be the largest. It has the highest capacity risk. Type II — the 2005-base-year estimated accommodation capacity is larger than both the 1995-base-year official record accommodation capacity and the affordable area-based accommodation capacity, but smaller than the 1995-base-year official/non-official record accommodation capacity. It has a high-moderate accommodation capacity risk. Type III — the 2005-base-year estimated accommodation capacity is smaller than the 1995-base-year official record accommodation capacity or the affordable area-based accommodation capacity. It has a moderate accommodation capacity risk. Type IV — the 2005-base-year estimated accommodation capacity is the smallest. It has a relatively low accommodation capacity risk. According to this reasoning, the four types in capacity risk for the designated shelters in the Nagata Ward are derived (Table 3.4).

Table 3.4 shows that 18 (72%) shelters belong to type III, and 5 (20%) belong to type IV, which have low accommodation capacity risk. The shelters No. 1, 2, 3, 4, 5, 6, 9, 10, 11, 12 and 14 are located in the areas which experienced small house damages in percentage during the 1995 Hanshin-Awaji earthquake disaster, and the ratio or the total numbers of residents took refuge are very low or small, so their 1995-base-year official record accommodation capacity and 1995-base-year official/non-official record accommodation capacity are defined to be very small in this analysis. There are one shelter of type I — Hasuike Elementary School (No.8) and one shelter of type II — Miyagawa Elementary School (No.13), and households in the area of F and D with high access risk are located in the refuge zones of these two shelters, respectively (Fig.3.6). While, if the population density data in 1995 (after the Hanshi-Awaji earthquake) is used, the 2005-base-year estimated accommodation capacity will be less than the affordable area-based accommodation capacity and the 1995-base-year official/non-official record accommodation capacity of these two shelters, and they will belong to type III — low accommodation capacity risk. Since the population density is increasing, it is proposed to assign additional accommodation shelters in these areas in order to reduce the capacity risks.

Table 3.4: Accommodation capacity and type of shelters in the Nagata Ward in 2005

ID	Name	C_1	C_2	C_3	C_4	Type
1	Hibarigaoka Middle School	810	0	2790	0	III
2	Hibarigaoka Elementary School	1120	15	1310	15	III
3	Maruyama Middle School	940	270	2530	270	III
4	Maruyama Elementary School	1450	120	2750	120	III
5	Rehabilitation Center for Children	2410	30	2410	70	III
6	Nagura Elementary School	2600	1000	2820	1400	III
7	Ikeda Elementary School	1580	1000	2660	3400	III
8	Hasuike Elementary School	3950	2300	2980	2900	I
9	Takatoridai Middle School	630	400	3940	400	III
10	Ikuei High School	920	600	6050	600	III
11	Goinoike Elementary School	2180	1600	2360	1600	III
12	Murouchi Elementary School	1610	400	3720	2845	III
13	Miyagawa Elementary School	2440	800	1980	4091	II
14	Nagata Elementary School	2630	500	2490	500	III
15	Nagata Community Center	1030	2500	1160	2500	IV
16	Nagata High School	540	1700	5760	1700	IV
17	Nishidai Middle School	1050	800	3470	1000	III
18	Mikura Elementary School	1960	2500	2470	2600	IV
19	Komagabayashi Middle School	2290	2000	3520	2400	III
20	Futaba Elementary School	2400	4200	1600	4650	III
21	Nagaraku Elementary School	1720	3000	2480	3450	IV
22	Nagata Middle School	1020	600	1850	2760	III
23	Nagata Southern ES	1570	1000	2930	2920	III
24	Mano Elementary School	1770	3000	1630	3060	III
25	Shinyo Elementary School	2340	5000	3030	6050	IV
Total		42960	35335	70690	51301	—

*C_1: 2005-base-year estimated accommodation capacity (person); C_2: 1995-base-year official record accommodation capacity (person); C_3: Affordable area-based accommodation capacity (person); C_4: 1995-base-year official/non-official record accommodation capacity (person).

3.4 Conclusions

By reviewing the current status, disaster shelters are classified into two types according to their functions, viz. primary shelter (or temporary shelter) and accommodation shelter (or secondary shelter). In the primary shelter living facilities are not available. This basically serves the purpose of temporary stay for the refugees. The accommodation shelter serves for long term stay of the refugees if the disaster lasts or extents over time.

According to the existing shelters, four different levels (household level, neighborhood level, community level and regional level) of shelter planning are basically addressed in various countries' shelter policies.

The performance criteria for shelter planning have been addressed, classified into and then integrated together with three basic functions from the viewpoint of the Vitae System. Accordingly these three types of approaches, different in priority and order of the three basic functions, i.e., "Survivability", "Vitality" and "Communication" have been proposed. The specific forms of these criteria of shelter planning can vary, dependent on the particular disaster related context. It has been found that the basic approach presented here will help the decision makers (particularly local government officials) to overall work out prospective alternatives of shelter planning.

To further examine these prospective alternatives, the accessibility to shelters and the shelter accommodation capacity have been assessed in the case of the Nagata Ward, Kobe City. Results have shown that according to the existing administrative plan, in the areas of A, C, D, E, F, G and I (middle zone), where the population density is moderate or high (Fig.3.5), the evacuation time of residents to shelters tends to be long, and residents are assigned to such a shelter with high accommodation capacity risk (Table 3.4). It is proposed to revise the plan by adding new shelters, reassigning residents, or extending the existing accommodation capacity in these high risk areas.

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Chapter 4 Shelter Planning based on Collaborative Modeling

In Chapter 3, the current governmental planning of resident' assignment to shelter has been assessed by considering the shelter capacity and the accessible distance.

In this chapter, a collaborative model for shelter planning is developed based on a questionnaire survey. Based on this model, the current residents' assignment to shelters in the Nagata Elementary School Community is analyzed. The performance criteria and the reassignment planning are discussed and examined by inviting local residents to workshops and crossroad game[4]. Residents' feedbacks are used to develop the collaborative modeling.

4.1 Introduction

As mentioned in Chapter 3, many countries have set up disaster shelters and released corresponding management manuals. Most of these manuals are developed by the central or local government or disaster prevention organizations along with the involvement of experts and/or local community leaders. Yet local residents are not commonly involved in the process of disaster shelter planning.

The situation is not so different in academic research, although there are already many studies carried out on shelter planning (e.g., Coulbourne *et al.*, 2002; Kongsomsaksakul *et al.*, 2005; Pine *et al.*, 2003; Takagi *et al.*, 2006; Xu *et al.*, 2006; and Yamada *et al.*, 2004). There have been still a limited number of research works done on how to involve local residents in shelter planning. Yamada *et al.* (2004) attempted to structure a shelter location planning support system by considering shelter capacity, food storage and household characteristic. Takagi *et al.* (2006) tried to develop evaluation indicators for shelter planning based on a questionnaire survey with the case study where most of the local residents have no disaster experience.

In this chapter, the disaster shelter planning determined by the local government is assessed from the viewpoint of local residents based on the questionnaire survey and workshop in the Nagata Elementary School Community (Fig.4.1) with a focus on earthquake disaster.

The Nagata Elementary School Community with a population of 8,300 has one designated accommodation disaster shelter, namely Nagata Elementary School (Nagata ES) and there are three accommodation shelters, i.e., Takatoridai Middle School (Takatoridai MS), Nagata High School (Nagata HS), and Miyagawa Elementary School (Miyagawa ES) in the neighboring communities (Fig.4.1).

4.2 Proposed framework for residents' assignment planning in this study

Fig.4.2 shows the proposed framework used in this study for assessing and revising residents' assignment planning. Basically, there are four stages, and after stage 1 there are also three columns along which model parameter identification has been conducted in parallel, and then

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[4] The work in this chapter is mainly based on Xu *et al.* (2007a, 2007b).

later integrated. (The exact definition of indicators, criteria and performance criteria are given later.)

(i) Stage 0 determines the indicators and performance criteria through literature review, brain storming and interviewing local residents;

(ii) Stage 1-the left column is to obtain key parametric values such as the absolute value of each indicator through the questionnaire survey, the absolute value of each criterion, and then the weights of performance criteria;

(iii) Stage 1-the middle column and Stage 1-the right column are to obtain the absolute and relative value of each criterion, respectively, through a workshop involving representative residents, and then the weights of performance criteria according to the pairwise comparison;

(iv) Stage 2 operates alternative selection models and calculates satisfaction level for each household, and assesses and revises residents' assignment planning to each shelter; and

(v) Stage 3 shares the results with local residents, and agrees on the performance criteria and assignment result.

Three column processing tasks run in parallel from Step 2 to Step 4. The weights of the performance criteria and residents' reassignment results to shelter are obtained based on the questionnaire survey. In parallel, as comparison, participants' personal judgment and group discussion results are derived to determine the weights of the performance criteria. Stage 3 is designed to serve for the purpose of integrating the results of the three respective results. For limited time and availability of participants, this final stage was exercised only once, just by adopting the right hand side flow results. The details of weights calculating and reassignment results are presented in the following sections.

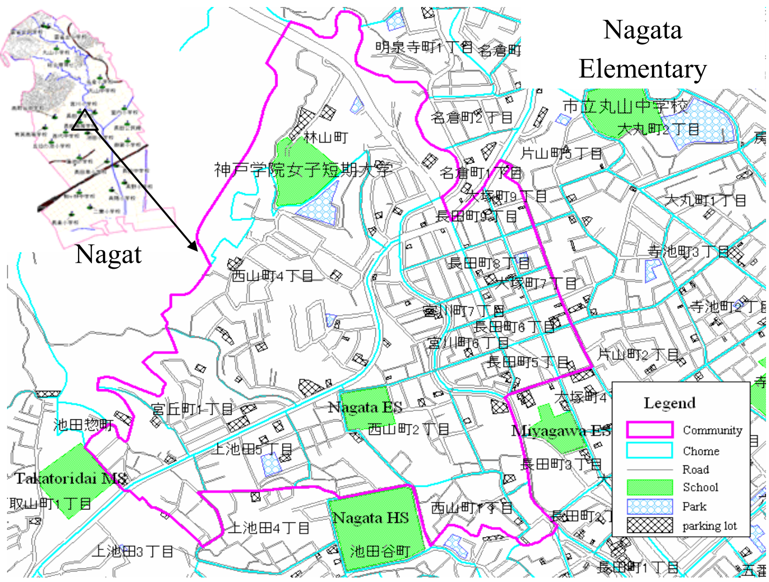


Fig.4.1: Location of the Nagata Elementary School Community

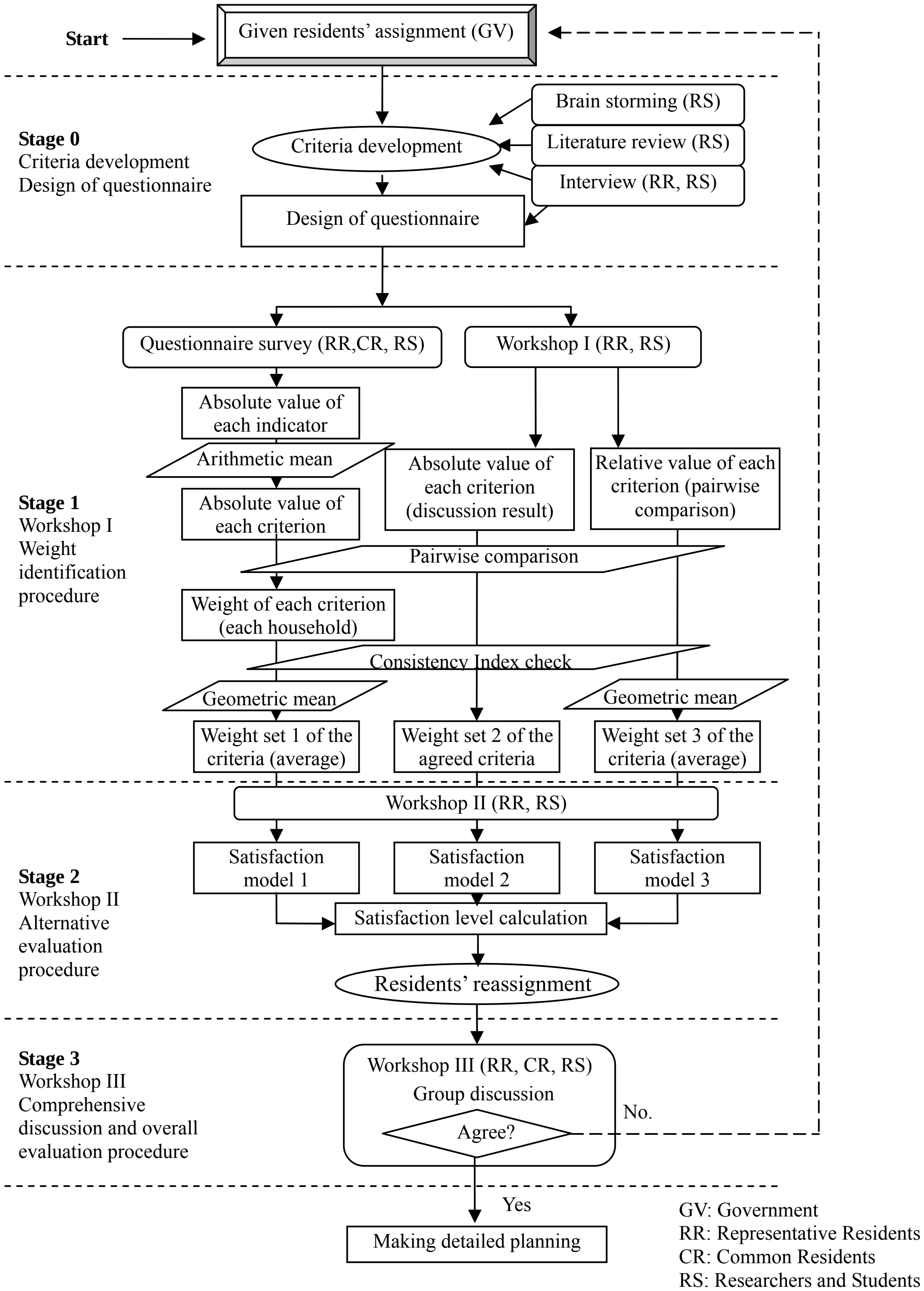
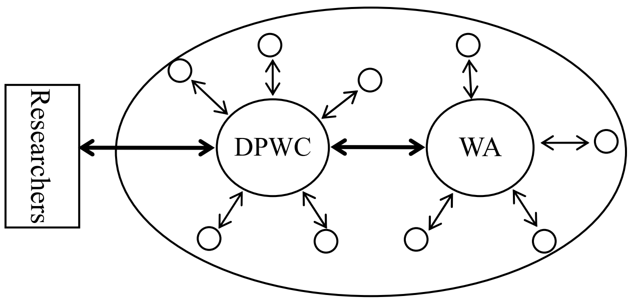


Fig.4.2: Proposed framework for residents' assignment planning to shelters

4.3 Developing collaborative modeling for shelter planning

The leaders of "Bousai Fukushi Community" and "Fujin-kai" (Women's Association) in the Nagata Elementary School Community are identified as key persons who serve as the bridges between researchers and local residents in the questionnaire survey, which helps to obtain the data for calculating the weight of each criterion (Fig.4.3).



