A Model Analysis Approach for Reassessment of the Public Shelter Plan Focusing both on Accessibility and Accommodation Capacity for Residents - Case Study of Nagata Ward in Kobe City, Japan

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ABSTRACT

In this paper, we address the needs for reassessing and improving the implementability of the public shelter plan that has been completed exclusively by some local administrative bodies. Using a case study in Nagata Ward of Kobe City, Japan, we propose a simulation and GIS-based model approach to reassess implementability by focusing on residents' accessibility to nearby shelters and their accommodation capacity. The results show that there are significant differences in evacuation time among Cho-Chome community areas within Nagata Ward. It was also found that communities vary in accommodation capacity risk. Policy implications have been derived to identify suspect areas for further investigation and possible improvement, by way of promoting local residents agreement on their temporary shelters, and adding new designated shelters in appropriate locations. The paper concludes with a list of further research needed in order to integrate the proposed approach for implementation of the public shelter plan.

1. INTRODUCTION

When a disaster occurs, people who need to take refugee should be accommodated and protected in a shelter with disaster-robust conditions, such as stable ground, aseismatic structure, fireproof walls and lifeline support system. Due to increasing preparedness and awareness of disaster, more and more countries have started to set up disaster shelters. In Japan, more than 1000 cities or wards have set up disaster shelters (ANCE, 2005), and thus this disaster-prone country seems to be leading the world in disaster evacuation and shelter arrangement. In fact, local governments have long examined and decided the location of shelters as part of their disaster planning ("Bosai Keikaku" in Japanese).

In Japan most 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 refugees for recovery. The former type of shelter is called a "temporary (primary) shelter" and the latter type of shelter is called an "accommodation (secondary) shelter." In practice the above-mentioned designated shelters tend to be selected from commonly used public facilities and spaces such as elementary schools or public halls. In principle, they are determined by considering multiple functions of shelters required in the event of a disaster such as the distance to shelters, its capacity to accommodate potential refugees, etc. However, in actual administrative shelter planning, such systematic examination of multiple functionalities tends to be practiced rather implicitly, and not so systematically. Moreover, local details are often not well considered, which may affect implementablity (based on usability and executability by local residents) of designated shelters. Actual disasters that affected Japan after the Hanshin-Awaji Earthquake

Disaster have shown that such local focuses are often crucial to making the public plan implementable from the viewpoint of local residents.

For the above reasons, this paper proposes a preliminary model in order to eventually develop a systematic approach to this type of shelter planning problem.

2. CRITERIA DEVELOPED AND USED FOR CONVENTIONAL SHELTER PLANNING

In conventional shelter location planning, assuming different hazard types and shelter types, different countries have developed and used different criteria, including location security, route condition, service distance (or evacuation distance), and accommodation capacity (FEMA, 1998, 2000; Tokyo, 2000; Aichi, 2005; Beijing, 2004).

Regarding the evacuation distance, many researchers have discussed methods of selecting shelter locations and deciding their service areas based on, for example, the Voronoi Diagram approach (Kashiwabara *et al.*, 1998; Kamiya *et al.*, 2000; Hasobe 2005 and Morita *et al.*, 2004a). The recent development of both GIS and databases has increasingly advanced simulation technology, and evacuation routes can be considered when arranging the shelter location by using evacuation simulation methods (Shima *et al.*, 2002; Morita *et al.*, 2004b). The shelter accommodation capacity for determining the maximum number of people who take refuge is also considered when selecting shelter location and assigning residents to corresponding shelters (Yamada, *et al.*, 2004).

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3. SCOPING AND STRUCTURING OF THE PLANNING PROBLEM

We first assume that shelters are located and designated as official shelters in the publicized administrative shelter plan. This assumption is made because we will use a list of designated shelters as the outputs of an existing public shelter plan. Given such a list, the problem is to systematically assign potential victims (residents) from various neighborhood communities to the designated shelters characterized by their own conditions such as accommodation capacity as mentioned above. This assignment problem is to determine the optimal assignment of residents (potential refugees) to their shelter facilities as constrained by their respective accommodation capacity.

