World Academy of Science, Engineering and Technology
International Journal of Humanities and Social Sciences
Vol:7, No:8, 2013

Comparative Analysis of Measures to Secure Two-Way Evacuation Routes for Vulnerable People during Large Disasters in a Historic Area

Nobuo Mishima, Naomi Miyamoto, and Yoko Taguchi

***Abstract*—**Historic preservation areas are extremely vulnerable to disasters because they are home to many vulnerable people and contain many closely spaced wooden houses. However, the narrow streets in these regions have historic meaning, which means that they cannot be widened and can become blocked easily during large disasters. Here, we describe our efforts to establish a methodology for the planning of evacuation route sin such historic preservation areas. In particular, this study aims to clarify the effectiveness of measures intended to secure two-way evacuation routes for vulnerable people during large disasters in a historic area preserved under the Cultural Properties Protection Law, Japan.

***Keywords*—**Historic preservation, evacuation route analysis, vulnerable people, street blockade.

I. Introduction

A. Background

EVACUATION induced by large disasters, including both natural and manmade events, causes complex problems that must be solved while taking many factors into account. Many previous studies have highlighted the necessity of developing appropriate systems to ensure the safe evacuation of vulnerable people during disasters [1], [2].In particular, it has been noted that shelters and safe places must be established, and evacuees notified of their locations in advance, in order to reduce evacuation-related risks and costs [3]. Furthermore, evacuation zones must be established before disasters occur [4].

Approaches to their search of evacuation route planning can be grouped into several categories. Studies investigating the behavior of evacuees have analyzed the effects of different behavioral and managerial factors on evacuation [5]–[7], the velocity of walking on stairs [8],and the effects of merges on staircases and the ease of merging under various conditions [9].

Nobuo Mishima is at Saga University, Saga, 840-8502 Japan. (phone: +81-952-28-8703; fax: +81-952-28-8703; email: mishiman@cc.saga-u.ac.jp).

Naomi Miyamoto was a Masters student at Saga University, Saga, 840-8502 Japan. She is now with the Fukuoka branch of Land Brain Co., Fukuoka, 810-0001 Japan (email: naomi0627_com@yahoo.co.jp).

Yoko Taguchi is with the Graduate School of Science and Engineering, Saga University, Saga, 840-8502 Japan, on leave from the Yonago, Japan (email: ytaguchi@cc.saga-u.ac.jp).

This study has been supported by a Grant-in-Aid for Scientific Research (C) of the Japan Society for the Promotion of Science since April 2009 (representative researcher: Mishima), and by the Program for Promoting Methodological Innovation in Humanities and Social Sciences by Cross-disciplinary Fusing (representative researcher: Prof. Dr. Kitagawa, Saga University) of the Japan Society for the Promotion of Science since October 2009.

Surveys have been conducted to analyze residents' perceptions of volcanic hazards [10], to clarify the risks of and reasons for evacuation [11], and to assess tourists' perception of hurricanes based on forecasts [12]. Algorithms and programming methods have been developed to generalize optimal evacuation plans, e.g., models for the analysis of building evacuability [13], mathematical modeling to simulate evacuation problems [14], GIS-based maps of evacuation choices during earthquakes [15], the new multiagent system (Sim Tread) for calculation of the shortest walking time [16], and an evacuation simulator [17]. Finally, evacuation times have been evaluated to determine optimal routes, and decision support systems have been implemented in evacuation planning. Previous studies conducted in this regard include the evaluation of an evacuation plan using a microscopic simulation model [18], analysis of smoke exhaustion and evacuation time in the arcade of a traditional Korean market [19], the development of a heuristic method with an incremental data structure that uses real-world scenarios [20], and a network optimization approach to addressing problems with evacuation planning at short notice [21].

However, historic preservation areas are among the areas most vulnerable to disaster, because many elderly people live in such areas in closely spaced wooden houses. Previous studies have investigated a disaster prevention plan for protection of the traditional buildings of Kanazawa City, Japan [22], and have assessed increases in local safety due to the shortening of evacuation routes in Senbon-syaka-do in Kyoto, Japan [23]. Streets in these areas can be narrower than 4 m, and it can be difficult to widen these streets while maintaining their historic value. Accordingly, these streets can easily become clogged or blocked during large disasters such as great earthquakes and large fires, which can destroy buildings and block exits. If the preferred evacuation route becomes blocked, residents must evacuate by other routes. Therefore, securing two-way evacuation routes for each house is one of the most critical aspects of disaster prevention for people living in historic preservation areas. However, this must be achieved while maintaining the narrow widths of the paths. A previous study investigated the effectiveness of historic wooden back doors in Kyoto [24]. Moreover, in a previous study [25], we assessed evacuation routes in a historic preservation area in Japan by conducting intensive interviews with its residents. Based on the results, we were able to propose a procedure for evacuation route planning for the study area. Our results indicated that maintenance of the open space at the center of the study area is a useful method for improving evacuation routes from each house to a primary evacuation place [25]. However, it is neither clear nor easy to plan routes and solve the extensive problems inherent insecuring two-way evacuation routes. To address this and maintain the historical value of the area, several measures must be analyzed comparatively.

B. Aim

This study aims to comparatively analyze measures for securing two-way evacuation routes for a historic preservation area, focusing on the occurrence of large earthquakes in which houses may be easily destroyed and streets may be blocked.