DPWC — Key persons of "Bousai Fukushi Community"
WA — Key persons of "Fujin-kai"
○ — Local resident

Fig.4.3: The questionnaire survey collection system in the Nagata ES Community

This questionnaire which consists of the heads of the 50 households is carried out from July 21 to August 4, 2006 (Fig.4.4 shows the distribution of the respondent households). The questionnaires include queries as to disaster experience and evacuation experience, disaster shelter planning, evacuation route, hazard map and personal information (Details can be found in the Appendix). 100% response rate is attained (regarding the content of shelter planning, the response rate is 90%), and among all the respondents, 92% have experience in disaster.

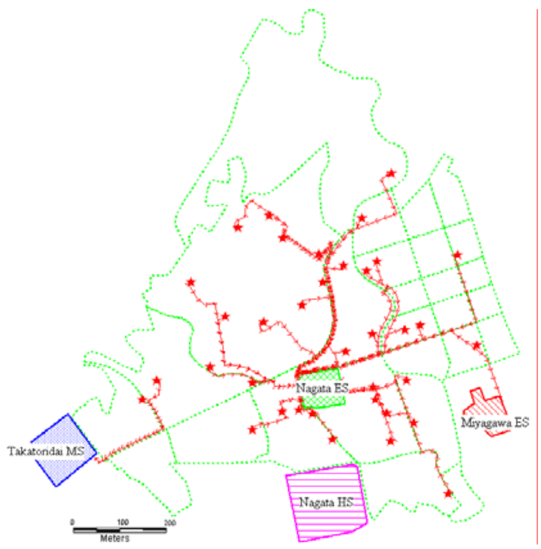


Fig.4.4: The entire area of the questionnaire survey in the Nagata ES Community

By reviewing some related works (e.g., Takagi *et al.*, 2006) and interviewing with the key person of "Bousai Fukushi Community", 17 indicators such as shelter location safety, evacuation distance, evacuation road condition, lifeline maintenance service, and information support are specified by focusing on earthquake disaster shelters and also by differentiating temporary shelters (primary shelters) from accommodation shelters (secondary shelters). Each indicator is denoted by one corresponding question, the specifics of the disaster shelter planning in the survey are listed in Table 4.1. Then 17 indicators are grouped into six categories (performance criteria), namely security, stability and continuity of lifeline service (shorted as stability and continuity), accommodation capacity (shorted as capacity), conformability, accessibility to shelter (shorted as accessibility), and connectivity to external resources and information (shorted as connectivity) (Table 4.1) according to the work done by Xu *et al.* (2006).

As a result, it is concluded that the above identified categories meet well with the three cardinal functions of any living body (here interpreted as "vital shelters") to be integrative as prescribed by the Vitae System Model proposed by Okada (2005). The three functions are "Survivability", "Vitality" and "Communication" (see Chapter 3 and Table 4.1). The criteria of shelter planning can be varied in the particular disaster related context. But this basic approach may certainly help the decision maker to consider it as a base for further extensions. Therefore, the six performance criteria for shelter planning may not be exclusive but are considered to represent the main features of shelter planning.

Table 4.1: Design of the questionnaire for shelter planning assuming three-level performance criteria

Function	Category (Criterion)	ID	Question (Indicator)
Survivability	Security	1	There is no danger in the shelter
		2	There is a safe road available to evacuate
	Stable and continued lifeline service	3	Equipment, such as toilet is satisfactorily installed
		4	Drinking water and food are enough
		5	Rain, wind, cold and hot are kept off
		6	Injury and illness can be cured
Vitality	Accommodation capacity	7	Area per capita in the shelter is large enough
	Comfortability	8	Private space is available
		9	There is no noise pollution
Communication	Accessibility to shelter	10	It is possible to evacuate in a short time
		11	A wide road without slope and step is available to evacuate
		12	Other people's help is offered when evacuating
		13	Understandable guide is offered when evacuating
	Connectivity to external resource and information	14	Sufficient information is offered
		15	Safety confirmation can be done
		16	It is easy to go to hospital and other facilities
		17	Social support such as voluntary and consultation is received

For respondents' better understanding, five options (five levels) for each question (indicator) are used, namely "Strongly disagree", "Disagree", "Neither agree nor disagree", and "Agree" "Strongly agree", which are denoted by the absolute values of "1", "3", "5", "7" and "9" respectively for calculation. Assuming that for a certain performance criterion, its indicators are equally important, then the absolute value of each criterion is represented by the arithmetic mean of corresponding absolute values of indicators to represent. After that the pared comparison method is used to specify the priority or relative importance of performance criteria. Thus priority weights of these criteria are calculated for each household (All the values of Consistency Index are smaller than 0.10). At last, the final weights of the criteria are calculated by using the geometric mean of the weights of all households (Kasahara, 2005) (Table 4.2). The relative values of criteria, which are calculated via the average absolute values of sub-criteria (indicators), are different in nature from that of the standard AHP method (Satty, 1980), in which the data are directly judged by decision maker. Such calculation process is discussed in the workshop, and all the participants tentatively agreed to adopt the result based on the questionnaire survey (coming out of the left column flow) as show in Table 4.2. Therefore it is concluded that the result can be used for further analysis. Thus local residents' relative preferences for the shelter planning performance criteria are specified. Interpretably, The larger the weight, the more the criterion preferred.

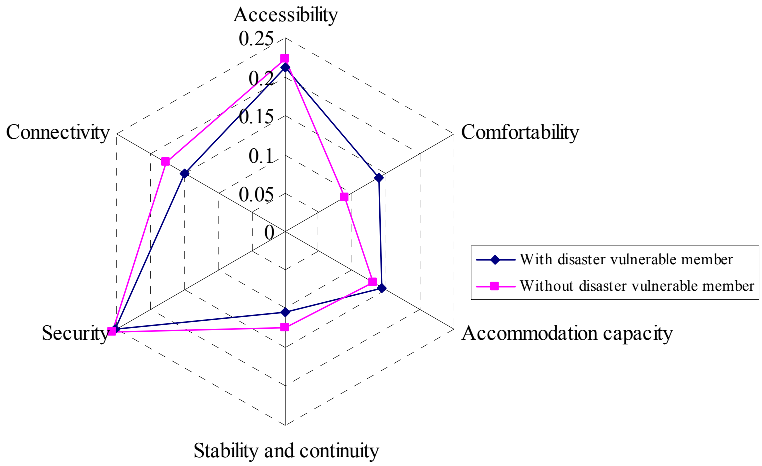
Table 4.2: Weights of the performance criteria for shelter planning based on the questionnaire survey in the Nagata ES Community

Temporary shelter			Accommodation shelter		
Category	Rank	Weight	Category	Rank	Weight
Security	1	0.253	Connectivity	1	0.212
Accessibility	2	0.214	Security	2	0.198
Connectivity	3	0.160	Stability and continuity	3	0.189
Capacity	4	0.140	Accessibility	4	0.179
Comfortability	5	0.122	Capacity	5	0.113
Stability and continuity	6	0.111	Comfortability	6	0.108

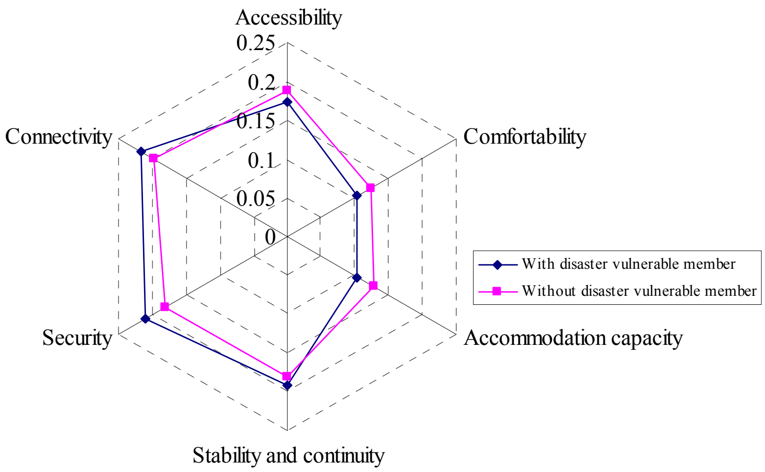
For temporary shelter, the weights of criteria can be classified into three ranges: the highest level (valued larger than 0.2) includes security and accessibility criteria, the middle level (valued larger than 0.15 and smaller than 0.2) includes connectivity criterion; and the lowest level (valued smaller than 0.15) includes capacity, comfortability and stability and continuity criteria. That is to say, for temporary disaster, the relative importance starts from security and accessibility criteria followed as connectivity criterion, and then capacity, comfortability and stability and continuity criteria. A temporary shelter, where living facilities are not available, is often used as a shelter for a short period (less than half a day) or even as a temporary congregation place to temporarily protect people during a disaster chaos period. Therefore, in order to keep them alive immediately after a disaster, to find a safer and easily accessible place seems to be the most important for local people. For this reason, security and accessibility should be taken the priority when making a temporary disaster shelter planning.

For accommodation shelter, the weights of criteria can also be separated into three ranges: the highest level (valued larger than 0.2) includes connectivity criterion; the middle level (valued larger than 0.15 and smaller than 0.2) includes security, stability and continuity and accessibility criteria; and the lowest level (valued smaller than 0.15) includes capacity and comfortability criteria. That is to say, for accommodation shelter, the relative importance starts from connectivity criterion followed as security, stability and continuity and accessibility criteria, and then capacity and comfortability criteria. An accommodation shelter having the living facilities is often used as a secondary shelter rather than used as a primary shelter during the disaster relief and rescue periods, and/or even recovery and restoration period. Therefore, to find a place as a shelter, besides safety and accessibility criteria, weights of connectivity and stability and continuity criteria are relatively high, like where daily life can be easily maintained, and external resources and information can be easily connected become important in a disaster relief and rescue periods.

Taking the example of households with disaster vulnerable members[5] and households without disaster vulnerable members, the weights of criteria are found to be different for different kinds of households (Fig.4.5).



(a) Temporary disaster shelter



(b) Accommodation disaster shelter

Fig.4.5: Radar charts of weights of performance criteria for shelter planning based on the questionnaire survey in the Nagata ES Community

[5] Disaster vulnerable member here means the person who is older than 65, younger than 6, a handicapped or the person who can not evacuate to the shelter without help.

For temporary shelter, the weights of security and accessibility criteria which take a high priority for all criteria are found to be almost same for these two kinds of households. In the case of the weights of connectivity and stability and continuity criteria for households with disaster vulnerable members are relatively smaller than those for households without disaster vulnerable members. In the case of the weights of accommodation capacity and connectivity criteria for households, while for accommodation shelter, the weights of connectivity, security and stability and continuity criteria for households with disaster vulnerable members are larger than those for households without disaster vulnerable members.

A shelter planning mainly includes two types of planning activities, namely location planning (of evacuation centers) and assignment planning (of local residents in a place to the station). This study mainly focuses on residents' assignment planning, by assuming that the shelters have already been located. It is intended to consider how local residents will prefer and best select their own shelter. The purpose of residents' assignment planning is to distinctively identify the satisfaction degree for both community and government.

The contents, weights and ranks of the performance criteria were discussed with local residents in a workshop, 20 people (most of them are the responders to the questionnaire sheets) attended and most of them agreed to adopt the results derived from the questionnaire survey. According to the work done by Yamada *et al.*(2004) and with local residents agreement, residents' satisfaction level is determined to take the following linear Equation (4.1), which is the simplest and operable form of the function.

$$Z_{ij} = w_s S_{ij} + w_d D_{ij} + w_c C_{ij} + w_v V_{ij} + w_a A_{ij} + w_e E_{ij} + \delta \tag{4.1}$$

Where i denotes household, j denotes shelter. Z_{ij} is the satisfaction level; S_{ij}, D_{ij}, C_{ij}, V_{ij}, A_{ij} and E_{ij} denote the surrogate value of security, stability and continuity, capacity, comfortability, accessibility and connectivity criteria, respectively. w_s, w_d, w_c, w_v, w_a and w_e are weights, and δ is a constant or constraint (criterion) that affects the result and is used to revise the model. By "surrogate value" we mean a normalized value of some actual facility or service level implications, instead of more collective attribute of a given criterion.