We will use the findings of the Hanshin-Awaji earthquake in Japan in 1995, as a reference case to derive policy implications for improvement of public shelter plans by formulating and analyzing our assignment planning problem. Nagata Ward of Kobe City, Hyogo Prefecture, which was heavily damaged during the Hanshin-Awaji earthquake, is composed of 94 Chos (403 Cho-Chomes) and has a population of 103681 (Jan.1, 2006)(Nagata Ward, 2006).

During the Hanshin-Awaji earthquake, there were about 70 accommodation shelters in Nagata Ward, while now there remain only 25 designated accommodation shelters (Nagata Ward, 2005a) (**Fig. 1**). The residents who are supposed to evacuate from each Cho-Chome to designated shelters are also determined nominally by the local government based on the elementary school area (Nagata Ward, 2005b). In this paper, we 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, we examine the evacuation time and accommodation capacity of each designated shelter in Nagata Ward of Kobe City, Hyogo Prefecture, Japan.
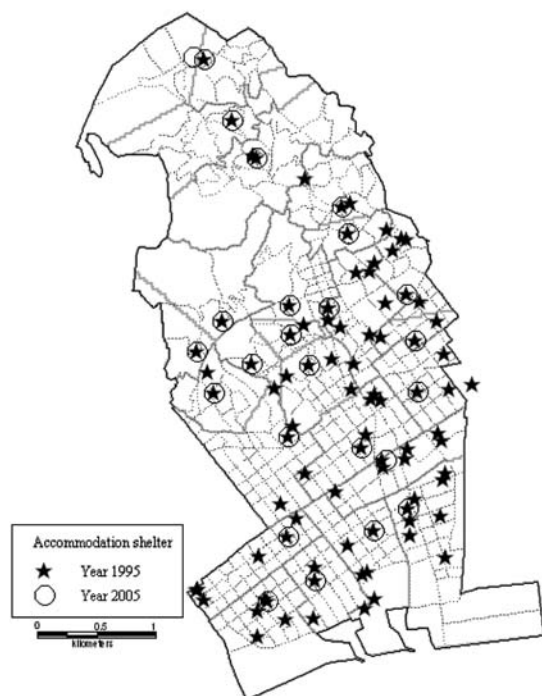
4. ANALYSIS OF THE PLAN OF RESIDENTS' ASSIGNMENT TO THE DESIGNATED SHELTER IN NAGATA WARD

4.1 Evacuation Time Analysis
1) Calculation of Evacuation Time

Evacuation time, which is calculated by dividing the evacuation distance by the evacuation velocity, is one of the most important indicators for evaluating the performance level of a resident taking refuge immediately after a disaster occurs.

Evacuation means (evacuation mode) is one of the main factors affecting 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 route status (conditions such as road width, road surface, slope, and barrier), refugees (gender, age, and physical status) and weather, etc., can also affect the evacuation speed.

As for road conditions, the Ministry of Construction, Government of Japan (1997) set the standard that roads that are narrower than 4 meters are considered inappropriate as evacuation routes, and the National Institute of Occupational Safety and Health, Japan (2002) specified the evacuation speed of people for different road surfaces and slopes based on experiments.

Accordingly, in this paper we assume:
  ・ 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[1] for adults when the slope of the evacuation route is flatter than 10 degrees; and 0.80m/s and 1.10m/s[1] respectively when the slope is steeper than 10 degrees.

Based on the above assumptions, we developed a GIS-based simulation model to calculate the shortest evacuation time of each household to the designated shelter, along available routes, in accordance with the designated assignment plan developed by Nagata Ward, Kobe City. The thus calculated shortest evacuation time is averaged over all households located in the given area of the ward. The averaged shortest evacuation time for each area is simply called the "evacuation time of households (residents) in the area".

Thus, the map of the evacuation time of households in each Cho-Chome (**Fig. 2**) is developed with the help of GIS in this area, based on the designated shelter plan (2005).

2) General Findings

In the entire Nagata Ward, the evacuation time of households in 155 (38%) Cho-Chomes is less than 5 minutes (bright areas), in 184 (46%) Cho-Chomes it takes on a value ranging between 5 minutes and 10 minutes, and in 16 (4%) Cho-Chomes is longer than 15 minutes (gray areas) (**Fig. 2**). Those households with shorter evacuation time are found to be mainly concentrated in the middle area of the ward.