II. Methodology

A. Study Area

Our study area is Hamashozu Machi Hamakanaya Machi, which is located in Kashima City, Saga Prefecture, and has been designated an important preservation district of traditional buildings under the Act on Protection of Cultural Properties, Japan. The study area is a local town near the mouth of the Hama River, which flows to the Ariake Sea. The town is characterized by straw- and tile-roofed wooden townhouses that run along narrow streets and the Nagasaki Road, which was built in the Edo era to connect Kokura and Nagasaki (see Figs. 1 and 2).

In 2010, to preserve the characteristics of this area, the Kashima city authority enacted a relaxation ordinance for the building standard law in 2010 with the aim of preserving the characteristics of this area. Space was made available for the quasi-fire prevention area by bringing about changes in city planning. The ordinance led to the relaxed regulation of roof structures and imposed restrictions on the parts of building that encroached streets; these regulations and restrictions were realized by adopting alternative methods such as providing two exits for each traditional house. Additionally, two-way evacuation routes from each house to a designated final evacuation place are advisable, though such routes have not been recommended in the ordinance.

B. Previous Study

In a previously submitted paper [25], we calculated evacuation time from each house to a primary evacuation place via a temporary safe place. Moreover, we presented the effects of maintaining the open space in the preservation area, which comprisesa wetland known as “Gaboi,” taking into account the results of analysis of current evacuation routes.

C. Present Study

In the present study, we compare the calculated evacuation times for the current evacuation routes and discuss two measures that solve some of the problems associated with current evacuation routes. The first of these measures is the maintenance of open space at the center of the study area, as we have discussed previously; we refer to this as Measure I. Measure II takes Measure I into account but also assesses improvements in the exits of each house, considering whether the original form of traditional houses has been affected, especially on façades that can be seen from public streets. Measure II does not need to be assessed for nontraditional houses. We also compare potential blockades of the streets in the study area (Fig. 3). Incidentally, in our previous study, we presented only cases without blockades and with a blockade along path B. The previous study has shown that the maintenance of open space at the center of the study area can decrease the evacuation time for nonvulnerable people and vulnerable people who can walk (here, called vulnerable people I). Here, we focus on the simulation of cases involving vulnerable people who cannot walk without help (vulnerable people II).

Fig. 1 A narrow street with straw-roofed houses in the study area

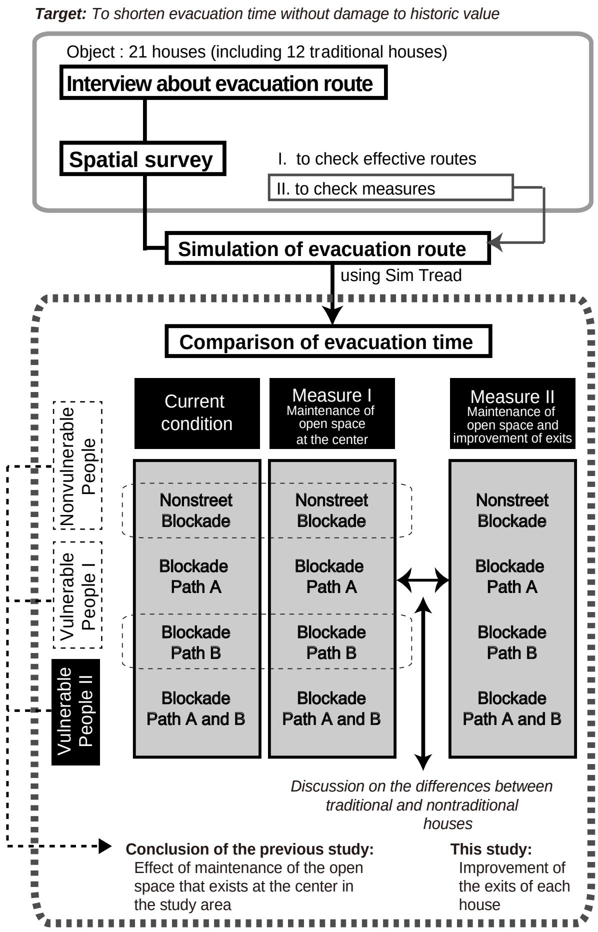

Fig. 2 Methods for the present study and their relationship to previous research

D.Analysis Methods

We use a multiagent system known as Sim Tread, which can calculate walking time in a three-dimensional model considering the spatial characteristics of the study area, including heights of windows and steps and widths of walkway. We set virtual walkers at the exits of each object house in the categories of simulations as nonvulnerable people, vulnerable people I, and vulnerable people II in order to grasp the evacuation time required for the routes from their respective houses to the temporary safe place. We calculate evacuation time from each house to a primary evacuation place through a temporary safe place by this simulation.

Normal walking speeds are as follows:

Nonvulnerable people 1.30 m/s

Vulnerable people I 1.00 m/s

Vulnerable people II 0.50 m/s

The velocity of nonvulnerable people is based on Japanese verification methods for determining safe evacuation of a floor and building; these methods were recently introduced to evaluate the ability of residents to evacuate buildings in Japan. The velocity of vulnerable people is determined based on [26]. Based on a previous study [16], we consider the walking velocities of each group on stairs to be half their respective normal velocities.