Therefore, by referring to the questionnaire results, Equation (4.2) is identified as follows:

$$Z_{ij} = 0.198 S_{ij} + 0.189 D_{ij} + 0.113 C_{ij} + 0.108 V_{ij} + 0.179 A_{ij} + 0.212 E_{ij} + \delta \tag{4.2}$$

4.4 Usage of collaborative modeling

Shelter location planning (of evacuation centers) and assignment planning (of local residents in a place to station) are two types of the most important activities of a shelter planning. The objective of planning the shelter location or selecting the best location for a shelter is to maximize the total value of Z_{ij} for all households, namely,

$$\bar{Z}_j = \max_j \left(\sum_i (0.198 S_{ij} + 0.189 D_{ij} + 0.113 C_{ij} + 0.108 V_{ij} + 0.179 A_{ij} + 0.212 E_{ij})\right) + \delta \tag{4.3}$$

While the objective of assigning the local residents to the designated shelter is to maximize the

Z_{ij} for each households, namely

$$Z_{ij^*_{(i)}} = \max_j (0.198S_{ij} + 0.189D_{ij} + 0.113C_{ij} + 0.108V_{ij} + 0.179A_{ij} + 0.212E_{ij}) + \delta \quad (4.4)$$

4.5 Assessment and revision of residents' assignment based on collaborative modeling

To explain the meaning behind, the following explanations may merit attention .In AHP method, the weights of the alternatives for each criterion are often calculated by using the pairwise comparison based on subjective judgment data. Such weights are relative values, from which it can not get the exact values and ratios to corresponding variables. If using the pairwise comparison to obtain the weight, the participants in the workshops found difficult to practice, particularly when the sample is very large, especially in the case of making quick and easy, and many repeated assessments. Since the purpose of this chapter is to assess residents' assignment problem, namely to help local residents select the best shelter, the weights or value of the shelters for each criterion should be calculated, if possible, household by household. The value of evacuation distance indicator (which is one of the important parts of the accessibility criterion), are different from household to household, and the average value seems unreasonable. Therefore, the absolute value is alternatively chosen to represent the weight of each criterion for the shelter planning. To avoid the effect of units, S_{ij}, D_{ij}, C_{ij}, V_{ij}, A_{ij} and E_{ij} are normalized and calculated by

$$S_{ij} = \frac{n_j}{N_j} \quad (4.5)$$

N_j — Number of buildings within a radius of 500m from shelter j

n_j — Number of buildings with no damage within a radius of 500m from shelter j as evidenced by the 1995 Hanshin-Awaji earthquake

$$D_{ij} = \frac{fw_j}{P_j} \Big/ fwp_s \quad (4.6)$$

This means that the value of the stability and continuity criterion is measured in term of the ratio of the available number of food and water set per capita to the standard number of food and water set per capita.

fw_j — Number of prepared food and water set in shelter j

P_j — Population evacuating to shelter j

fwp_s — Standard number of prepared food and water per capita in a shelter (It is set to "1" in this study.)

$$C_{ij} = \frac{s_j}{P_j} \Big/ 1.65 \quad (4.7)$$

This means that the value of the accommodation capacity criterion is measured in term of the ratio of the available per capita area to the standard per capita area (1.65m^2/person).

s_j — Area needed for accepting refugees in shelter j

P_j — Population evacuating to shelter j

$$V_{ij} = \frac{pv_j}{P_j} \Big/ pvp_s \tag{4.8}$$

This means that the value of the comfortability criterion is measured in terms of the ratio of the available privacy area per capita to the standard privacy space per capita.

pv_j — Total privacy space in area for shelter j

P_j — Population evacuating to shelter j

pvp_s — Standard privacy space per capita in shelters

Since the data on the privacy space in shelters for each person is not available, here V_{ij} is arbitrarily set to 0.5.

$$A_{ij} = \begin{cases} 1 & d_{ij} \le 100 \\ \dfrac{100}{d_{ij}} & d_{ij} > 100 \end{cases} \tag{4.9}$$

d_{ij} — Shortest evacuation distance (meter) from household i to shelter j

$$E_{ij} = \frac{1}{15}\left(8 \times \frac{e_{1j}}{\max_j e_{1j}} + 4 \times \frac{e_{2j}}{\max_j e_{2j}} + 2 \times \frac{e_{3j}}{\max_j e_{3j}} + \frac{e_{4j}}{\max_j e_{4j}}\right) \tag{4.10}$$

e_{1j}, e_{2j}, e_{3j}, e_{4j} — Number of neighboring shelters located between 0~500m, 500~1000m, 1000~2000m and ≥ 2000m in distance from shelter j separately (here, the shelters of the whole Nagata Ward are considered). Set δ=0.

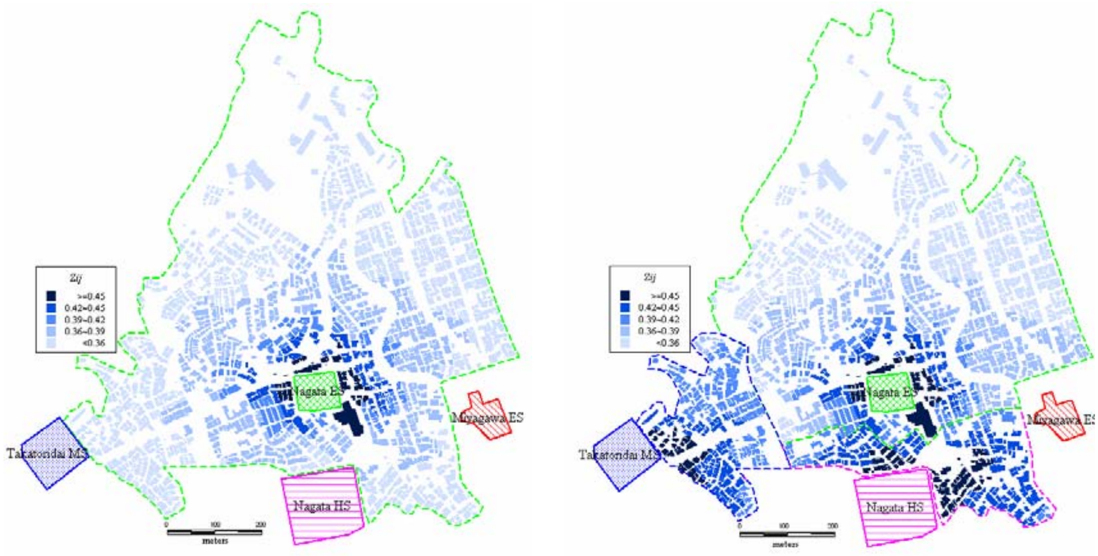
Then, both the values and weights of all the criteria are set (Table 4.3), and the satisfaction level Z_{ij} of each household is calculated for evacuating to the different shelters (Fig.4.6).

Table 4.3: Values and weights of the performance criteria for the designated shelters in the Nagata ES Community

Symbol	Performance criterion	Weight (w_i)	Value			
			Nagata ES	Takatoridai ES	Nagata HS	Miyagawa ES
S_{ij}	Security	0.198	0.57	0.71	0.54	0.56
D_{ij}	Stability and continuity	0.189	200/P_1	200/ P_2	200/ P_3	200/P_4
C_{ij}	Capacity	0.113	450/P_1/1.65	367/ P_2/1.65	475/ P_3/1.65	440/P_4/1.65
V_{ij}	Comfortability	0.108	0.5	0.5	0.5	0.5
A_{ij}	Accessibility	0.179	A_{i1}	A_{i2}	A_{i3}	A_{i4}
E_{ij}	Connectivity	0.212	0.55	0.49	0.59	0.56

Importantly a first glance tells that there is a large difference found between the current assignment that residents are assumed to follow at least officially (Fig.4.6(a)) and the revision assignment obtained from the viewpoint of local residents (Fig.4.6(b)).

The Z_{ij} value of household in Fig.4.6(a) corresponds to the case for evacuation only to the Nagata Elementary School as prescribed by the local government's official shelter planning, and the Z_{ij} value of the household in Fig.4.6(b) corresponds to the evacuation to the respective optimal shelters. In Fig.4.6(b), each household has the maximum value of Z_{ij}, and accordingly people will evacuate to three different shelters: 730 households (16% of total) located in the south-west will evacuate to the Takatoridai MS; 660(15%) households located in the south will evacuate to the Nagata HS; and the rest means to evacuate to the Nagata ES. There is no household evacuating to the Miyagawa ES, where the community has a high capacity risk and high access risk as mentioned in Chapter 3.



(a) Evacuation only to the Nagata ES as prescribed by the official shelter plan

(b) Evacuation to the respective optimal accommodation

Fig.4.6: Assessment of evaluation results for the satisfaction level (Z_{ij}) of households in the Nagata ES Community

In Fig.4.6(a), there are only 90 households (2% of total) whose Z_{ij} value are larger than 0.45, while in Fig.4.6(b) there are 320 (7%). The number of households whose Z_{ij} value is larger than 0.42 and larger than 0.39 are in Fig.4.6(a) 280(6%) and 550 (12%) respectively, while in Fig.4.6(b) are 1120 (25%) and 1900 (42%) respectively. The number of households whose Z_{ij} value is smaller than 0.36 in Fig.4.6(a) is 2520 (56%), while in Fig.4.6(b) the number is 1510 (34%). The average Z_{ij} value has approximately a 7 percentage increase from 0.364 in Fig.4.6(a) to 0.389 in Fig.4.6(b).

In the current assignment planning designated by the local government, the population evacuating to the Nagata ES and Miyagawa ES is much larger than that evacuating to the Nagata HS and Takatoridai MS. Reassigning some households to the Nagata HS and Takatoridai MS can help to reduce the number of people who evacuate to the Nagata ES and Miyagawa ES. At the same time, the evacuation distance of the reassigned households becomes shorter (Fig.4.6(b)). While four shelters, they have same volume of prepared food and water sets, almost same available space to accept refugees, close value of security and connectivity criteria, and same value of comfortability (Table 4.3). That is why in Fig.4.6(b), the Z_{ij} value of household is larger than that in Fig.4.6(a). Though the evacuation distance of some households to the Nagata ES is longer than to the Miyagawa ES, while the population evacuates to the latter shelter is also large, that is why in Fig.4.6(a), there is no household assigned to the Miyagawa ES. This meets with the conclusion derived in the Chapter 3 (though approached differently), where the Miyagawa ES has a high accessible and capacity risk.

When evacuating to the same shelter, all the households have the same value of S_{ij}, D_{ij}, C_{ij}, V_{ij}, and E_{ij}, and the Z_{ij} value changes only with A_{ij}, according to the calculation rule set above. Households located closer to the shelter have a shorter evacuation distance and higher A_{ij} value, with its Z_{ij} value being also larger. That explains why in Fig.4.6(a) and in each sub-region of Fig.4.6(b), the households with the same Z_{ij} value take on homocentric circles.

The maximum Z_{ij} value of each household in both figures is no larger than 0.60. If it intends to increase this value without changing designated shelter locations, and residents' reassignment remaining the same, reasonable countermeasures are i) to enhance the stability and continuality by increasing food and water storage and supply, and also ii) to improve security by retrofitting the shelter buildings. Of course, alternatively the accommodation capacity of designated shelters even could be increased, which, however would require a full-scale revision of the current shelter planning developed by the local government.

4.6 Performance criteria and modeling modification

4.6.1 Workshop

For the purpose of complementary analysis and comparison, the weights of the above six performance criteria for accommodation shelter are also calculated based on the absolute value (directly judged by the participants, using "Case II") and relative value (nine points scale (Nijkamp *et al.*, 1990) for relative preference using "Case III") (Workshop I in Fig.4.1). To validate the model for resident's assignment, and to examine the differences between the two assignment cases, local residents' feedbacks are obtained via workshops (Works II and III in Fig.4.2) held in the case study area. Table 4.4 lists the weights of the performance criteria for shelter planning based on the questionnaire survey (using "Case I") and workshop.

Table 4.4: Weights of the performance criteria for accommodation shelter based on the questionnaire survey and workshop in the Nagata ES Community

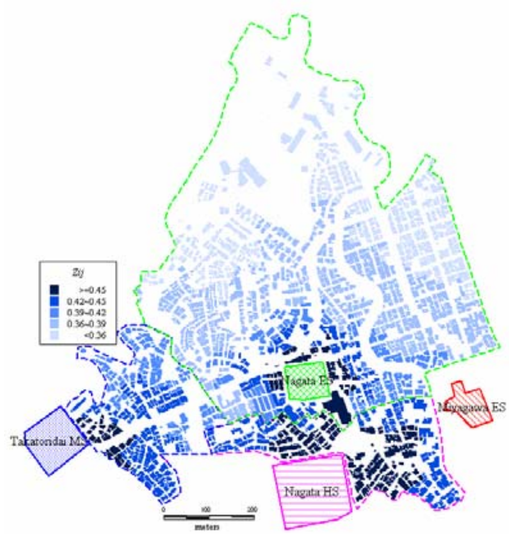
Criterion		Weight		
		Case I	Case II	Case III
Security	S_{ij}	0.198	0.226	0.271
Stability and continuity	D_{ij}	0.189	0.147	0.196
Capacity	C_{ij}	0.113	0.166	0.117
Comfortability	V_{ij}	0.108	0.161	0.170
Accessibility	A_{ij}	0.179	0.134	0.093
Connectivity	E_{ij}	0.212	0.166	0.157
Satisfaction	Z_{ij}	Equation (4.4)	Equation (4.11)	Equation (4.12)

Based on Equation (4.4) and the weights of each criterion, the model can be written as Equation (4.11) or Equation (4.12).

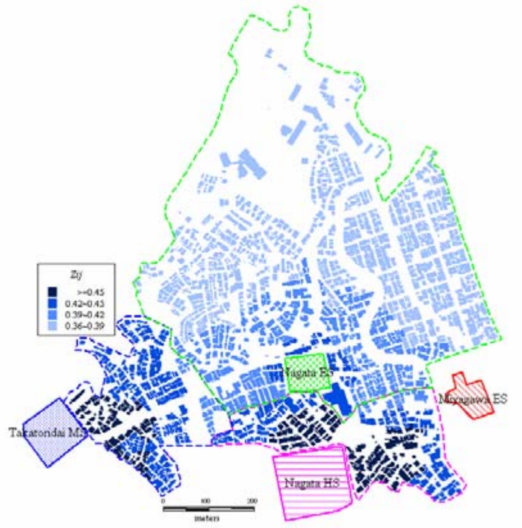
$$Z_{ij^*_{(i)}} = \max_j (0.226 S_{ij} + 0.147 D_{ij} + 0.166 C_{ij} + 0.134 V_{ij} + 0.166 A_{ij} + 0.212 E_{ij}) \qquad (4.11)$$

$$Z_{ij^*_{(i)}} = \max_j (0.271S_{ij} + 0.196D_{ij} + 0.117C_{ij} + 0.170V_{ij} + 0.093A_{ij} + 0.153E_{ij}) \qquad (4.12)$$

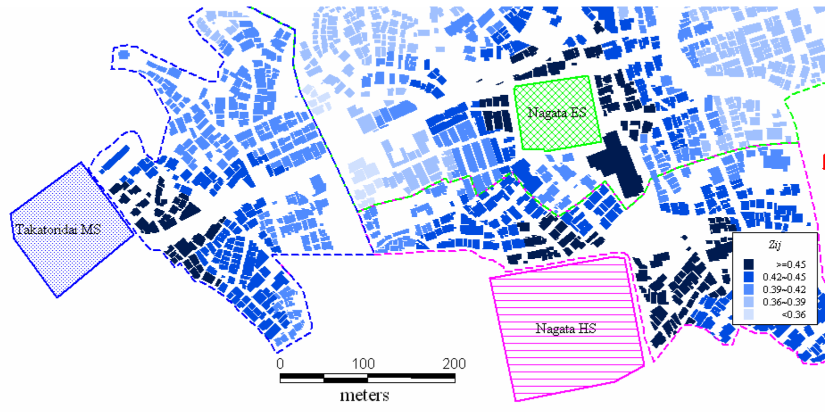
Accordingly, the local residents' satisfaction level can be calculated, and the assignment plans are given in Fig.4.7(a) and Fig.4.7(b).



