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A Diagnosis Model for Disaster Shelter Planning from the Viewpoint of Local People ----Case Study of Nagata Ward in Kobe City, Hyogo Prefecture, Japan

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Synopsis

This study presents a diagnosis model for shelter paining from the viewpoint of local people. This model is developed based on a questionnaire survey conducted in Nagata Elementary School Community of Nagata Ward, Kobe City, Hyogo Prefecture, Japan. It is shown that the proposed model can help local people with the assistance by disaster experts to plan shelter location and to assign people to respective designated shelters. Finally, illustration is made to demonstrate the applicability of the model with the help of GIS.

Keywords: shelter planning, participatory model, questionnaire survey

1. Introduction

Due to increasing preparedness and awareness of natural disaster, more and more countries have started to set up disaster shelters. For example, in Japan, salvation huts ("Osukui Goya" in Japanese) appeared in the Edo Period as the rudiments of disaster evacuation. Now in Japan, more than 1000 cities or wards have been set up as disaster shelters. In USA, after the 1999 tornadoes (on January 21, that year, 56 tornadoes struck Arkadelphia, Arkansan and on May 3, 68 tornadoes struck Oklahoma and Kansas), tornadoes and hurricane shelters have been set up in many states. To respond to the recent demand for community shelters, many guidelines for shelter planning have also been released. For example, in USA, the American Red Cross published a guideline for hurricane shelter selection in 1992, and the FEMA released the national performance for tornado shelter in 1999, and also developed the guidance for community shelters for hurricane evacuation shelter selection in cases of extreme wind events in 2000. In Japan, most of the prefectures have already released the guidelines for shelter management. In China, the regional standard of shelter planning has been published since the first disaster shelter was set up in Beijing in 2003 (Yang et al, 2004). Most of these guidelines are developed by the central or local governments or government-run disaster prevention organizations along with the involvement of experts and local community leaders' participation. However cases of involving local residents are still thought to be very few. Moreover the performance criteria for shelter planning against a specific disaster are not always identical from country to country, or even from province (prefecture) to province (prefecture) (Xu et al, 2006b).

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, Pine et al, 2003 and Kongsomsaksakul, et al, 2005). Xu et al (2006a) diagnosed the residents' assignment planning to current shelter by considering the accessible time and shelter capacity in Nagata Ward of Kobe City. Yamada et al. (2004) developed a shelter location planning support system by considering the shelter capacity, food storage and household characteristic. Takagi et al. (2006) attempted to develop evaluation indicators for shelter planning based on the questionnaire survey with the case study where most of the local people have no disaster experience. Yet only few research work has been conducted to study how to involve local residents in shelter planning. We note that the lessons learned from the Great Hanshin-Awaji earthquake in Japan in 1995 should be used as a reference case to analyze and solve the shelter planning performance criteria, location setting 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 jurisdictional areas of elementary schools ("Shogakko ku" in Japanese).

This study proposes a diagnosis model to assess the disaster shelter planning from the viewpoint of local residents based on questionnaire survey preformed in the case study area of the Nagata Elementary School Community, as a complement work of the shelter planning model developed by Xu et al (2007). This community which is located in the middle of the northern part of the Nagata Ward (of Kobe City, Hyogo Prefecture, Japan), was heavily damaged by the 1995 Hanshin-Awaji earthquake. More than 40% of people have experienced disaster evacuation in this area.

2. Questionnaire survey in the Nagata Elementary School Community

The Nagata Elementary School Community with a population of 9000 has a single designated accommodation disaster shelter, namely Nagata Elementary School (Nagata ES) and three designated secondary shelters, i.e., Takatoridai Middle School (Takatoridai MS), Nagata High School (Nagata HS), and Miyagawa Elementary School (Miyagawa ES). The leaders of local Disaster-prevention and Welfare Community and Women's Association are identified as key persons who serve as the bridges between researchers and local people in our questionnaire survey.

This questionnaire which consists of the heads of 50 households was carried out from July 21st to August 4th of 2006 (Fig. 1 shows the distribution of

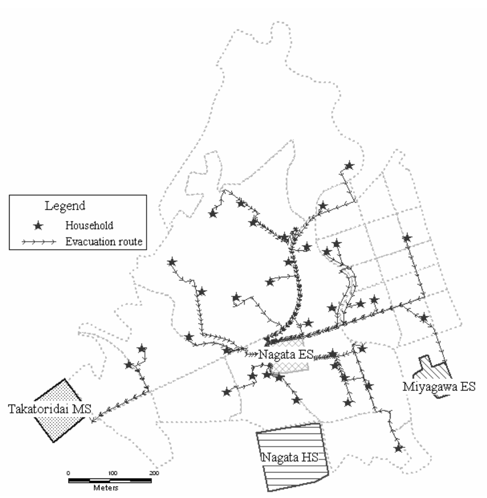


Fig. 1 The entire area of questionnaire survey in study (Nagata Elementary School Community)

the respondent households), and 100% response rate is attained. Among all the respondents, 70% were females and 92% have experienced some disaster(s). The specifics of the disaster shelter planning in the survey are listed in Table 1. By focusing on earthquake disaster shelters, 17 indicators such as shelter location safety, evacuation distance, evacuation road condition, lifeline maintenance service, and information support are specified by referring to the shelter planning indicators summarized by Tagaki (2006). Each indicator is denoted by one corresponding question (Table 1).