E. Consideration of Barriers in the Study Area

Many barriers exist in the study area, and these create obstacles for people. We set the velocities of walking around these barriers by considering current conditions; for example, we assess narrow spaces between buildings, the Gaboi wetland (which is overgrown with weeds and overflows easily in response to rain because a watercourse flows to the study area from an area of highland nearby), and high windows. The velocities around these barriers are determined through a fire drill and experiments. In terms of surmounting barriers, the upper limits of vulnerable people I and IIare500 mm and 400 mm, respectively. Therefore, vulnerable people must use a stool or break walls to pass obstacles greater than 500 mm or 400 mm in height, i.e., they must evacuate in two movements. The time taken for people to achieve such changes in height is presented in Table I. The walking paces of nonvulnerable, vulnerable I, and vulnerable II people in the wetland are0.1 m/s, 0.02 m/s, and 0.01 m/s, respectively. The pace of walking is slowed by spaces narrower than 600 mm, and people cannot pass through spaces of 300 mm or less. Thus, the velocity is defined as

$$V = (2w - 600)/600 * V0. \qquad (1)$$

Here, V0 represents the pace of walking and w the width of the narrow space. Additionally, people tend to open windows or doors when existing. Accordingly, we set a fixed time for exiting for our simulation: 2 s, 3 s, and 4 s for nonvulnerable, vulnerable I, and vulnerable II people, respectively.

III. Temporary Safe Places and Exits for Evacuation Routes

A. Residents' Perceptions of Evacuation Routes

Before simulation of evacuation routes, we assess residents' perceptions of two-way evacuation routes to understand where they exit their houses from and where their temporary safe places are during evacuation in response to a large-scale earthquake. We conduct interviews with 21 residents in the study area (Fig. 4; Table II).

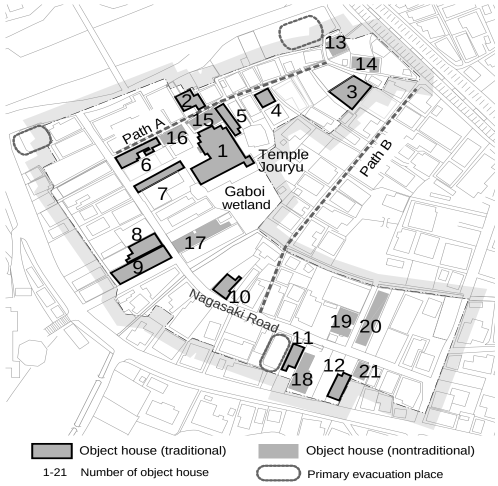

Fig. 3 Setting of the study area

TABLE I
Walking Velocities Based On Differences In Level

	Time (s)	Nonvulnerable		Vulnerable I		Vulnerable II	
		Up	Down	Up	Down	Up	Down
	Height (mm)						
Difference	0<h≤100	0.3	0.25	1.5	1.25	3.0	2.5
	100<h≤200	0.6	0.5	3.0	2.5	6.0	5.0
	200<h≤300	0.7	0.75	3.5	3.75	7.0	7.5
	300<h≤400	0.8	0.9	4.0	4.5	8.0	9.0
	400<h≤500	1.2	1.4	7.0	7.5	14.0	15.0
	500<h≤600	1.6	1.9	8.0	9.0	16.0	18.0
	600<h≤700	2.0	5.0	8.0	9.0	16.0	18.0

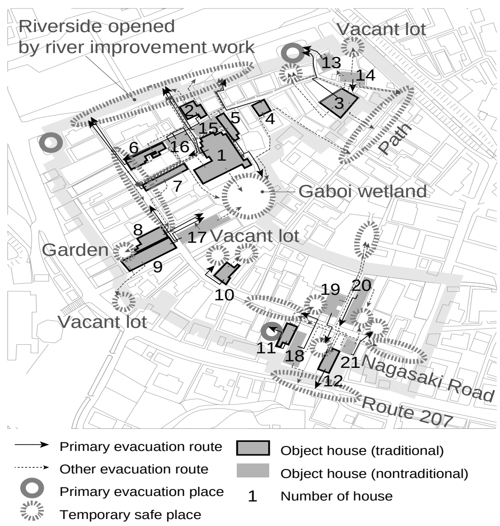

Fig. 4 Temporary safe places based on residents' perception

B. Problems Associated with Exits on Evacuation Routes

Table II illustrates the problems associated with exits on evacuation routes, as perceived by residents. One high window of a traditional house exists on the primary evacuation route, and a total of eight exist on the other routes. Four nontraditional houses are present on the other routes.

In the case of nontraditional houses, it is easy to address the heights of windows by altering them to form low windows or normal exits, because such buildings have no historical meaning. However, it is difficult to make improvements to traditional houses without affecting their historical value.