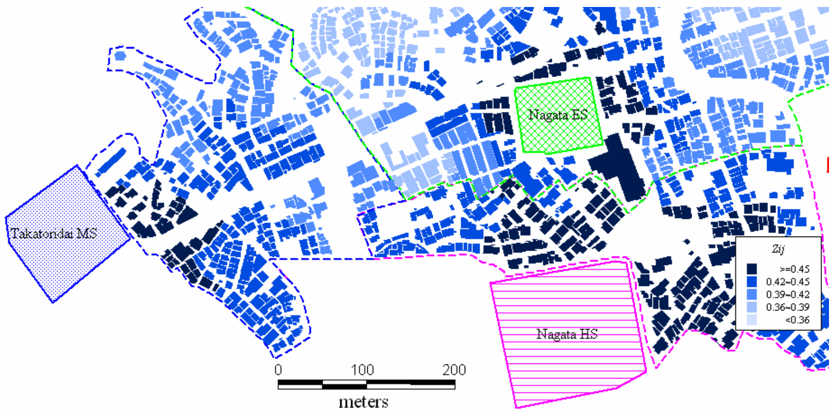
(a) Case II



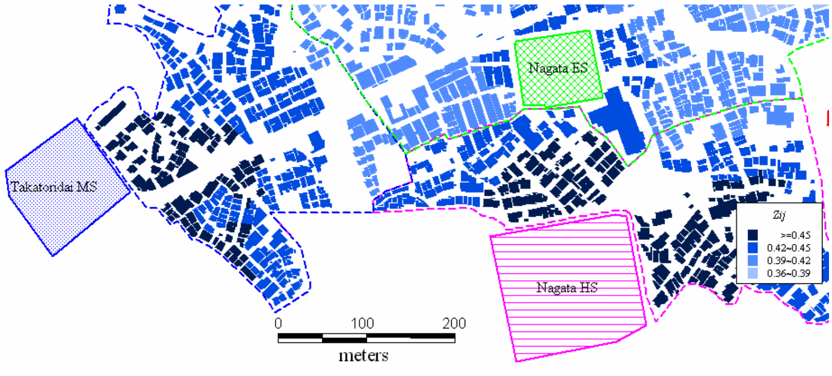
(b) Case III



(c) Case I (zoomed in)



(d) Case II (zoomed in)



(e) Case III (zoomed in)

Fig.4.7: Satisfaction level (Z_{ij}) of households in the Nagata ES Community

The following findings are itemized.

(i) The weights of a same performance criterion are different based on the residents' direct judgment and relative preferences. The weights and their ranking based on the direct judgment are closer to residents' preferences and this way of calculation is regarded as much easier to be accepted by the residents.

(ii) Workshop participants claimed that the performance criteria may vary during and after a disaster (Table 4.4). Generally, the security criterion is considered the most important soon after a disaster (Cases II and III), and the connectivity criterion becomes more and more important in the process of recovery (Case I).

(iii) Basically the reassignment results are very similar in these three cases. In Cases II and III, the average satisfaction levels are higher than that in Case I (Fig.4.7, Table 4.5). More households, even which are close to the Nagata ES, are assigned to the Takatoridai MS and Nagata HS in Cases II and III (Fig.4.7(c), (d), (e)). Because in the latter two cases, the local residents prefer more safety criterion to others, especially to the accessibility criterion.

(iv) In Fig.4.6(b), the assignment area, where residents are assigned to the Takatoridai MS, is the same as the current assignment decided by the local residents. Namely if a disaster happens they prefer evacuating to the Takatoridai MS than to the Nagata ES. Evacuating to the Nagata HS can also help to reduce the capacity risk of the Nagata ES and shorten the residents' evacuation distance (Fig.4.6(b)).

(v) The area, where residents are assigned to the Nagata HS (Fig.4.6 and Fig.4.7), does not meet well with the current assignment since most of the participants are familiar with the Nagata ES and some of them are the members of the "Bousai Fukushi Community" or the "Fujin-kai". They are voluntary organizations to help others in the Nagata ES. If the Nagata ES is found unable to accommodate all the evacuees tentatively due to its limited capacity, shortage of water and food supply, and lack of toilets, some of them should be displaced to the Nagata HS for secondary evacuation. In fact this is precisely the case that happened in the 1995 Great Hanshin-Awaji earthquake disaster. Therefore, it is pointed out that local residents' familiarity should also be considered as a modification of the participatory shelter planning modeling to help the local residents' assignment to respective shelters.

Table 4.5: Number of households at each satisfaction level in different cases when evacuation to the respective optimal accommodation shelters

Z_{ij}	Case I		Case II		Case III	
	Number of household	Percentage (%)	Number of household	Percentage (%)	Number of household	Percentage (%)
≥ 0.45	320	7	520	11	910	11
0.42~0.45	780	18	930	21	1800	22
0.39~0.42	780	17	630	14	1640	20
0.36~0.39	1090	24	1420	32	3840	47
<0.36	1510	34	1000	22	0	0

4.6.2 Crossroad game

As mentioned in Chapter 2, this game was developed by Kikkawa *et al.* (2004) for the purpose of increasing general public and disaster response personnel awareness of the problems faced in disaster situations. Here, this game is used to determine the shelter planning criteria and the necessity for setting up a secondary shelter for the Nagata Elementary School Community. It was also expected that this kind of participatory brain storming game will activate lively discussions among participatory residents related to their local concerns and knowledge.

The game was carried out on April 1, 2007, and 33 participants including local residents and facilitators joined this game, and they were separated into 5 groups (7-7-7-5-7). The content of the question related with the shelter planning is shown in Fig.4.8. In the game card question, it is assumed that there are two shelters, the Nagata ES and the Miyagawa ES, the former one is crowded and the latter one still has space to accept refugees. Considering the different conditions for secondary evacuation, the advantages and disadvantages are summarized in Table 4.6. The participants were asked to write down their reasons for secondary evacuation.

The number of respondents who are selected as reasons for changing shelters is listed in Table 4.7. According to the game result, it is concluded that:

(i) The reason of making choice can be summarized into 7 categories (including familiarity) as mentioned above.

(ii) For all criteria except the accessibility criterion, the number of respondents selected as reasons for "Yes" is larger than that for "No" if the former takes advantage, and smaller if the former takes disadvantage.

(iii) As secondary evacuation, security and stability and continuity criteria seem to be less important than first evacuation, while accessibility and connectivity criteria are more important, namely the "Survivability" function becomes less important and the "Communication" function becomes more important.

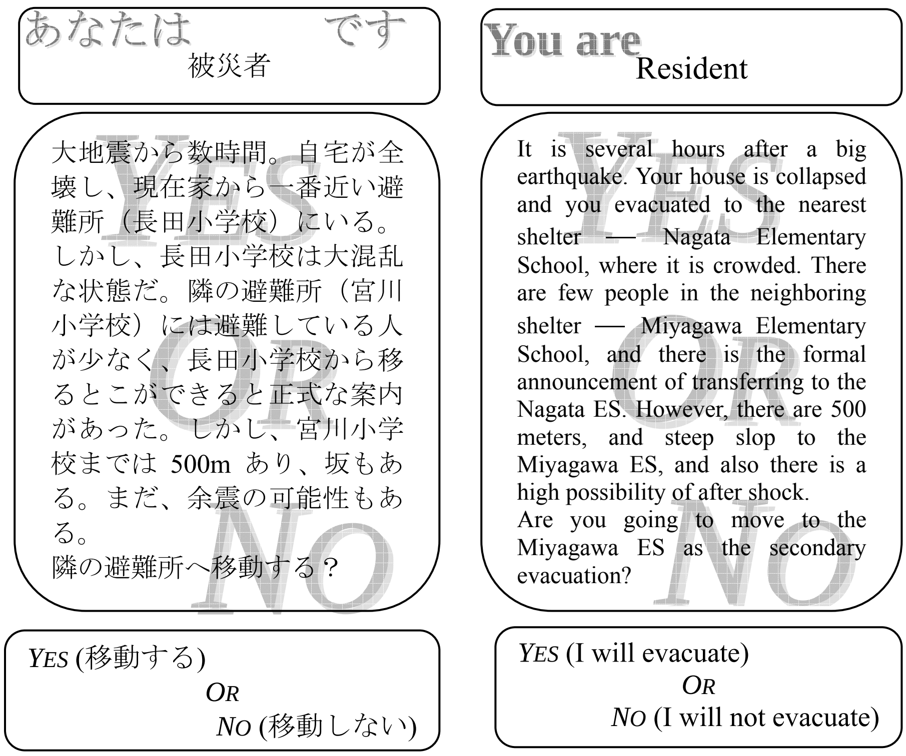
(iv) All the residents, who want to evacuate with the reason of accessibility, are young or all the members in their families are young. Though there is a steep slope, they prefer a better environment to stay.

(v) Al the residents, who will not evacuate with the reason of connectivity, are "Bousai Fukushi Community" members who are responsible to take care of others in the Nagata ES, or people who want to stay with their families.

(vi) All the residents with the reason of familiarity do not want to evacuate, because they want to stay with their families or friends, in this sense, this reason can also be grouped into connectivity, which includes communication with family.

(vii) As for the secondary shelter of this community, in the question card, it is assumed to be the "Miyagawa Elementary School", while most of the participants argued that if a big earthquake happens, the place must be also crowded in the Miyagawa ES, in that case, the Nagata High School would be more practical. Actually during the 1995 Hanshin-Awaji earthquake, people were transferred to the Nagata HS to reduce the accommodation capacity risk and comfortability risk. In this sense, the Nagata HS could be assigned as the secondary shelter in this community.

As a whole, it may merit affection that this kind of participatory approach will serve well for activating lively and interactive discussions, thus enabling people to reexamine their own evacuation planning.



(Japanese version) (English version)

Fig.4.8: Crossroad game question

Table 4.6: Assumed conditions of the Miyagawa ES as compared to the Nagata ES

Criterion	Nagata ES	Miyagawa ES
Security	-	+
Accommodation capacity	+	-
Comfortability	+	-
Accessibility	-	+
Connectivity	-	+
Familiarity	-	+
Stability and continuity	+	-

*"+": advantage, which means that the condition (criterion) is positive to the participants;

"-": disadvantage, which means that the condition is negative to the participants.

Table 4.7: The number of respondents who are selected as reasons

Criterion	Yes (I will evacuate)	No (I will not evacuate)	Total
Security	1	2	3
Accommodation capacity	3	0	3
Comfortability	4	2	6
Accessibility	7	3	10
Connectivity	1	9	10
Familiarity	0	3	3
Stability and continuity	0	0	0
Total	16	19	35

4.7 Conclusions

In this chapter, a collaborative modeling for shelter planning (shelter location planning and residents' assignment planning) has been developed, and based on which a questionnaire survey has been designed and conducted in the Nagata Elementary School Community, with a focus on earthquake disaster. The current administrative residents' assignment plan has been reassessed in the framework of the collaborative modeling. To make an overall assessment of prospective residents' assignment alternatives based on a mathematical model, workshops and crossroad game are also held. The participants' ideas and their opinions are best used to adaptively modify and eventually reach the most appropriate assignment plan.

Six basic performance criteria have been specified and focused, "security", "stability and continuity", "accommodation capacity", "comfortability", "accessibility to shelter", and "connectivity to external resource and information". Local residents' preferences against these criteria vary in different stages after a disaster. There is a large difference found between the current official assignment plan (evacuation only to the Nagata Elementary School) and the revised assignment plan obtained (evacuation separately to the Nagata Elementary School and the Takatoridai Middle School). It is claimed that the revised assignment plan is better than the former one in terms of the modeled overall performance value. Workshops which have been organized as a part of collaborative modeling were found to be effective to activate participatory deliberations over the focused plans. Though both the workshop participants and questionnaire respondents are considered "somewhat biased samples" in terms of both the concerns and capacity for evacuation activities, and thus caution is to be taken to interpret the results of the findings. To overcome this problem, further efforts should be made to include more average people in workshops as well as questionnaire surveys. In conclusion, the framework of collaborative modeling has been found to be effective and useful to reassess (the officially determined) shelter planning from the viewpoint of residents for this type of participatory evacuation planning.

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Chapter 5 Developing Multi-stakeholder Earthquake Disaster Evacuation Simulation Model

In Chapters 3 and 4, the current official assignment planning to disaster shelter was reassessed.

In this chapter, community-based safety map, which is the collaborative product of expert knowledge and local knowledge, is discussed as a useful data base of the evacuation simulation for the focused community. To utilize the existing administrative assignment plan and revise it by reflecting community's evacuation activities, an earthquake disaster evacuation simulation model is developed for the Nagata Elementary School Community assuming the involvement of local residents, "Bousai Fukushi Community" members, and firemen. Based on this simulation model, earthquake disaster evacuation simulations are carried out[6].