By using the AHP method (Saaty, 1980), these 17 indicators are grouped into six categories (criteria), namely, security, stability and continuity of lifeline service, accommodation capacity, conformability, accessibility to shelter, and connectivity to external resources and information (Table 1).

3. Shelter planning model from the residents' viewpoint in the Nagata Elementary School Community

3.1 Weights of the performance criteria for shelter planning

To help respondents' simply describe and answer, we use the verbal statements method by setting five options (five levels), namely "Strongly disagree" "Disagree" "Neither agree nor disagree" "Agree" "Strongly agree", which are denoted by "1", "3", "5", "7" and "9", respectively for calculation. Thus we

Table 1 Questions about shelter planning 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.	Easy to go to hospital and other facilities
		17.	Social support such as voluntary & consultation is received

Table 2 Weight of the performance criteria for shelter planning

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

use the paired comparison method to specify priority or relative importance of indicators and criteria. After that, priority weights of these criteria are calculated (Table 2). This way local people's relative preferences for the shelter planning criteria are specified. The larger the weight is, more preferred the criterion is.

3.2 Accommodation disaster shelter planning model

According to expression above, a shelter planning model can be written as

$$U_{ij} = u(S_{ij}, D_{ij}, C_{ij}, V_{ij}, A_{ij}, E_{ij}) \quad (1)$$

where i denotes household, j shelter, U_{ij} , the Evaluation Index, S_{ij}, D_{ij}, C_{ij}, V_{ij}, $A_{ij,}$ and $E_{ij,}$ the value of security, stability and continuity, capacity, comfortability, accessibility and connectivity criteria, respectively.

One of simple functions of the U_{ij} can be determined to take the following linear formula (2)

$$U_{ij} = w_s S_{ij} + w_d D_{ij} + w_c C_{ij} + w_v V_{ij} + w_a A_{ij} + w_e E_{ij} + \delta \quad (2)$$

where w_s, w_d, w_c, w_v, w_a and w_e are weights, and δ is a constant.

According to the questionnaire results and setting δ=0, formula (2) is identified as follows:

$$U_{ij} = 0.198S_{ij} + 0.189D_{ij} + 0.113C_{ij} + 0.108V_{ij} + 0.179A_{ij} + 0.212E_{ij} \quad (3)$$

Normally, 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 station). The objective of planning the shelter location or selecting the best location for a shelter is to maximize the total value of U_{ij} for all households, namely

$$\bar{U}_j = \underset{j}{Max}\left(\sum_i (0.198S_{ij} + 0.189D_{ij} + 0.113C_{ij} + 0.108V_{ij} + 0.179A_{ij} + 0.212E_{ij})\right) \quad (4)$$

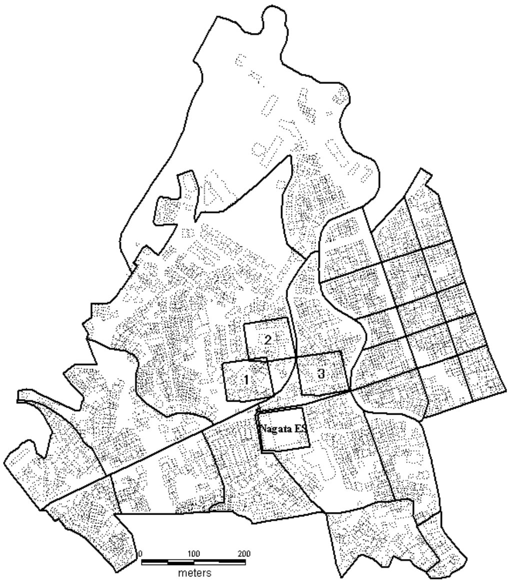


Fig. 2 Assumed shelter locations

While the objective of assigning the local residents to the designated shelter is to maximize the U_{ij} for each households, namely

$$U_{ij^*_{(i)}} = \underset{j}{Max}((0.198S_{ij} + 0.189D_{ij} + 0.113C_{ij} + 0.108V_{ij} + 0.179A_{ij} + 0.212E_{ij}) \quad (5)$$

As a result, we have concluded that the above identified categories coordinate well 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 Table 1).