TABLE II
RESIDENTS' PERCEPTIONS OF EVACUATION ROUTE

Building Type	No.	Evacuation routes obtained by interviewing residents			
		Primary route	Second route	Third route	Fourth route
Several Traditional Buildings	1 Temple Jouryu	From the main exit of the main building to the open space of the riverside	From the main exit to Nagasaki Road	From the engawa to the Gaboi wetland	From the window of the restroom to Gaboi wetland
Single Traditional Building	2	From the main exit to Nagasaki Road or to the temple	From the high window to the street behind	From the high window to the neighbor's parking space	-
	3	From the main exit to the Hama River	From the back door to the front between the buildings	From the engawa to the Gaboi wetland	-
	4	From the main exit to the neighbor's parking space, along the path	From the high window to the street of the Gaboi wetland	From the second-floor window to the neighbor's house via the roof	-
	5	From the back door of the kitchen to the Gaboi wetland	From the main exit to Nagasaki Road or to the riverside	From the side door to Nagasaki Road through the neighbor's property	-
	6	From the main exit to the bridge or to the front parking space	From the side door to the Hama River	From the back door to the front street between the buildings	-
	7	From the front of the house to the bridge over the Hama River	From the side door to the Hama River through the temple approach	Break through the neighbor's wall and go outside	-
	8	From the main exit to the front parking space	From the back door to the back yard	-	-
	9	From the main exit to the front parking space	From the back door to the vacant lot of the neighbor	Jump from the second-floor window to the outside	-
	10	From the main exit to the neighbor's vacant lot	From the back door to the garden	From the engawa to the garden	-
	11	From the back door to the neighbor's vacant lot	From the engawa to the neighbor's vacant lot	From the main exit to the front neighbor's parking space	From the side window to the street through the neighbor's lot
	12	From the back window to the opposite side of the street	From the main exit to the neighbor's vacant lot	From the engawa beside the main exit to the front street	-
Nontraditional Building	13	From the main exit to the Hama River	From the low window to the Hama River	Several high windows may be used with difficulty	-
	14	From the main exit to the street	From the door to the back vacant lot	From the engawa to the neighbor's garden	From the side window to the open space of the Hama River
	15	From the main exit to the open space of the Hama River through the path	From the door of the kitchen to the parking space beyond the street	From the side window to Nagasaki Road through the temple approach	From the window of the bathroom to the neighbor's garden
	16	From the main exit to Nagasaki Road	From the engawa to the front yard of the Temple Jouryu	From the back door to Nagasaki Road through the temple	-
	17	From the front exit to Nagasaki Road	From the side door to the parking space	From the back door to the Gaboi wetland	-
	18	From the main exit to Nagasaki Road	From the engawa to Road 207	From the back door to the neighbor's lot	From another back door to the neighbor's vacant lot
	19	From the main exit to the front vacant lot	From the high window to the back vacant lot	-	-
	20	From the main exit to the front street	From the high window to the vacant lot	-	-
	21	From the main exit to the front open space	From the back door to the front street	From the high window to the street	-

			Primary route	Second route	Third route	Fourth route
Number of Evacuation Routes	Route		20	12	6	1
	Route	Subtotal	0	4	4	0
		From the engawa	0	3	4	0
		From low window	0	1	0	0
	Route	Subtotal	1	5	6	4
		From high window	1	4	4	4
		Through buildings	0	1	2	0
	Route		0	0	2	0
	-		0	0	3	16
			21	21	18	5
Total						65

Route A route without problems

Route A route with small difficulties (e.g., a high step or a route through another building)

Route A route with large difficulties (e.g., from a high window, between buildings)

Route An impossible route (e.g., from the second floor via the roof)

Note: An engawa is a type of veranda that is typical of Japanese houses and is generally located between the garden and the guest room.

C. Improvement of Exits

To compare evacuation time required for the current evacuation routes with those determined taking the two measures into account, we first propose a method of improving exits in order to shorten evacuation time from each house to a primary evacuation place.

1) Traditional houses: We improve only the high windows on the back (i.e., those that do not face onto the public street) by converting them into lower windows. The high window and the engawa (a form of veranda that is typical of Japanese houses and is often located between the garden and the guest room; Fig. 5) and the windows on the front are not altered owing to the historical significance of these houses.

Fig. 5 An example of the engawato be preserved

2) Nontraditional houses: We improve all of the high windows, not only those on the back (Fig. 6). If the house is landscaped according to the traditional style, the exit should also be designed according to the traditional form.

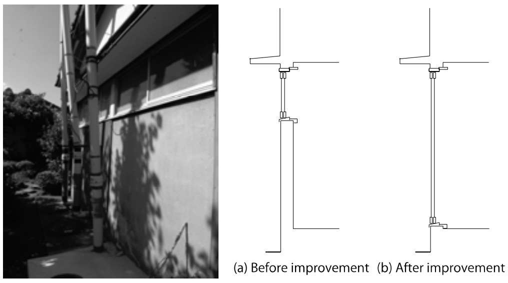

Fig. 6 An example of improvement of the exit for a nontraditional house

IV. Results of Analysis of Evacuation Time

A. Category of Evacuation Time

Evacuation times are categorized into under 7 minutes, under 10 minutes, and over 10 minutes; these particular times are chosen because fire engines can arrive at the study area within 10 minutes of the initial fire alarm.

B. Analysis of Evacuation Time

Evacuation time in each case, without or with blockade of paths A and B, is calculated as shown in the figures in the appendix of this paper (Table III). The information presented in Table III can be summarized as follows.

1) *The placement of the blockade influences evacuation time. If path A is blocked, the evacuation time for the primary evacuation route is slightly longer than that without the blockade. This is due to that the walkers who take the routes through the Gaboi wetland have changed to take roundabouts.*
2) *Measure I is effective in shortening the evacuation time, except with blockades of path A or both paths.*
3) *Measure II can shorten evacuation times only in some instances. The agent changes the primary route to ensure exit from the back of the house if path A is blocked.*

V. Discussion and Conclusions

The effects of improving high windows are limited in comparison to the benefits achieved by maintaining the open space at the center of the study area. Our proposed measures for improvements in evacuation route planning are respectful of the historic nature of our study site, yet still effective in assisting vulnerable people who cannot walk without help, although our methods do involve some limitations.