5.1 Introduction

As mentioned in Chapter 1, a lesson learned from the 1995 Hanshin-Awaji earthquake tells that public aids for disaster risk management are as important as self-help and mutual aids. To illustrate how self-help and mutual aids help local resident to evacuate in rescue and relief phase, various studies on evacuation simulations have been carried out and corresponding models also developed. In the existing literature, most of disaster evacuation simulations have been developed by assuming the self-help of individual persons. Most of the simulations have intended to take into account the evacuees' mutual helps under various conditions (such as road width, route blockage, and traffic jam). Table 5.1 lists typical examples of simulation works. Generally, the evacuation simulations can be separated into two types, namely mesh data based simulation and GIS network (vector data) based simulation, according to their data types. Most of the existing simulation works are based on the mesh data, typically using KKMAS — a Multi Agent Simulator, while works based on GIS network are still very few.

Regarding the evacuation route conditions, slopes and steps, which will greatly affect evacuees' speed and behavior especially in mountain areas, are often neglected because most works tend to focus on tsunami disaster (or earthquake trigged tsunami disaster) or flood disaster, and the case study areas are often assumed to be flat.

There are many research works have been carried out on single stakeholder's (agent's) disaster evacuation. However, very few studies have been conducted to examine multi-stakeholder evacuation, by assuming such stakeholders as the local government, fire stations, community disaster prevention organizations, and/or other related organizations, etc.

In building and operating a certain simulation model, the parameter would be one of the key components of affecting the simulation results. Generally higher quality data make the simulation results closer to the reality, and also to effectively use such results is considered to help stakeholders to make community's evacuation planning. To obtain high quality data, besides local governmental and experts' efforts, local community's and individual citizens'

[6] The work in this chapter is mainly based on Xu *et al.* (2005, 2007).

involvement should also be considered. Recently, some communities, organizations or communities have used community safety map for the purpose of raising public awareness about risks and improving disaster preparedness in the respective jurisdictional areas (e.g., UN/ISDR, 2001; and ADRC, 2003). This kind of map, which is the collaborative product of the expert knowledge and the local knowledge, will also be considered to serve as a useful information dashboard (packet), which makes rapid simulation and assessment possible.

To illustrate the above idea, in this chapter, a multi-stakeholder earthquake disaster evacuation simulation model is developed based on DiMSIS (Kakumoto *et al.*, 1997) for the case study of the Nagata Elementary School Community, Kobe City.

Table 5.1: Comparison of selected multi-agent evacuation simulation models

Author	Hazard	Agent	Stakeholder	Route condition	Data type	Remark
Arai *et al.*, 2003	Earthquake	Young, old, handicapped	The public	—	Mesh	Inside a public building
Meguro *et al.*, 2003	Fire	Young, old Male, female	Local residents	Blockage, width	Mesh	—
Katada *et al.*, 2004	Tsunami	Young, old	Local residents	Blockage	Mesh	—
Nozawa *et al.*, 2005	Tsunami	Young, old	Local residents, local government	Blockage, slope, steps	Mesh	—
Ashibe 2006	Earthquake	Leader, follower	Local residents	—	GIS network	—
Ohata *et al.*, 2006	Tsunami	Young, old, handicapped	Local residents	—	GIS network	—
Kumagai *et al.*, 2006	Tsunami	Young, old	Local residents	Blockage, width	GIS network	—
Xu *et al.*, 2007 (this chapter)	Earthquake	Young, old, handicapped	Local residents, “Bousai Fukuji Community” member, firemen	Blockage, width, slopes, steps	GIS network	—

5.2 Community-based safety map

The community safety map is an effective medium of communication and useful database to help both the local government and local residents to manage the community for a safer living environment. The process of developing the community-based safety map can help to enhance community’s awareness and preparedness of disaster risk, as well as it helps them to know their community better.

The definition of the community-based safety map can be made differently for various communities. Here, “Community safety means preventing, reducing or containing the social, environmental and intermediate factors which affect people’s right to live without fear of crime and which impact upon their quality of life. It includes preventative measures that contribute to crime reduction and tackle anti-social behaviour.” (Community Safety Unite, 2003) In this thesis, the meaning of community safety is somewhat narrower, to focus on the multiple natural disasters. Generally the community-based safety map is a kind of map which needs to be collaboratively developed by both the government and local residents with the help of experts, private companies or others; it is to serve for community disaster management, to be installed with basic information and disaster preparedness information, and to be operated, updated and maintained by both the government and local residents.

In the Nagata Elementary School, a Community Safety Map developed in 2000 by the local government was distributed to the local residents for disaster reduction. To cater to local residents' needs of updating the map, a questionnaire survey was carried out to determine the contents, and then a new map was developed with the help of DiMSIS (Fig.5.1).

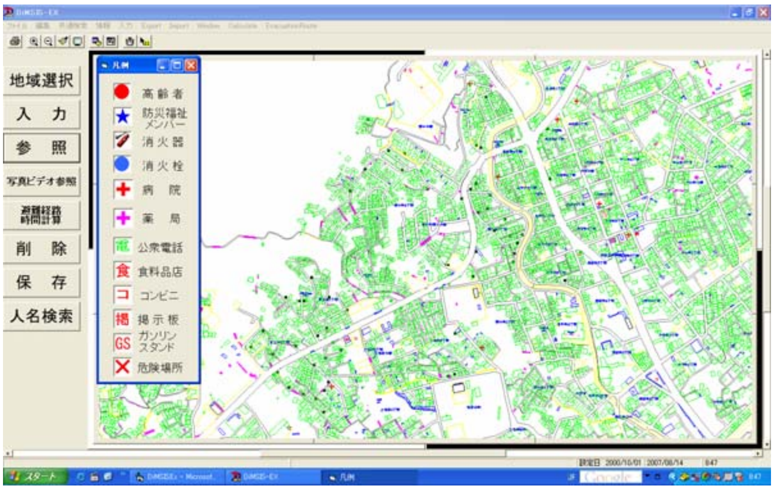


Fig.5.1: The community safety map in the Nagata ES Community

As for the contents, dangerous points and areas, old people and handicapped people, parking lots, slopes and steps information are added to the new map, for example, by local residents who have participated in town-watch walks (Table 5.2, Fig.5.1).

Based on the advantages of DiMSIS, the digital version of the map has also some special functions. They include: (i) Photo and Video display: besides the symbol information, the photo information of building, dangerous point, shelter etc. and the video information along the route can be easily displayed, which makes the condition visual and more imaginable. (ii) Temporal information: all the contents have some temporal attribute (year 2000 and year 2007), that makes temporal comparison possible. (iii) Evacuation distance and time calculation: by selecting the start and end point, the evacuation distance, evacuation route (viable routes) and evacuation route condition (slope, step) can be displayed. This map has not distributed to each household since it is a digital version, however this map has been already used to help community leaders to manage the community.

Regarding the risk level in the community according to the field survey and map-making result, the following can be mentioned. The most frequently mentioned hazards by local residents are earthquake and earthquake-triggered fires in this community, and most countermeasures are taken to reduce such hazards. Many buildings, which were slightly affected during the Hanshin-Awaji earthquake, are used as resident houses after simple repair in this community, especially in Kamiikeda 6 Chome (Fig.5.1). Therefore, most buildings are traditional wooden houses, which are very vulnerable to an earthquake and a fire hazards in these areas. Roads between those buildings which remain narrow as before the 1995 earthquake are highly likely to block fire engines to enter and carry out defense activities. Moreover, the numbers of fire hydrants and fire extinguishers are very few. All these are considered to put the area of Kamiikeda 6 Chome under a very high risk to an earthquake and a fire, though this area is very close to the designated community accommodation shelter. Besides earthquake and fire hazards, Nishiyama 4 Chome, located in hilly area, is also a landslide prone area. This area has a large population density, and 30% people are older than 65. Most roads are narrow and steep slopes or steps It is very difficult to evacuate to the designated shelter because of the long distance, narrow and steep routes, and the situation is much worse during heavy rain. These two areas are administratively designated as the high risk areas.

This kind of information gives a useful database and parameter for community's evacuation simulation.

Table 5.2: Contents of the community-based safety maps in the Nagata ES Community

Category	Version 2000	Questionnaire survey*	New Version*
Hazard information	—	Dangerous point	Dangerous point and area
Medical institution information	Hospital, drugstore	—	—
Lifeline management information	Pool, well, convenience shop, food shop, bulletin board, gas station, park public telephone	—	—
Disaster-vulnerable people information	Elementary school	—	Old people and handicapped people
Shelter information	Accommodation shelter, evacuation route	—	—
Disaster emergency information	Fire hydrant and fire extinguisher, disaster prevention materials warehouse	—	—
Others	—	Parking lot	Parking lot, slop and step

*Contents needs to be added to the version 2000 map

5.3 Multi-stakeholder evacuation simulation model

In the Kobe City of Hyogo Prefecture, the city office has published an earthquake disaster evacuation system , which is mainly composed of evacuation instruction, instruction transmission, shelter opening, and evacuation guidance (Kobe City, 2005) (Fig.5.2). In evacuation, residents will evacuate to the shelters by themselves or with others' help, especially for the physically vulnerable people, and those injured need to be sent to hospitals. If there are blockages on evacuation routes, they have to be removed by responsible organizations or persons, such as policemen, firemen or local disaster prevention organization members.

The evacuation simulation model in this study mainly focuses on the activities after the evacuation instruction is transmitted. Besides the self-help and/or mutual helps between local residents, fire stations and the "Bousai Fukushi Community" are expected to remove traffic barriers and help people with evacuation. As for the evacuation route conditions, besides width, slopes and steps are also considered as well as the occurrence of route blockage and barrier removing activities. The algorithm of selecting the optimal evacuation route is shown in Fig.5.3.

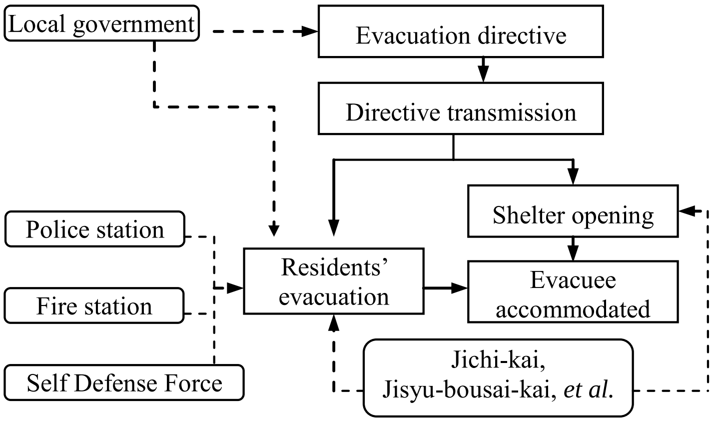


Fig.5.2: The evacuation system for earthquake disaster in Kobe City

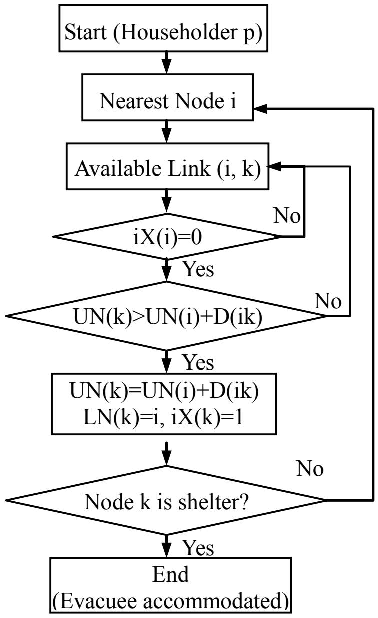


Fig.5.3: Algorithm of optimal route choice

iX(k): Node check mark, Node is checked if equals to 1, and not checked when equals to 0.

UN(k):Shortest distance from start Node i to Node k

D(ik):Distance between link (i, k) (Distance between neighboring Node i and Node k)

LN(k): Previous Node ID

5.4 Case study

As mentioned before, the Nagata Elementary School Community (Fig.5.1) is located in the middle of the northern part of the Nagata Ward, and was heavily damaged due to the 1995 Hanshin-Awaji earthquake. A half of this community is located in a hilly area, and there are many steps and steep slopes as well as narrow roads. There is a community's autonomous disaster prevention organization named "Bousai Fukushi Community" which works actively and communicates closely with the local fire station. In this study, the effect of the hazard to the simulation is mainly described by the building collapse rate and route blockage rate. And other basic assumptions are presented as followings.

5.4.1 Evacuee

It is assumed that all the evacuees are local residents and some of them are quite familiar with their evacuation routes and evacuation centers. Household which is the basic unit of evacuation (according to the crossroad game on April 1, 2007) is categorized into three types, namely handicapped, old, and young types, according to member's physical condition. A household with at least one handicapped is grouped into the handicapped type, a household with no handicapped, but with at least one people older than 80[7] is grouped into the old type, and others are grouped into the young type. According to the data provided by the "Bousai Fukushi Community" (a survey done by them), 191 households belong to the old type and 4 belong to the handicapped type, the left 3,331[8] households belong to the young type.

Table 5.3: Administrative region and population of the the Nagata ES Community

Cho	Chome	Household	Population
Nagata	5~9	268	554
Miyagawa	3~9	536	1266
Ooduka	5~9	192	413
Hayashiyama	-	497	1295
Nishiyama	1~4	1086	2526
Miyaoka	1,2	306	694
Kamiikeda*	3,5,6	641	1592
Total	-	3526	8340

* Only part of the Kamiikeda 3 Chome is assigned to the Nagata ES community

As for mutual assistance among residents, a young type household is viewed as a rescuer. A handicapped type household or a single and old type household, who can not evacuate without help, belongs to a rescuee. As for the old but not single household, the young member can help the old one (self-help) and mutual help from other people is not necessary to this type of household when evacuation. According the Crossroad Game result, in this community, 70% (Liu *et al.*, 2007) young type households are going to help the single and old or handicapped type households near by, and the speed of the former will be same as the one of the latter. One rescue can only help one rescuee.

7 Normally a person older than 65 is viewed an old person in Japan, while local people in this community argued that 80 years may be better during the workshop on April 1,2007.
8 Kobe City homepage, available: http://www.city.kobe.jp/cityoffice/06/013/data/tyoujinkou/17tyoujinkou/17nagata2.xls

In this study, the simulations are conducted for the evacuation rate of 10%, 30%, 50%, 80% and 100%, respectively. The old and young types of households in the basic area unit (Cho-Chome) are randomly selected according to the evacuation rate. And the evacuation rate of the handicapped type households is fixed to 100% since there are only 4 handicapped type households.