3.3 Examples of using the model for shelter planning

In this part, two examples of using the diagnosis model for shelter planning are given by taking the case of Nagata Elementary School Community.

(1) Example of shelter local planning

As mentioned above, formula (4) can be used for selecting shelter location(s) or to evaluate the current shelter location. Since in the Nagata Elementary School Community, there is an existing accommodation shelter, we will take an example of evaluating the current shelter location.

Assuming that beside the existing shelter (Nagata ES), there are three locations (location 1, 2 and 3) are suitable for setting up the disaster shelter (Fig.2). The values of S_{ij}, D_{ij}, C_{ij}, V_{ij} and E_{ij}, which are obtained from the Nagata Ward Office, are set to be the same for each situation. Their weights are shown in Table 2, according to formula (4), the total value of U_{ij} of each situation is calculated. The results are given in Table 3.

Comparing these four situations, the total U_{ij} value for the current situation is found to be the smallest,

Table 3 U_{ij} value of household at each situation

U_{ij}	Location 1		Location 2		Location 3		Existing (Nagata ES)	
	No.	%	No.	%	No.	%	No.	%
≥0.45	183	4.06	228	5.06	233	5.18	168	3.74
0.40~0.45	322	7.15	280	6.23	373	8.28	365	8.12
0.37~0.42	1047	23.27	1053	23.39	487	10.81	859	19.09
0.35~0.37	1403	31.19	1622	36.05	1773	39.39	1279	28.41
<0.35	1544	34.32	1317	29.26	1635	36.33	1829	40.64
Average	0.366244		0.368243		0.36424		0.364049	
Total	1648.10		1657.09		1639.08		1638.22	

Table 4 Values and weights of the criteria for the designated shelters in Nagata Element School Community

Symbol	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

P_i: Number of people evacuating to the corresponding shelter while the differences are not so obvious. If the shelter location is shifted from the current situation to location 2 (the best one of these four situations), there is only an increase about 1.2% of the total U_{ij} value. Actually, the increase rate would be 2% if the current shelter is shifted to the optimal location. The acceptable location can be found for the case where the total U_{ij} value is optimal. If it is 5%, the current location of Nagata Elementary School is judged as acceptable.

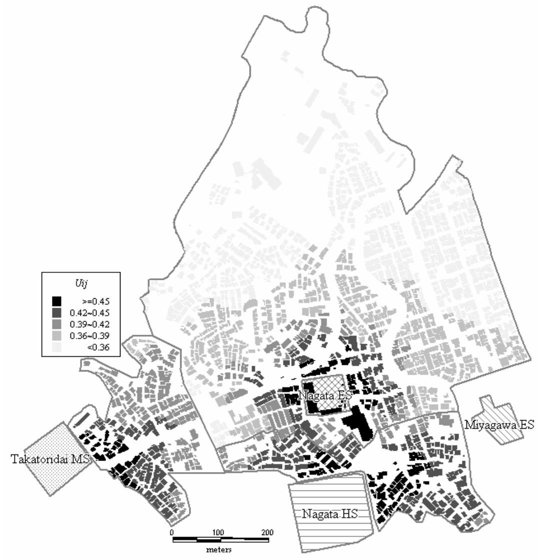
(2) Example of residents' assignment planning

Here, we will intend to consider how local people will prefer and best select their own shelter, given shelter locations designated.

There are four shelters in this community, and the values and weights of all criteria are set as shown in Table 4. According to formula (5), the evaluation index U_{ij} of each household is calculated.

Importantly a first glance tells us that there is a large difference found between the current assignment residents are assumed to follow at least officially (Fig.3(a)) and the revision assignment obtained from the viewpoint of local residents (Fig.3(b)).

The U_{ij} of household i for shelter j in Fig.3(a) corresponds to evacuation only to the Nagata Elementary School, just as prescribed by the local government's official shelter plan, and the U_{ij} of the household in Fig.3 (b) corresponds to the evacuation to the respective optimal shelters. In Fig.3 (b), each



(b) Evacuating to the respective optimal accommodation shelters

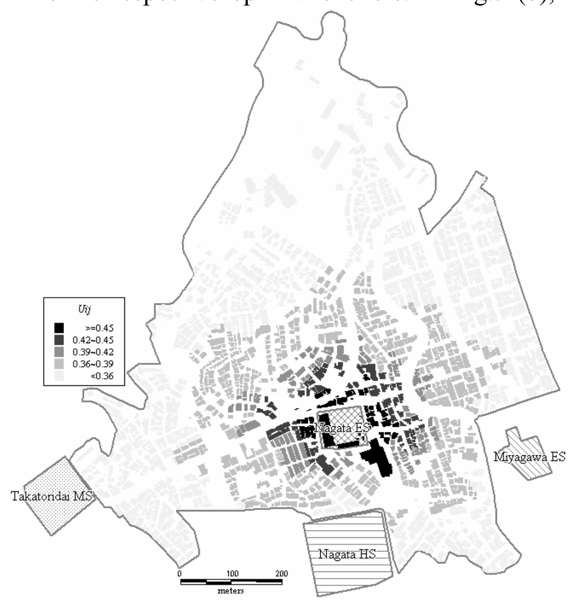
Fig.3 Assessment of evaluation results for index (U_{ij}) of households in Nagata Elementary School Community

household has the maximum value of U_{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, and they will evacuate to the Nagata HS; and the rest will evacuate to the Nagata ES.