In order to ensure preservation of the study area, it is important to develop a mutual aid system in which the status and characteristics of vulnerable people (e.g., where they sleep, their evacuation plan, and the conditions of their houses) can be assessed.

TABLE III
Residents' Perceptions of Evacuation Route

			Primary route			Other routes		
			Under 7 min	7 to 10 min	Over 10 min	Under 7 min	7 to 10 min	Over 10 min
Without blockades	Current conditions	Trad	9	1	2	13	5	5
		Non	6	3	0	12	3	4
		Total	15	4	2	25	8	9
	Measure I	Trad	9	3	0	14	8	1
		Non	6	3	0	12	4	3
		Total	15	6	0	26	12	4
	Measure II	Trad	9	3	0	14	8	1
		Non	6	3	0	14	4	1
		Total	15	6	0	27	12	2
With blockade of path A	Current conditions	Trad	6	6	0	14	3	7
		Non	3	5	1	10	3	5
		Total	9	11	1	24	6	12
	Measure I	Trad	6	6	0	14	5	5
		Non	3	5	1	11	4	3
		Total	9	11	1	25	9	8
	Measure II	Trad	6	6	0	14	5	5
		Non	3	5	1	11	5	2
		Total	9	11	1	25	10	7
With blockade of path B	Current conditions	Trad	9	1	2	13	1	10
		Non	5	0	4	11	0	7
		Total	14	1	6	24	1	17
	Measure I	Trad	9	3	0	14	3	7
		Non	5	0	4	11	1	6
		Total	14	3	4	24	4	13
	Measure II	Trad	9	3	0	13	3	7
		Non	5	0	4	12	1	5
		Total	14	3	4	25	4	12
With blockade of both	Current conditions	Trad	7	3	2	13	0	11
		Non	4	1	4	9	2	7
		Total	11	4	6	22	2	18
	Measure I	Trad	7	3	2	15	1	8
		Non	4	1	4	10	3	5
		Total	11	4	6	25	4	13
	Measure II	Trad	7	4	1	15	1	8
		Non	4	1	4	10	3	5
		Total	11	5	5	25	4	13

Trad: Traditional house Non: Nontraditional house

APPENDIX

A. Results of Simulations without Blockades

Here, we present the results of simulations for cases with blockades for the primary (Fig. 7) and other (Fig. 8) evacuation routes.