5.4.2 Evacuation route type

The Ministry of Land, Infrastructure and Transport Construction of Japan (Disaster Prevention Office, 1997) set a standard that the road which is narrower than 4 meters is considered not appropriate as an evacuation route, narrower than 8 meters has a high possibility to be blocked, and wider than 16 meters are recommended to be used for safe and secured evacuation. Since there are no more details prescribed about how the road conditions affect people's behavior, in this study the route is separated into 16 types according to its width and gradient condition, and then the priority (rank) of each type is also determined based on the interview with some local residents (Table 5.4).

Table 5.4: Route type and its priority when evacuation

r_k	$\omega \geq 16$	$8 \leq \omega < 16m$	$4m \leq \omega < 8m$	$\omega < 4m$
$\alpha < 3°$	1	2	5	10
$3 \leq \alpha < 10°$	3	4	8	13
$\alpha \geq 10°$	6	7	12	14
steps	9	11	15	16

*α is the road gradient, ω is the road width, and r_k represents the rank of route type k, r_k=k(1,2,…,16)

5.4.3 Route blockage model

Many blockage models have been proposed to calculate the blockage rate by mainly considering the road width, house characteristics, house density and distance from house to road (Ieda *et al.*, 1997, Ichikawa *et al.*, 2004). The width of broken roof tile (meter) is simply calculated by multiplying the height of building (meter) by the outflow rate of broken tile, which is related with the building cover rate (Shingai *et al.*, 2001). In this manner, the evacuation route blockage rate and unblocked route width can be calculated.

5.4.4 Evacuation speed

Evacuation means (evacuation mode) is one of the main factors that affect the evacuation velocity. During the Hanshin-Awaji earthquake in 1995, about 73% evacuees evacuated to shelters by walking (Kashiwabara *et al.*, 1998) which is also assumed as the standard main evacuation means in many cities and wards in Japan. The National Institute of Occupational Safety and Health, Japan (NIOSH/JP, 2002) conducted experiments and specified that people's evacuation speeds are different among road surfaces and slopes. However, an actual standard speed is not issued, and therefore it is assumed that walking is the only mode of evacuation, and the hypothetical evacuation speeds for each type of road and household are arbitrarily set (Table 5.5). If the unblocked width is narrower than 1 meter, then the route is assumed to be not available to evacuate (Bureau of Kochi Prefecture, 2005), and the evacuation speed is 0.

Table 5.5: Evacuation speed of each household type and different road gradient

Type	Gradient α	Direction	Evacuation speed(m/s)		
			Young	Old	Handicapped
1	$\alpha < 3°$	Bidirection	1.30	1.10	0.65
2^+	$3 \leq \alpha < 10°$	Going up	1.10	0.90	0.55
2^-	$3 \leq \alpha < 10°$	Falling	1.20	1.00	0.60
3^+	$\alpha \geq 10°$	Going up	1.00*	0.70	0.45
3^-	$\alpha \geq 10°$	Falling	1.10*	0.80	0.50
4^+	Steps	Going up	0.80*	0.60	0
4^-	Steps	Falling	0.90*	0.70	0

*The data are obtained according to on-site experiments conducted by the author and others.

5.4.5 Simulation interfaces

According to the above description and local community's needs, two basic simulation interfaces are developed.

(i) One interface is to simulate the evacuation route selection behavior of any single household in the simulation. In the simulation, the user can arbitrarily select the start and end location of a household' evacuation by clicking on the map, and then the shortest simulation route will be displayed in the map. The evacuation time can also be calculated by changing the evacuation speed (Fig.5.4). The visual information of the evacuation route can also be displayed by photos and videos, which greatly avails the user to understand the evacuation route condition and to help the evacuee to find the safest and best route. This function has already used for community' evacuation management by the leader of "Bousai Fukushi Community".

(ii) Another interface is to simulate the evacuation actives of all households in the community. In the simulation, the information of evacuation rate, residents' mutual helps, route blockage rate, evacuation start time and shelters can be easily changed by the user, as well as the activities of removing the route blockage. As the result, the real time information of the evacuation success rate and number of evacuation success households can be obtained (Fig.5.5).

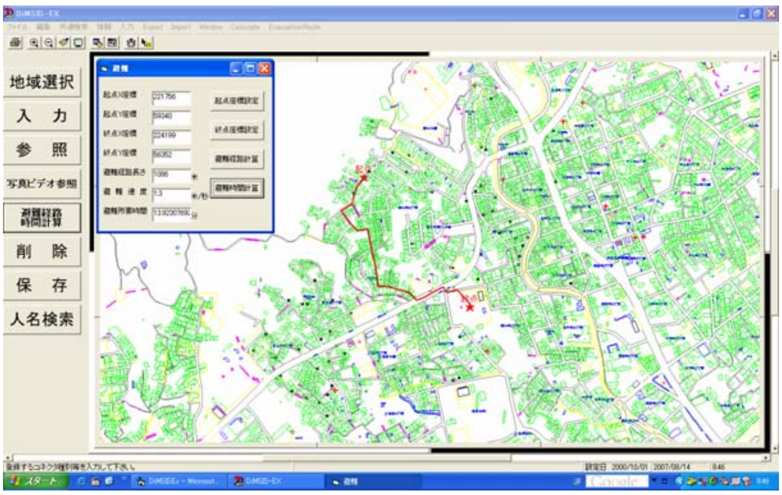


Fig.5.4: Evacuation simulation interface 1

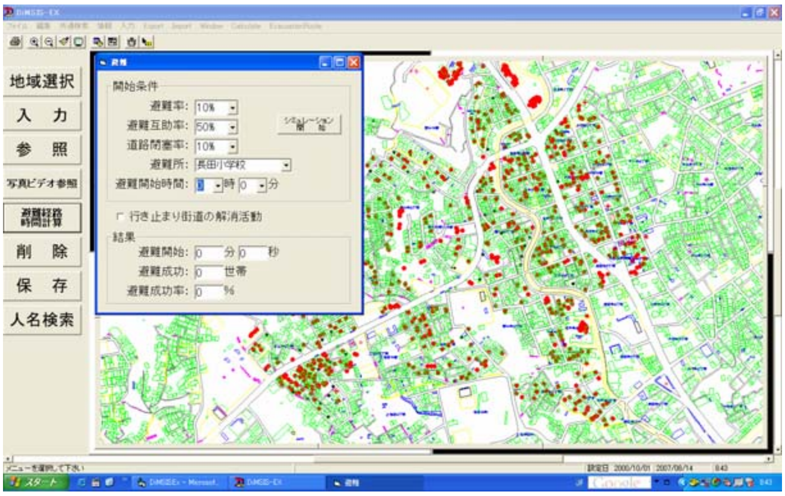


Fig.5.5: Evacuation simulation interface 2

5.4.6 Scenario cases

As discussed in the previous sections, simulations are conducted in this study by preparing the following scenario cases (Table 5.6).

Table 5.6: Scenario cases of simulation

Case	Condition
I	Current geographical condition (without route blockage)
II	With route blockage
III	With route blockage, and blockage is later removed
IV	Current geographical condition, residents evacuate separately

In Case I, simulation is conducted according to the current (day to day) geographical and behavioral conditions, and there is no route blockage.

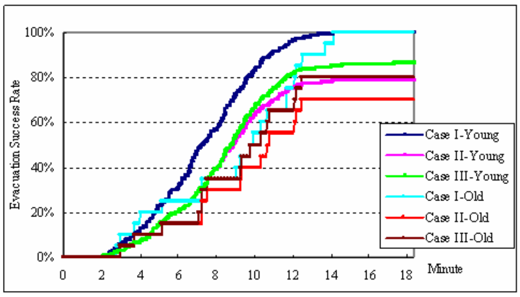
In Case II, route blockage rate is about 20%, and steps, steeper slope roads and narrower roads are easy to be blocked. It can be obviously found that in Kamiikeda 6 Chome and Nishiyama 4 Chome, many roads are very narrow and both the building density and population density are high as can be found from the safety map, which made the roads easily to be blocked.

In Case III, obstacle-removing operation is performed by fire men or members of “Bousai Fukushi Community”. The route blockages in Kamiikeda 6 Chome and Nishiyama 4 Chome, can be removed by the fire men and the “Bousai Fukushi Community” members within 10 and 15 minutes, respectively, after an earthquake happens. (This is roughly judged by referring to the location of fire station, the movement and obstacle-removing speed of fire men and “Bousai Fukushi Community” members’ in the disaster drill of Nagata Ward.)

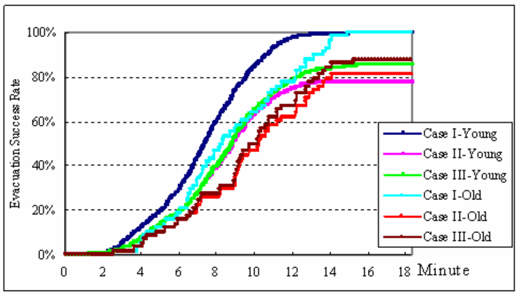
In Cases I, II, and III, all the residents are supposed to evacuate only to the Nagata Elementary School according to the current governmental assignment planning. In case IV, residents are supposed to evacuate to the optimal shelter, namely the Nagata Elementary School (Nagata ES) and Takatoridai Middle School (Takatoridai MS), separately (See Chapter 4, Fig.4.6(b)). In all these cases, people will evacuate at the same time and soon after an earthquake happens since they are scared of likely-to-happen after shocks and other second disasters such as a fire.

5.4.7 Simulation results

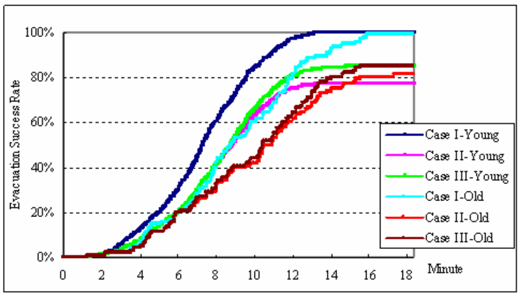
A simulation system is developed based on DiMSIS and simulations were run 5 times for each case. The average results of the simulated number of successful evacuation households and evacuation success rate are shown in Fig.5.6. For further analysis, the relations between the evacuation time (minutes) and the evacuation success rate are listed in Table 5.7.



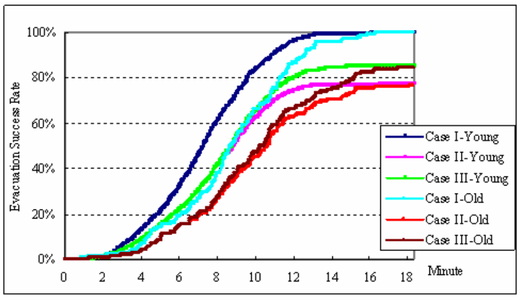
Cases I, II and III, 10%



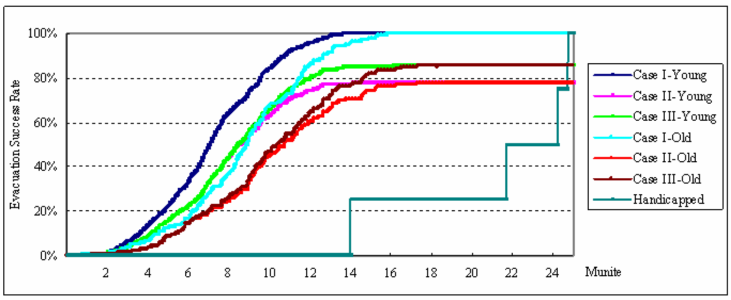
Cases I, II and III, 30%



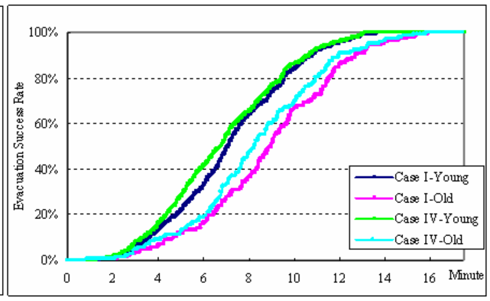
Cases I, II and III, 50%



Cases I, II and III, 80%



Cases I, II, III and Handicapped included, 100%



Cases I and IV, 100%

Fig.5.6: Evacuation success rate

Table 5.7: Relations between evacuation time (minute) and evacuation success rate

Evacuation	Case I		Case II		Case III		Case IV	
success rate	Young	Old	Young	Old	Young	Old	Young	Old
10%	3.6	4.6	4.2	5.5	4.2	5.5	3.3	4.3
20%	4.8	6.4	5.6	7.1	5.6	7.1	4.3	6.2
30%	5.7	7.2	6.8	9.0	6.8	8.6	5.1	6.8
40%	6.5	8.3	7.6	9.6	7.6	9.4	5.9	7.7
50%	7.0	9.0	8.6	10.8	8.4	10.4	6.7	8.3
60%	7.6	9.6	9.6	12.0	9.4	11.6	7.4	8.9
70%	8.7	10.7	10.9	13.8	10.4	12.7	8.4	10.1
80%	9.6	11.5	16.2 [a)]	18.3 [b)]	12.0	14.7	9.4	11.0
90%	10.8	12.7	--	--	16.2 [c)]	18.3 [d)]	10.6	12.0
100%	17.5	15.9	--	--	--	--	17.5	15.9

a), b), c) and d): Time when the evacuation success rates are 77%, 78%, 85% and 86% respectively, which are the maximum evacuation success rates for the corresponding cases. Actually in each case, when the evacuation success rate is maximum and the evacuation time of the young type household is 24.7 minutes, which is the time that all the handicapped type households evacuate to the shelter since the mutual help is existing.

It can be easily found that:
The evacuation success rate of each type of household in Case I (100%) is lager than that in Case III (85% for the young type households and 86% for the old ones), and also larger than that in Case II (77% for the young and 78% for the old). Tere is an increase of 9% in the rate of the succeed evacuation households to the whole households, from Case II to Case III in which the route obstacles are removed by the firemen and/or “Bousai Fukushi Community” members.

In Case I, almost all of the young type households will successfully evacuate to the shelter within 13 minutes, 1 minute ahead of that in the Case II and 2 minutes ahead of that in the Case III. The time for all the young type households evacuating to the shelter is 16 minutes in Case I, and 18 minutes in Cases II and III.