Fig. 1 Accommodation shelters in Nagata Ward in 1995 and 2005

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[1] The data for adults are obtained according to on-site experiments conducted by the authors and local people.
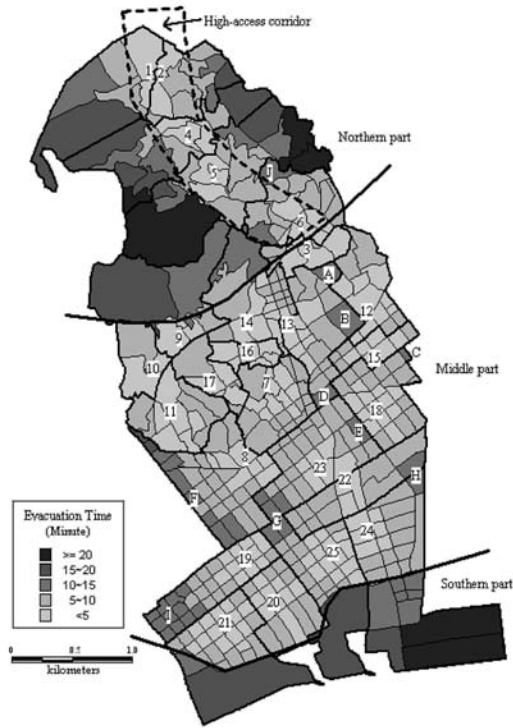
Fig. 2 Evacuation time of households in each Cho-Chome of Nagata Ward according to the designated shelter plan in 2005
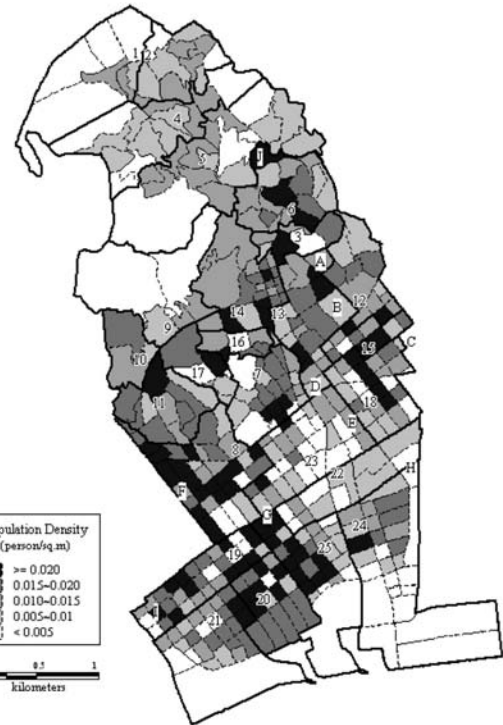

Fig. 3 Population Density of each Cho-Chome of Nagata Ward in 2005

3) Findings and Implications of the Middle Area

In the middle area, the evacuation time of 90% households is less than 10 minutes. There are, however, such light gray areas with an evacuation time longer than 10 minutes Most of them are found to distribute over the Cho-Chome areas of A, B, C, D, E, F, G, H, all of which belong to the Middle Area (**Fig. 2**). In area B where Hyogo Prefectural Minatogawa High School is located, and in area F which is an open area, population density (**Fig. 3**) is very low (almost no people live there at night).

This implies that in order to reduce evacuation time here it might be worth considering additional use of some already built nearby public places (schools or open spaces) at least as temporary shelters. If intended to be used mainly for temporary sheltering, selection of the most appropriate shelter can be best made by local residents under the guidance of the local government.

Areas 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.)

Although in areas A, C, D, E and G, the population density is moderate or low (**Fig. 3**), it takes households in these areas longer to evacuate. Their evacuation risk is found to be relatively high but less than in area F.

Therefore, in terms of evacuation time, there are significant differences found among Cho-Chome community areas within Middle Nagata Ward. Although based on very simplified assumptions, this analytical finding prompts us to question whether this status should remain unchanged and whether such a gap among community areas is acceptable in light of equity. We should probably discuss this issue and proceed step-by-step.