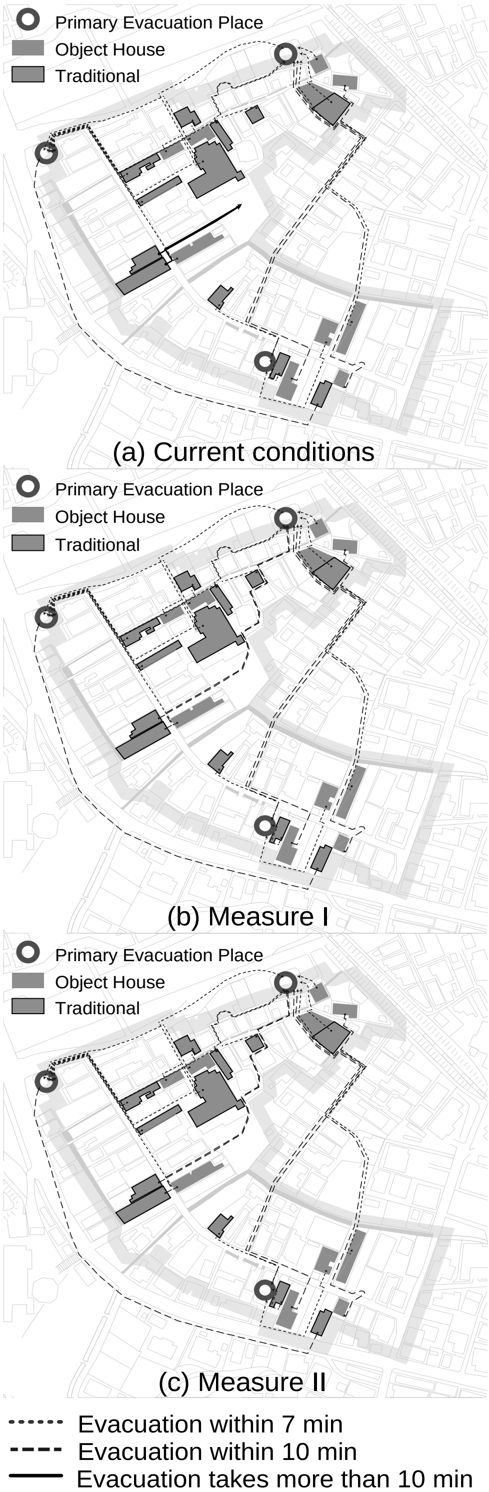

Fig. 7 Simulation results for primary routes without blockades

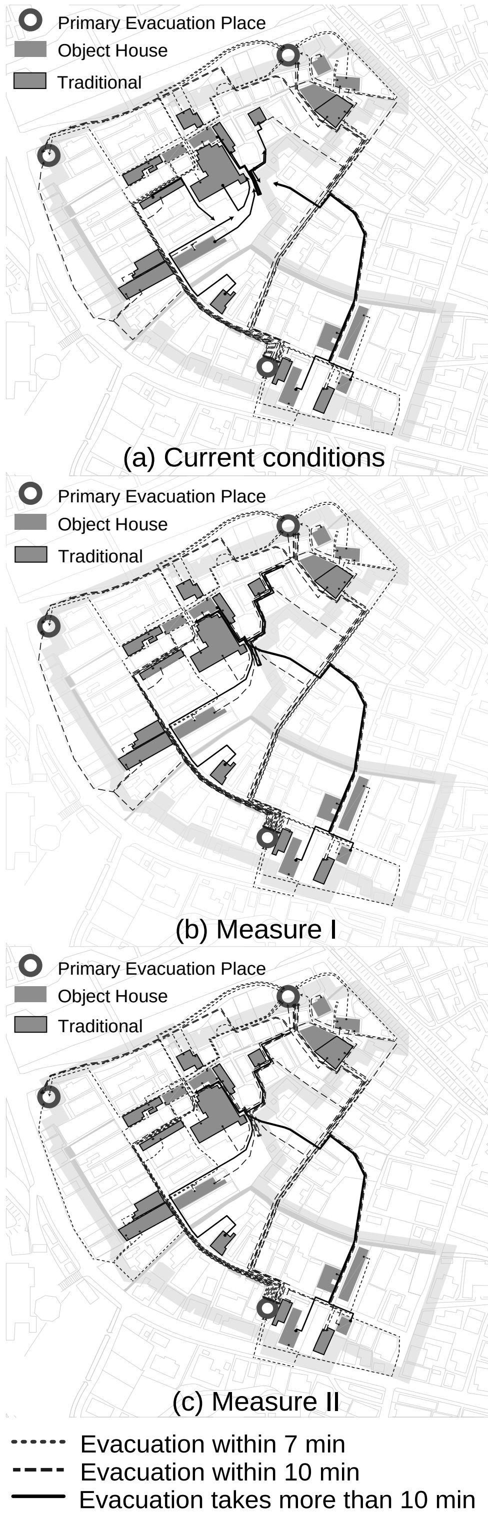

Fig. 8 Simulation results for other routes without blockades

B. Results of Simulations with Blockade of Path A

Here, we present the results of simulations for cases with blockade of path A for the primary (Fig. 9) and other (Fig. 10) evacuation routes.