Though it takes the same time for either of the young or old type households to evacuate completely in Cases I and IV, in Case IV the evacuation success rate is lager than that in Case I. Namely, in Case IV people will evacuate to the shelter faster than that in Case I. The maximum difference of the rate is 6% for the young type households and 7% for the old ones. From this viewpoint, the residents’ assignment in Case IV is better than that in Case I, which basically meets with the conclusions that have been derived from the related research work in Chapter 4 (though approached differently).

In the same case, the maximum evacuation success rates for the young type households and the old type households are almost the same. The larger the evacuation rate is, the smaller difference is found between the two types, although. While the young type households tend to have a larger evacuation success rate than the old type households until they reach their maximum evacuation success rate. The maximum difference is estimated to be 20%.

As for the handicapped type households, whether there is a road blockage or not, the evacuation success rate is calculated to be 100%. This is due to an extremely small portion of those handicapped as compared to the total population, that is, the number of handicapped persons being only four. It will take about 25 minutes for all of this type of households to evacuate.

As explained above, the simulation model provides a useful knowledge base and baseline information for assessment of community's coping capacity, given different service levels of available governmental assistance. Effective use of this model may well be made for implementing multiple-stakeholder community disaster drill to be led by the local government. The model is considered to help them to make community's evacuation planning in close collaboration with the local residents.

5.5 Conclusions

In conclusion, the following summary of this research merits attention.

In this chapter, a multi-stakeholder evacuation simulation model has been developed by using DiMSIS by taking into account evacuee's characteristics (physical condition and mutual help) and route condition (width, slope and steps). In the evacuation model, besides individual citizens' mutual aids, the activities of fire station and the "Bousai Fukushi Community" are considered and they are assumed to assist evacuees by removing obstacles.

On the basis of the scenario cases, evacuating separately to the Nagata Elementary School and Takatoridai Middle School (Case IV) has been found better than only evacuating to the Nagata Elementary School (Case I). With the help of firemen or "Bousai Fukushi Community" members, local residents' evacuation success rate can be increased.

The proposed simulation model was constructed and operated under different assumptions and scenarios. If such assumptions and scenarios are changed, the specifics of the above findings will be different. It has, however, been shown that the proposed simulation model with the assistance of DiMSIS as an information and technology media, helps the concerned multi-stakeholders virtually imagine and experience evacuation difficulties and bottlenecks in the event of a catastrophic earthquake disaster.

From the viewpoint of collaborative modeling, this prototype simulation model can be further improved and evolved if it is actually used in a participatory workshop involving respective stakeholders. In this sense this prototype model can be fully used to provide as an initial basis for collaborative modeling although it has many assumptions and pre-set scenarios which are considered to address only a very limited scope of much broader possibilities. It is also noted that this kind of multi-agent simulation model will be effectively operated as a means of risk communication with potential stakeholders such as local residents, thus enabling them to get engaged in communicative survey as a complementary method to collaborative modeling. Some preliminary attempts to practice such an approach have already been discussed with community people living in the Nagata Elementary School Community.

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Chapter 6 Conclusions

6.1 Summary of research outcomes

In this thesis, an evacuation planning methodology has been developed based on field-survey based collaborative modeling approach. The achievements of each chapter are as follows:

In Chapter 1, an overall overview of the background, objective and approaches of this thesis have been discussed.

In Chapter 2, the status quo of the practice and research works regarding the evacuation planning has been reviewed with a focus on Japan. It specifically underlines the need to study, and thus gives an overview of the participatory shelter planning process in reference with the PDCA cycle. The focused evacuation planning (and management) in this thesis is supported by DiMSIS, and the framework of "Communicative Survey" combined with the PDCA cycle have been proposed to systematically carry out community-based participatory approach for disaster evacuation planning.

Chapter 3 has discussed two kinds of disaster shelters, that is, primary (or temporary) shelter and accommodation shelter. The primary shelter serves the purpose of temporary stay for the refugees. The accommodation shelter servers the purpose of long term stay for the refugees if the disaster lasts or extends over time. Different administrative and spatial levels of shelter planning have been discussed. They included the levels of household, neighborhood, community, municipality (city, town or village), or a wider level of region (such as prefecture). After that, the performance criteria for shelter planning have been addressed, classified into and then integrated together with three basic functions from the viewpoint of the Vitae System. Accordingly these three types of approaches, different in priority and order of the three basic functions, i.e., survivability, vitality and communication have been proposed. The specific forms of these criteria of shelter planning can vary, dependent on the particular disaster related context. It has been found that the basic approach presented here will help the decision makers (particularly local government officials) to overall work out prospective alternatives of shelter planning.

To further examine these prospective alternatives, the accessibility to shelters and the shelter accommodation capacity have been assessed in the case of the Nagata Ward, Kobe City. Results show that according to the existing administrative plan, in those areas, where the population density is moderate or high, the evacuation time of residents to shelters tends to be long, and residents are assigned to such a shelter with high accommodation capacity risk, have very high evacuation risk. It is proposed to revise the plan by adding new shelters, reassigning residents, or extending the existing accommodation capacity in these high risk areas.

In Chapter 4, a collaborative modeling for shelter planning (shelter location planning and residents' assignment planning) has been developed, and based on which a questionnaire survey has been designed and conducted in the Nagata Elementary School Community, with a focus on earthquake disaster. The current administrative residents' assignment plan has been reassessed in the framework of the collaborative modeling. To make an overall assessment of prospective residents' assignment alternatives based on a mathematical model, workshops and crossroad game were also held, and participants' ideas and opinions have been best used to adaptively modify and eventually reach the most appropriate assignment plan.

Six basic performance criteria have been specified and focused, “security”, “stability and continuity”, “accommodation capacity”, “comfortability”, “accessibility to shelter”, and “connectivity to external resource and information”. Local residents' preferences against these criteria vary in different stages after a disaster. There is a large difference found between the current official assignment plan (evacuation only to the Nagata Elementary School) and the revised assignment plan obtained (evacuation separately to the Nagata Elementary School and the Takatoridai Middle School). It is claimed that the revised assignment plan is better than the former one in terms of the modeled overall performance value. Workshops which have been organized as a part of collaborative modeling were found to be effective to activate participatory deliberations over the focused plans. In conclusion, the framework of collaborative modeling has been found to be effective and useful to reassess (the officially determined) shelter planning from the viewpoint of residents for this type of participatory evacuation planning.

In Chapter 5, a multi-stakeholder evacuation simulation model has been developed by using DiMSIS by taking into account evacuee's characteristics (physical condition and mutual help) and route condition (width, slope and steps). In the evacuation model, besides individual citizens' mutual aids, the relief and rescue activities of the responsible fire station and the “Bousai Fukushi Community” were considered and they have been assumed to assist evacuees by removing obstacles.

On the basis of the selected scenario cases, evacuating separately to the Nagata Elementary School and Takatoridai Middle School (Case IV) has been found better than only evacuating to the Nagata Elementary School (Case I). With the help of firemen or “Bousai Fukushi Community” members, local residents' evacuation success rate can be increased. The proposed simulation model was constructed and operated under different assumptions and scenarios. If such assumptions and scenarios are changed, the specifics of the above findings will be different. It has, however, been shown that the proposed simulation model with the assistance of DiMSIS as an information and technology media, helps the concerned multi-stakeholders virtually imagine and experience evacuation difficulties and bottlenecks in the event of a catastrophic earthquake disaster.

Chapter 6 summarizes the main contributions of this entire thesis including, the remaining remarks to follow:

6.2 Future research

The primary end users (customers) of evacuation planning, especially shelter planning are obviously local residents in an assumed disaster-prone area. Moreover they are different in age, living conditions, life style and local conditions. Some people may be physically handicapped.

This is the main reason why a more focus on participatory approach to earthquake disaster evacuation planning is needed. In order to address this issue, a framework for developing an integrated evaluation criteria of shelter location planning, and diagnosing the existing planning is becoming increasingly important.

This framework needs more rigorous conceptual refinement as well as more consistent theoretical and modeling examinations. This kind of research focuses also on a holistic setting (and the context) of evacuation planning (and management). For instance, whether it is mainly concerned about temporary or accommodation shelter, the respective modeling context will be different. Though this thesis intended to pay attention to such a context specification, through involving local residents, a greater care has to be taken to address this problem.

Another example: Besides local people's preferences, many other factors also affect residents' evacuation center selection, such as local government's rules or administrative constraints, e.g., to how much food should (and can) be prepared in a shelter and how long it might take to transport food to the shelter after a disaster happens. If so, another type of evacuation simulation is necessary, in which such specifics as shelter capacity, stored volume of emergency water in a well and food as well as local government's provision of water and food supply to the shelter should be taken into account.

As a whole, the proposed approach should also undergo more long-standing research, based on field works and by cohering to the process of the PDCA cycle process over relatively a long span of time. At the same time the collaborative modeling for shelter planning can be extended to help residents develop new capabilities and functionalities in the context of multi stakeholders' involvement in decision making process with reference to the PDCA cycle. The author wishes to take such a challenge as much as possible in the years to come.

Appendix

「避難所計画について地域の皆様と共に学ぶためのアンケート調査」

ご協力のお願い

時下ますますご清栄のこととお喜び申し上げます。

長田小学校区防災福祉コミュニティでは、長田小学校区にお住まいの皆様から防災への関心や考えをお伺いし、今後の避難所計画と災害時の避難所運営方法などの地域防災対策に反映することを目的として、長田小学校区婦人会、長田小学校区民生委員会、京都大学防災研究所と共同してアンケート調査を行うことといたしました。このアンケート調査の結果は、地域防災対策に反映することを目的をしているだけではなく、地域の皆様と防災について考える材料としていく予定です。今後、調査結果のご説明を兼ねて、皆様と共に防災について考える機会を設けたいと考えおりますので､その際には是非ご参加ください。

このアンケート調査の対象者は、長田小学校区にお住まいの全世帯です。アンケート用紙、返信用封筒にはお名前やご住所をご記入いただく必要はありません。また、本アンケートから得られた情報は、地域の防災対策に反映されるだけではなく、研究報告や学術出版物に掲載されることがありますが、結果は統計的な資料にまとめて発表いたしますので、皆様ひとりひとりのご意見が公表されることはありません。

地域防災のために、調査の趣旨をご理解いただき、ご協力くださいますようお願いいたします。ご不明な点がございましたら、下記までお問い合わせください。

2006 年 7 月 21 日

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「避難所計画について地域の皆様と共に学ぶためのアンケート調査」

長田小学校区防災福祉コミュニティ
長田小学校区婦人会・民生委員会
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- このアンケートには、お名前やご住所をご記入いただくことはありません。返信用の封筒についても同様です。
- ご回答は、調査票を受け取られた世帯主ご本人、またはご家族の中心となられている方や家事を担当されている方などがご回答ください。
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- アンケートのご回答は、「こういうご意見の方が何％」というように統計的にまとめますので、個人のお答えを公表することは一切ございません。

調査についてのお問合せと返送についてのお願い

- ご回答いただきましたアンケート用紙は、同封の返送用の封筒に入れ、**平成18年 7 月31 日(金)**までにお近くの郵便ポストに投函、もしくはお近くの防災福祉コミュニティ担当者、婦人会員・民生委員にお渡し下さい。
- このアンケートについてのご質問などは、下記までお問い合わせいただきますようお願いいたします。

問１ あなたの災害の経験についておたずねします。

問 1-1 あなたは、これまでに**洪水**による被害の経験がありますか。

a. ある	**b.** ない →	問 1-2へ進んでください

↓

それはいつですか	（　　年　　月頃）	（　　年　　月頃）	（　　年　　月頃）
どこでですか			
被害の程度			

a. 浸水・被害はなかった	**b.** 床下浸水した	**c.** 床上浸水した
d. 一部損壊・半壊した	**e.** 全壊・流出した	

問 1-2 あなたは、これまでに**がけ崩れ**による被害の経験がありますか。

a. ある	**b.** ない →	問 1-3 へ進んでください

↓

それはいつですか	（　　年　　月頃）	（　　年　　月頃）	（　　年　　月頃）
どこでですか			
被害の程度			

a. 被害はなかった	**b.** 一部損壊・半壊した	**c.** 全壊した

問 1-3 あなたは、**平成７年１月の阪神淡路大震災**による被害を経験しましたか。

a. ある	**b.** ない →	問 1-4へ進んでください

↓

被害の程度			
	a. 被害はなかった	**b.** 一部損壊・半壊した	**c.** 全壊した

問 1-4 あなたは、阪神淡路大震災以外に、**地震**による被害を経験したことがありますか。

a. ある	**b.** ない →	問 1-5 へ進んでください

↓

それはいつですか	（　　年　　月頃）	（　　年　　月頃）	（　　年　　月頃）
どこでですか			
被害の程度			

a. 被害はなかった	**b.** 一部損壊・半壊した	**c.** 全壊した

問 1-5 避難所で生活したことがありますか。

a. ある	**b.** ない

↓

問-1-6 避難所生活で困ったことがありますか。

a. ある → **b.** ない	それはどのようなですか（具体的にご記入ください）

問２ 長田小学校区における自然災害発生の可能性についておたずねします。

あなたの住んでいる地域が、今後10年以内に大規模な地震、洪水、がけ崩れが発生する可能性はどの程度だと思いますか。[各項について該当するものに○をつけてください]

地　震	洪　水	がけ崩れ
1. 非常に高い **2.** やや高い **3.** やや低い **4.** 非常に低い **5.** 分らない	**1.** 非常に高い **2.** やや高い **3.** やや低い **4.** 非常に低い **5.** 分らない	**1.** 非常に高い **2.** やや高い **3.** やや低い **4.** 非常に低い **5.** 分らない

問３ あなたの家庭では、地震災害に対して下記どのような備えをしていますか。[該当するものに○をつけてください]

a. 地域の防災コミュニティマップを確認している	**f.** 避難所などについて家族で話し合いをしている
b. 非常用の飲料水や食料品を用意している	**g.** 家具や食器棚の転倒防止措置を施している
c. 非常用の持ち出し品を袋などにまとめている	**h.** 地域の防災訓練などに積極的に参加している
d. 携帯ラジオや懐中電灯などを用意している	**i.** 近所の人たちと防災に関する活動を行っている
e. 地震保険に加入している	**j.** そのほか(　　　　　　　　　　　　　　)