First, it would be wise for respective communities, particularly

high evacuation risk areas to take this occasion to mutually examine whether there are any safe and secure commonly usable places for temporary sheltering, which may not necessarily mandate administrative commitment in official designation. Actually during the Hanshin-Awaji earthquake, other shelters were used in or close to these areas. Areas both F and I are characterized by high population density and a relatively long evacuation time for households. Obviously it is highly recommended for both local residents and local government to work together to meet such a challenge.

Secondly, in a longer term, we recommend that the local government sets more explicit criteria including the allowable range of evacuation time varying among communities, and to present a more accountable procedure to administratively determine further improved public shelter and evacuation planning and management.

4) Findings and Implications of the Southern Area

In the southern part of the ward, almost all of the Cho-Chome communities are found to be situated far away from shelters, and the evacuation time of households in this area is very long since these areas are far away from designated shelters. However, this area is a port area with very low population density. This explains why there was no designated shelter located around, or newly set up even during and after 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. Note that there are many people engaged in port and harbor businesses and that their business continuity plan and management including their employee's evacuation are equally important. But this is beyond the scope of this research.

5) Findings and Implications of Northern Area

In the northern part of the ward, a "high-access (blank) corridor" is benefited by those households with short evacuation time.

They are located near shelters No. 1, 2, 4, 5, 6, and 3, and households who have long evacuation time are located on both sides of the corridor. The gray color areas are all hilly areas with lower population density except area J, and there are no shelters found in their vicinity. It may be appropriate to leave it as it is since there is no significant increase expected in population. As for community J, it is recommended to determine their own temporary shelter in their vicinity, under the guidance of the local government.

4.2 Shelter Accommodation Capacity Analysis

Shelter accommodation capacity is another important factor to be considered in developing appropriate shelter planning. In our modeling, the following assumptions are made. The accommodation capacity of a shelter can be measured by the maximum acceptable number of refugees, which is 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. One quick calculation method for measuring the acceptable number of refugees for a shelter is 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, we refer to 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, $2.5m^2$/person in Nihonmastu City (2006) of Fukushima Prefecture, Japan, and $1.86m^2$/person for hurricanes in the USA (FEMA, 2000). In the following analysis, we will primarily use the standard of living area per capita of Higashiyamato City of Tokyo, Japan ($1.65m^2$/person) to calculate the maximum acceptable numbers of refugees. Complementarily we will also use another three capacities for comparison in 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 Nagata Ward, and we denote it as C_1.
· 1995-base-year official record accommodation capacity of shelter - estimated by the numbers of refugees accommodated to each shelter on Feb.1st, 1995 (Kashiwabara, *et al.*, 1998). It is the minimum of the already experienced accommodation capacity, and we denote it 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 the necessary living area per capita ($1.65m^2$/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

a refuge zone[3] including non-designated informal shelters used in 1995. It is the maximum of the already locally experienced accommodation capacities, and we denote it as C_4.

Based on the above four types of shelter accommodation capacity indices, we propose the following four types of shelter accommodation capacity risks (**Table 1**).

Type I - the 2005-base-year estimated accommodation capacity (needed) is found to be the largest. This corresponds to the case of the highest capacity risk in terms of high probability of overcrowding and inability to cope with disaster, particularly in secondary sheltering.

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 is smaller than 1995-base-year official/non-official record accommodation capacity. This corresponds to 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. The corresponding case is that of a moderate accommodation capacity risk.

Type IV - the 2005-base-year estimated accommodation capacity is the smallest. This is the case of a relatively low accommodation capacity risk.

Accordingly we have derived the four types of cases in capacity risk for the designated shelters in Nagata Ward (**Table 2**).

From **Table 2**, we find that 18 (72%) shelters belong to type III, and 5 (20%) to type IV, which have a relatively low accommodation capacity risk. Shelters No. 1, 2, 3, 4, 5, 6, 9, 10, 11, 12 and 14 are located in areas that suffered small percentage house damage during the 1995 Hanshin-Awaji earthquake disaster, and the ratio or the total number of residents who took refuge is very low or small, so their 1995-base-year official record accommodation capacity and 1995-base-year official/non-official record accommo-

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[2] 40%, the percentage of population that took refuge during the Hanshin-Awaji earthquake in 1995 in Nagata Ward. Numbers of refugees were 55641 at the peak time (http://www.city.kobe.jp/cityoffice/09/010/shiryokan/earthquake/earthquake04.html), and total population is 129,978 (http://www.city.kobe.jp/cityoffice/06/013/toukei/contents/tyoubetsujinkou.html). Here, we assume that residents will only evacuate to their designated shelters.