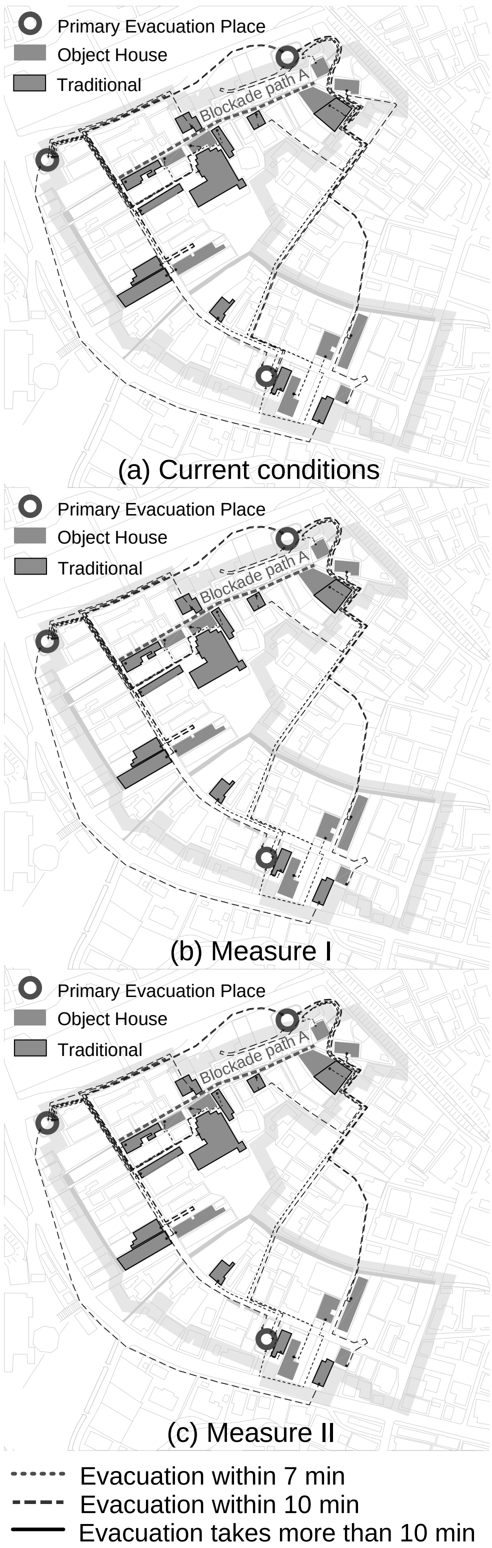

Fig. 9 Simulation results for primary routes with blockade of path A

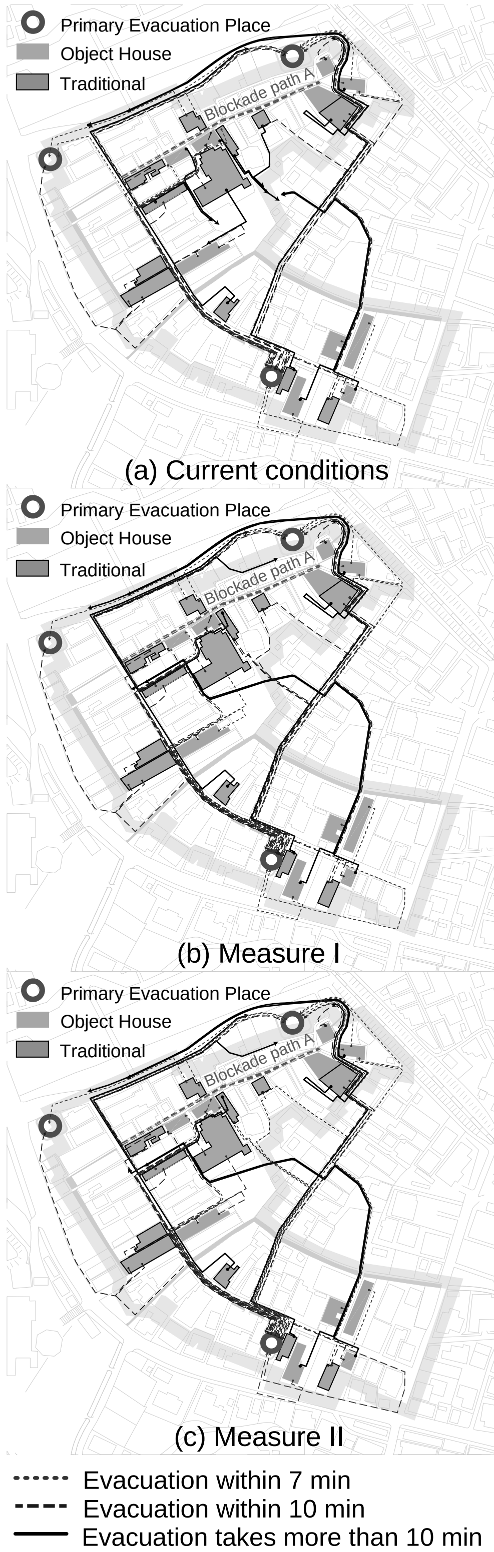

Fig. 10 Simulation results for other routes with blockade of path A

C. Results of Simulations with Blockade of Path B

Here, we present the results of simulations for cases with blockade of path B for the primary (Fig. 11) and other (Fig. 12) evacuation routes.