In Fig.3(a), there are only 90 households (2% of total) whose U_{ij} values are larger than 0.45, while in

Fig.3(b) there are 320 households(7%). The number of households whose U_{ij} value is larger than 0.42 and larger than 0.39 as shown in Fig.3(a) is 280(6%) and 550 (12%) respectively, while in Fig.3(b) are 1120(25%) and 1900(42%) respectively. The number of households whose U_{ij} value is smaller than 0.36 in Fig.3(a) is 2520(56%), while in Fig.3(b) is 1510(34%). And the average U_{ij} value has a 7 percentage increase from 0.364 in Fig.3(a) and it increases to 0.389 in Fig.3(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 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 that evacuate to the Nagata ES and Miyagawa ES. At the same time, the evacuation distance of the



(a) Evacuation only to the Nagata Elementary School as prescribed by the official shelter plan reassigned households becomes shorter (Fig.3(b)). While four shelters, they have the same volume of prepared food and water sets, almost same available space to accept refugees, close value of security and connectivity criteria, and the same value of comfortability (Table 3). That is why in Fig.3(b), the U_{ij} value of household is larger than that in Fig.3(a). Though the evacuation distance of some households to Nagata ES is longer than of the Miyagawa ES, while the population evacuates to the latter shelter is also large, that is why in Fig.3(a), there is no household assigned to the Miyagawa ES.

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 U_{ij} value is only changed with A_{ij} according to the calculation rule set above. Households closer to the shelter have a shorter evacuation distance and higher A_{ij} value, with its U_{ij} value being also larger. That explains why in Fig.3(a) and in each sub-region of Fig.3(b), the households with the same U_{ij} value take on homocentric circles.

The maximum value U_{ij} of each household in both figures is no larger than 0.60. If we intend 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 we could even increase the accommodation capacity of designated shelters, which, however would require a full-scale revision of the current shelter plan developed by the local government.

4. Conclusion and discussion

In this paper, a disaster shelter planning model is proposed from the viewpoint of local people in the Nagata Elementary School Community of Nagata Ward, Kobe City, Hyogo Prefecture, Japan, with a focus on earthquake disaster. This proposed participatory model is found to be helpful for local people with assistance by disaster reduction experts to select their respective optimal shelter location or assess the existing shelter location, and to assign local people to the designated shelters.

As for the assignment of local residents to the designated shelters in Nagata Elementary School Community, there is a large difference found between the revision assignment obtained and the current assignment which residents are assumed to follow, at least officially. To validate the model for resident's assignment, and examine the differences between the two assignment cases, local residents' feedbacks were obtained via a workshop held in the case study area.
We note here that GIS-based presentation of the results of our model calculations are considered as an effective media of communication with local residents.

The following findings are itemized.

[1] In Fig. 3(b), the assignment area where residents are assigned to the Takatoridai Middle School is the same as the current assignment decided by the local residents.

[2] The area where residents are assigned to the Nagata High School does not meet with the current assignment well since most of the participants are familiar with Nagata Elementary School and some of them are the members of Disaster Prevention and Welfare Community or Women Association. They are voluntary organizations to help others in the Nagata Elementary School.

If the Nagata Elementary School is found unable to accommodate all the evacuees tentatively due to its limited capacity, some of them should be displaced to the Nagata High School for secondary evacuation. In fact this was precisely the case with what happened in the 1995 Hanshin-Awaji earthquake disaster.

Therefore, it is pointed out that local people's familiarity should also be considered as a modification of the participatory shelter planning model to help local residents' assignment to respective shelters.

For further research it is yet to illustrate how to use our diagnosis model and present people its results to help develop residents' evacuation, and to examine how to inform and assist them with reexamining their alternatives.

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住民の視点から見た避難所計画のための診断モデルに関する研究
—神戸市長田区長田小学校コミュニティを事例として

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要　旨

本論文は、神戸市長田区長田小学校区の地域コミュニティを対象に、地震災害を対象とした避難所計画のための診断モデルを提案した。本モデルを用いることにより、避難所の配置計画と住民の避難場所割り当て計画を支援することができることが示された。最後に、地理情報システムを使って本診断モデルの付加価値を高めることができることも例示した。

キーワード：避難所計画、参加型モデル、アンケート調査