問４ もし地震災害が起きたら、あなたはどうしますか。[各項について該当するものに〇をつけてください]

a. 1 人で逃げる **b.** 家族と一緒に逃げる **c.** 隣の人と一緒に逃げる	**d.** 逃げない
a. どのタイミングで逃げますか。 ＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿ **b.** どのような情報をもとに逃げますか。 ＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿ **c.** 何処へ逃げますか。	理由： **a.** どこへ避難するかが分からない **b.** いつ避難するかが分からない **c.** 避難経路が安全かどうか分からない **d.** 家にいるのが安全だと思う **e.** 自分で逃げられない

問５ 避難所についておたずねします。
避難所には、**一時避難所**と**収容避難所**の２つがあります。下記の用語説明を参照したうえで、ご回答ください。

一時避難所：**一時的に避難できる広場、公園、空地などをいう。災害の状況を見る場合にも利用する。**
収容避難所：**自然災害等により住居等を失うなど、継続して救助を必要とする市民に対し、宿泊、給食等の生活機能を提供できる学校などをいう。各自治体が指定する。**

問 5-1 あなたの家の最寄りの**収容避難所**はどこですか。 [該当するものに〇をつけてください]

a. 長田小学校　**b.** 長田高等学校　**c.** 宮川小学校　**d.** 高取台中学校
e. その他＿＿＿＿＿＿＿＿＿＿　**f.** 分らない

問 5-2 あなたの家の最寄りの**収容避難所**までの距離はどのくらいですか。[該当するものに〇をつけてください]

a. 100 メートル未満　**b.** 500 メートル未満　**c.** 1000 メートル未満
d. 1500 メートル未満　**e.** 1500 メートル以上　**f.** 分らない

問 5-3 あなたの家から最寄りの**収容避難所**まで歩いてどのくらいかかりますか。[該当するものに〇をつけてください]

a. 10 分以内　**b.** 30 分以内　**c.** 60 分以内　**d.** 60 分以上　**e.** 分らない

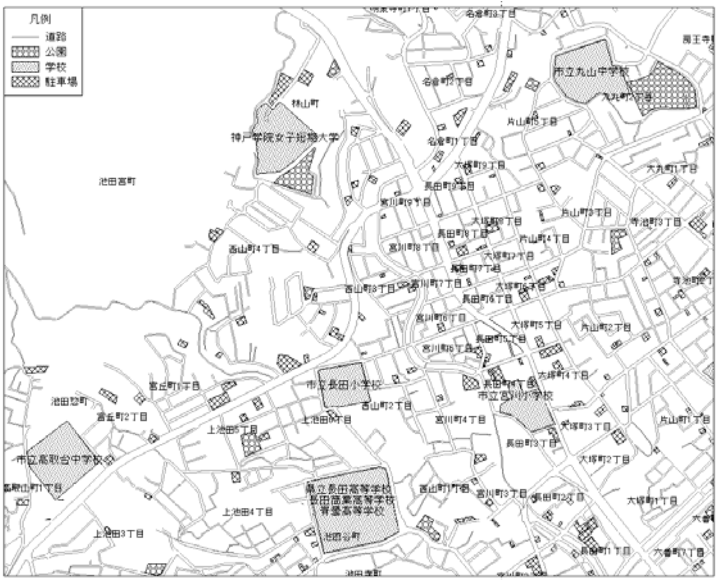
問 5-4 あなたはどこを**一時避難所**と考えていますか。それぞれの災害ごとにお答え下のうえ、その理由をお書き下さい。 [各項について該当するものに〇をつけてください]

地 震	洪 水	がけ崩れ
1. 最寄りの公園 **2.** 最寄りの広場 **3.** 最寄りの空地 **4.** 最寄りの駐車場 **5.** その他(　　　　　) **6.** 収容避難所 **7.** 避難しない	**1.** 最寄りの公園 **2.** 最寄りの広場 **3.** 最寄りの空地 **4.** 最寄りの駐車場 **5.** その他(　　　　　) **6.** 収容避難所 **7.** 避難しない	**1.** 最寄りの公園 **2.** 最寄りの広場 **3.** 最寄りの空地 **4.** 最寄りの駐車場 **5.** その他(　　　　　) **6.** 収容避難所 **7.** 避難しない
理由:	理由:	理由:

問 5-5 問 5-4 で一時避難所に 1~5 を選んだ方にお聞きします。災害が継続した場合、一時避難所から、どこへ移動しますか。それぞれの災害ごとにお答え下のうえ、その理由をお書き下さい。[各項について該当するものに〇をつけてください]

地 震	洪 水	がけ崩れ
1. 収容避難所 **2.** 最寄りの公園 **3.** 最寄りの広場 **4.** 最寄りの空地 **5.** 最寄りの駐車場 **6.** その他(　　　　　) **7.** 避難しない	**1.** 収容避難所 **2.** 最寄りの公園 **3.** 最寄りの広場 **4.** 最寄りの空地 **5.** 最寄りの駐車場 **6.** その他(　　　　　) **7.** 避難しない	**1.** 収容避難所 **2.** 最寄りの公園 **3.** 最寄りの広場 **4.** 最寄りの空地 **5.** 最寄りの駐車場 **6.** その他(　　　　　) **7.** 避難しない
理由:	理由:	理由:

問 5-6 あなたは避難するとしたら、どの避難経路を使用しますか。下記の図に、一時避難所を“▲”で、収容避難所を“〇”で記入した上で、避難経路を記入てください。



問 5-7 あなたはどのような条件を考慮して避難所を選択しますか。一時避難所と収容避難所、それぞれにご回答ください。他の条件があれば、追加してください。[各項について該当するものに〇をつけてください]

一時避難所の場合

		まったくそう思わない	あまりそう思わない	どちらでもない	ややそう思う	非常にそう思う
1.	避難所に危険(倒壊物、浸水など)がない	1	3	5	7	9
2.	危険(倒壊物など)がない道を避難できる	1	3	5	7	9
3.	短時間で避難所まで行かれる	1	3	5	7	9
4.	坂や段差が少ない道、または広い道で避難できる	1	3	5	7	9
5.	避難所への移動に他の人からの助けがある	1	3	5	7	9
6.	避難所まで分かりやすい誘導がある	1	3	5	7	9
7.	１人当りのスペースが十分ある	1	3	5	7	9
8.	プライベートが守られる空間がある	1	3	5	7	9
9.	騒音などがない	1	3	5	7	9
10.	トイレなど設備が充実している	1	3	5	7	9
11.	十分な飲料水、非常食などが得られる	1	3	5	7	9
12.	雨・風・寒さ・暑さがしのげる	1	3	5	7	9
13.	十分な情報が得られる	1	3	5	7	9
14.	怪我、病気などを治療してもらえる	1	3	5	7	9
15.	安否確認ができる	1	3	5	7	9
16.	病院などへ行きやすい	1	3	5	7	9
17.	ボランティアや相談などの社会的支援が受けられる	1	3	5	7	9
18.		1	3	5	7	9
19.		1	3	5	7	9
20.		1	3	5	7	9

収容避難所の場合

	まったくそう思わない	あまりそう思わない	どちらでもない	ややそう思う	非常にそう思う
1. 避難所に危険(倒壊物、浸水など)がない	1	3	5	7	9
2. 危険(倒壊物など)がない道を避難できる	1	3	5	7	9
3. 短時間で避難所まで行かれる	1	3	5	7	9
4. 坂や段差が少ない道、または広い道で避難できる	1	3	5	7	9
5. 避難所への移動に他の人からの助けがある	1	3	5	7	9
6. 避難所まで分かりやすい誘導がある	1	3	5	7	9
7. １人当りのスペースが十分ある	1	3	5	7	9
8. プライベートが守られる空間がある	1	3	5	7	9
9. 騒音などがない	1	3	5	7	9
10. トイレなど設備が充実している	1	3	5	7	9
11. 十分な飲料水、非常食などが得られる	1	3	5	7	9
12. 雨・風・寒さ・暑さがしのげる	1	3	5	7	9
13. 十分な情報が得られる	1	3	5	7	9
14. 怪我、病気などを治療してもらえる	1	3	5	7	9
15. 安否確認ができる	1	3	5	7	9
16. 病院などへ行きやすい	1	3	5	7	9
17. ボランティアや相談などの社会的支援が受けられる	1	3	5	7	9
18.	1	3	5	7	9
19.	1	3	5	7	9
20.	1	3	5	7	9

問 6 コミュニティ安全マップについておたずねします。

問 6-1 あなたは、長田小学校区におけるコミュニティ安全マップ(長田小学校区防災福祉コミュニティ――平成 12 年 3 月発行)があることを知っていますしたか。[該当するものに○をつけてください]

a. 知っていた	**b.** 知らなかった

問 6-2 あなたは、問 6-1 のコミュニティ安全マップの内容を見たことがありますか。[該当するものに○をつけてください]

a. 見たことがある	**b.** 見たことがない

問 6-3 あなたは、問 6-1 のコミュニティ安全マップをお持ちですか。[該当するものに○をつけてください]

a. 持っている	**b.** 持っていない

問 6-4 コミュニティ安全マップは平成１２年に発行されてから、更新されていません。あなたはコミュニティ安全マップ更新を希望しますか。

a. 希望する	**b.** 希望しない

問 6-5 コミュニティ安全マップ更新するために費用を負担するならば、いくらまで負担できますか。

a. 一世帯＿＿＿＿＿＿円まで負担する	**b.** 負担しない

問 6-6 長田小学校区におけるコミュニティ安全マップについて、どのような内容が必要ですか。他の内容があれば、追加してください。[該当するものに○をつけてください]

1. 避難（場）所	2. 避難経路	3. 消火栓、消火器
4. 防災資機材庫	5. 食料品店	6. 病院
7.	8.	9.
10.	11.	12.
13.	14.	15.

問 7　地域や社会、災害についておたずねします。［各項について該当するものに○をつけてください］

		まったくそう思わない	あまりそう思わない	どちらでもない	ややそう思う	非常にそう思う
1.	地域コミュニティの活動(町内会や自治会など)に積極的に参加している方だ	1	3	5	7	9
2.	地域全体で災害について準備しておけば、災害時の被害を減らすことができると思う	1	3	5	7	9
3.	災害に備えて地域で防災活動をするのは大変だと思う	1	3	5	7	9
4.	近所の皆さんとのつきあいは多い方だと思う	1	3	5	7	9
5.	地域でのお祭りや行事などの活動にはよく参加している方だ	1	3	5	7	9
6.	地域で防災活動に取り組むには、時間や手間がかかる	1	3	5	7	9
7.	地域コミュニティでの防災活動に積極的に参加したいと思う	1	3	5	7	9
8.	自分の住む地域についての防災の勉強会があれば、私もぜひ参加したいと思う	1	3	5	7	9
9.	行政機関や消防署が行う地域の防災訓練があるならば、参加したいと思う	1	3	5	7	9
10	防災訓練に参加すれば、災害の時に何かの役に立つと思う	1	3	5	7	9
11	地域での防災訓練に参加する時間を作るのは困難だ	1	3	5	7	9

問 8

問 8-1　あなたの年齢、性別とお宅の世帯人数についてお聞きします。

(1) 年齢

a. 30 歳未満	**b.** 30 歳以上~40 歳未満	**c.** 40 歳以上~50 歳未満
d. 50 歳以上~60 歳未満	**e.** 60 歳以上~70 歳未満	**f.** 70 歳以上

(2) 性別

a. 男性	**b.** 女性

(3) 世帯人数　あなたを含めて　(________)人

(4) あなたの世帯には災害弱者がいますか。

a. いる、____________人	**b.** いない

＊災害弱者とは、65 歳以上の成人と 6 歳以下の子供、災害が発生した場合、安全な場所への避難行動や避難場所での生活において大きな困難が生じ、まわりの人の手助けを必要とする人たちのことをいいます。例えば、移動が困難な人、車いす、補聴器などの補装具を必要とする人、情報を入手したり、発信したりすることが困難な人、急激な状況の変化に対応が困難な人、薬や医療装置が常に必要な人、精神的に不安定になりやすい人のことです。

(5) あなたの世帯の昼間の滞在人数は何人ですか。

月曜～金曜は __________人	土曜・日曜・祝日は __________人

(6) あなたの出身国は

a. 日本	**b.** 日本以外 __________________

問 8-2　あなたのお住まいについてお聞きします。

(1) あなたのお住まい

a. 一戸建てで　______階建ての家に住んでいる
b. 集合住宅で　______階建ての_____階に住んでいる

(2) あなたのお住まい

a. 持ち家	**b.** 賃貸

(3) あなたのお住まいの構造

a. 木造	**b.** 非木造(鉄筋や鉄骨造りなど)

(4) あなたは、現在の場所におよそ何年間住んでいらっしゃいますか。

a. 1 年未満	**b.** 1 年以上 3 年未満	**c.** 3 年以上 10 年未満
d. 10 年以上 20 年未満	**e.** 20 年以上 30 年未満	**f.** 30 年以上 40 年未満
g. 40 年以上 50 年未満	**h.** 50 年以上	

問 8-3　あなた地域での活動についてお聞きします。

(1) 現在あなたは長田小学校区で地域活動をしていますか

a. 防災福祉コミュニティ	**b.** 婦人会	**c.** 民生委員
d. 自治会	**e.** その他(　　　　　　　　)	

(2) 今後あなたは長田小学校区で地域活動を希望しますか

a. 防災福祉コミュニティ	**b.** 婦人会	**c.** 民生委員
d. 自治会	**e.** その他(　　　　　　　　)	

問 9

今回のアンケート結果、調査結果のご説明を兼ねて、皆様と共に防災について考える機会を設けたいと考えおります。また、再度アンケート調査を実施する予定でおります。このアンケート調査について、ご質問、ご意見など、または次回の調査に追加したい項目や勉強会で取り上げてほしいテーマがございましたら、ご自由にお書きください。

次回の調査

勉強会のテーマ

ご意見、ご質問など

以上で、調査は終わりです。ご協力ありがとうございました。