[3] The whole area where all the people locate should take refuge to a designated shelter which was set by local government in 2005.

Table 1 Shelter accommodation capacity risks

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 shelters & 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 shelters
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 shelters
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 and III, and it is taken for type III.

Table 2 Accommodation capacity and type of shelters in 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	Maluyama 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	Nagataku Elementary School	1720	3000	2480	3450	IV
22	Nagata Middle School	1020	600	1850	2760	III
23	Nagata Southern Elementary School	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; C_2: 1995-base-year official record accommodation capacity; C_3: Affordable area-based accommodation capacity; C_4: 1995-base-year official/non-official record accommodation capacity. Unit: person.

dation capacity are estimated to be very small from this analysis. There is one shelter of type I - Hasuike Elementary School (No.8) and one shelter of type II - Miyagawa Elementary School (No.13), and households in both areas F and D with high evacuation risk (as mentioned in the foregoing discussions) are located in the refuge zones of these two shelters, respectively (**Fig. 4**). Suppose alternatively such a scenario that the population density data in 1995 (after the Hanshi-Awaji earthquake) is used, the 2005-base-year estimated accommodation capacity (needed) will become less than both the affordable area-based accommodation capacity and the 1995-base-year official/non-official record accommodation capacity of these two shelters, and they will move down to type III - low accommodation capacity risk. The population density has been, however, increasing since then, which was the scenario based on our above analysis. So plausible advice is to make more comprehensive investigation and analysis to examine whether these two areas need to set up another designated secondary (accommodation) shelter.

5. CONCLUSIONS AND DISCUSSIONS

5.1 Conclusions

This paper presents a simulation and GIS-based model approach to reassess implementability by focusing and detailing both residents' accessibility to the nearby shelter and its accommodation capacity. The main calculation results show that there are significant differences found in evacuation time among Cho-Chome community areas within Nagata Ward. It was also found that communities vary in accommodation capacity risk. Policy implications have been derived to spot suspect areas for further investigation and possible improvement, by way of promoting local residents to agree on their temporary shelters, and adding new designated shelters in appropriate locations.

5.2 Discussion

The proposed approach is at a preliminary stage and further research is needed in order to integrate the proposed approach for implementation of the public shelter plan. The presented approach and its analytical results are based on a set of assumptions and simplifications and thus care should be taken in leading to policy
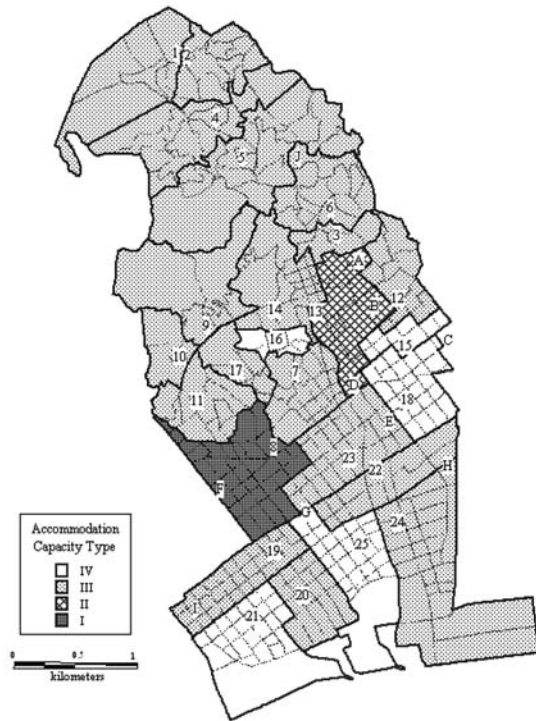
Fig. 4 Shelter accommodation capacity type in 2005

implementation. Despite reservations, this paper provides significant policy implications and clues to the refinement and reassessment of public shelter plans already completed and put in place.

Continued follow-up and extension of this research such as highlighting perceptions and the behavior of residents who evacuate is required. It is also important to set forth a more integrated planning and management framework for safe and secure evacuation.

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