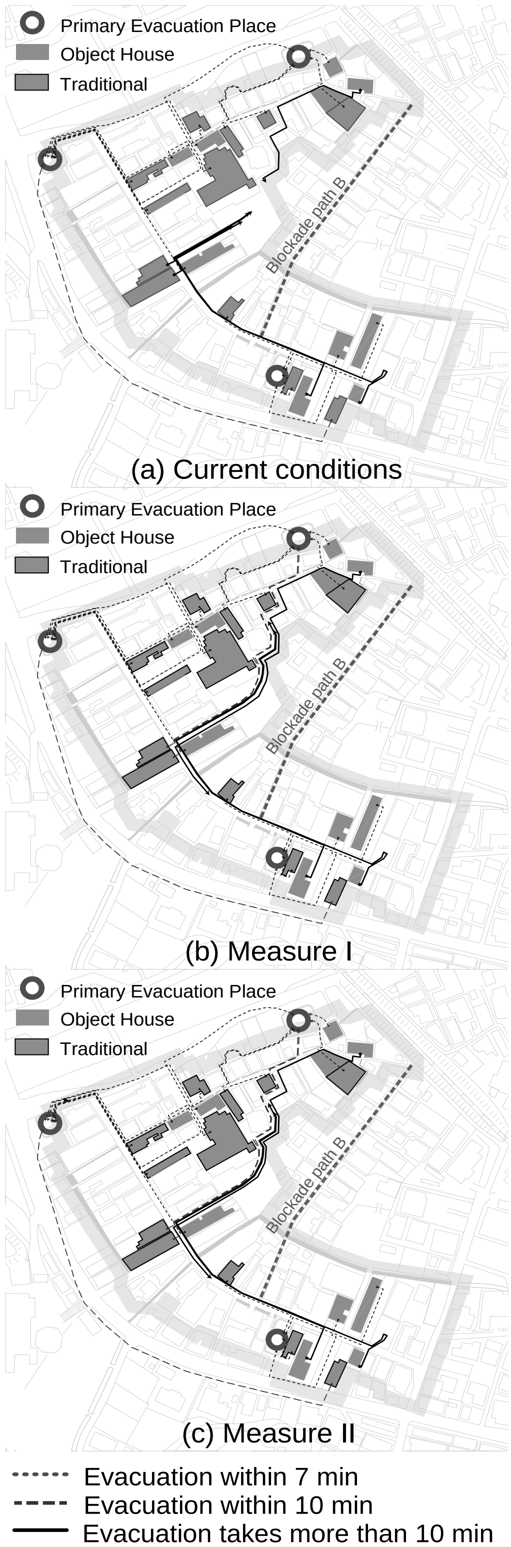

Fig. 11 Simulation results for primary routes with blockade of path B

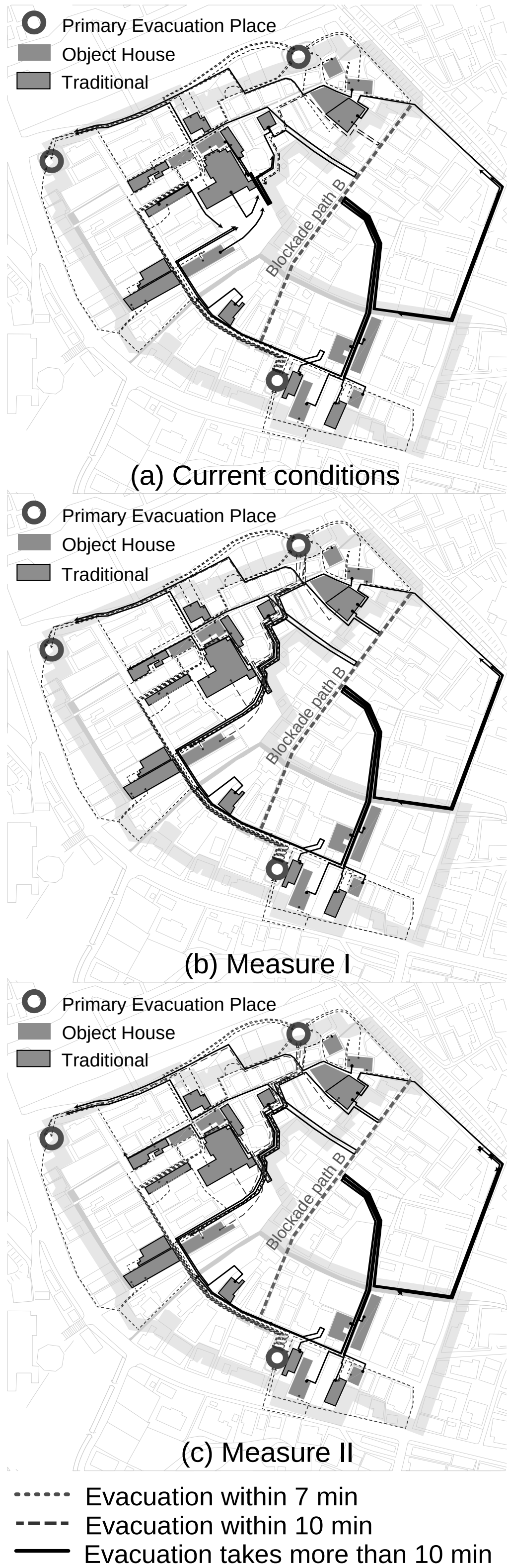

Fig. 12 Simulation results for other routes with blockade of path B

D.Results of Simulations with Blockade of Both Paths

Here, we present the results of simulations for cases with blockade of both paths for the primary (Fig. 13) and other (Fig. 14) evacuation routes.

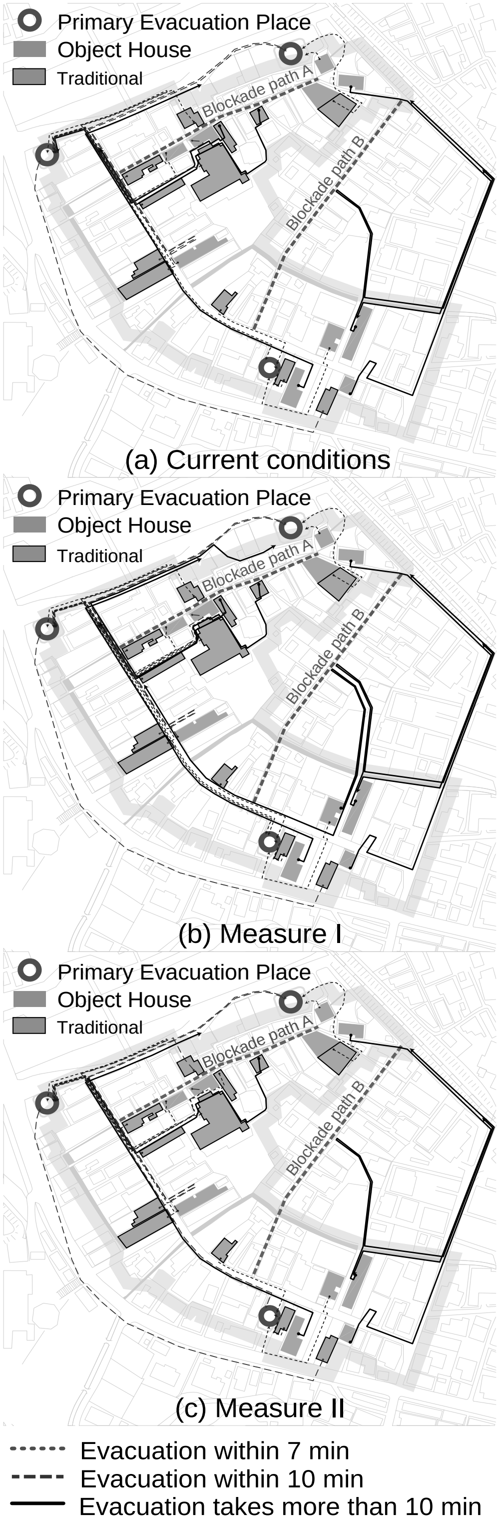

Fig. 13 Simulation results for primary routes with blockade of paths A and B

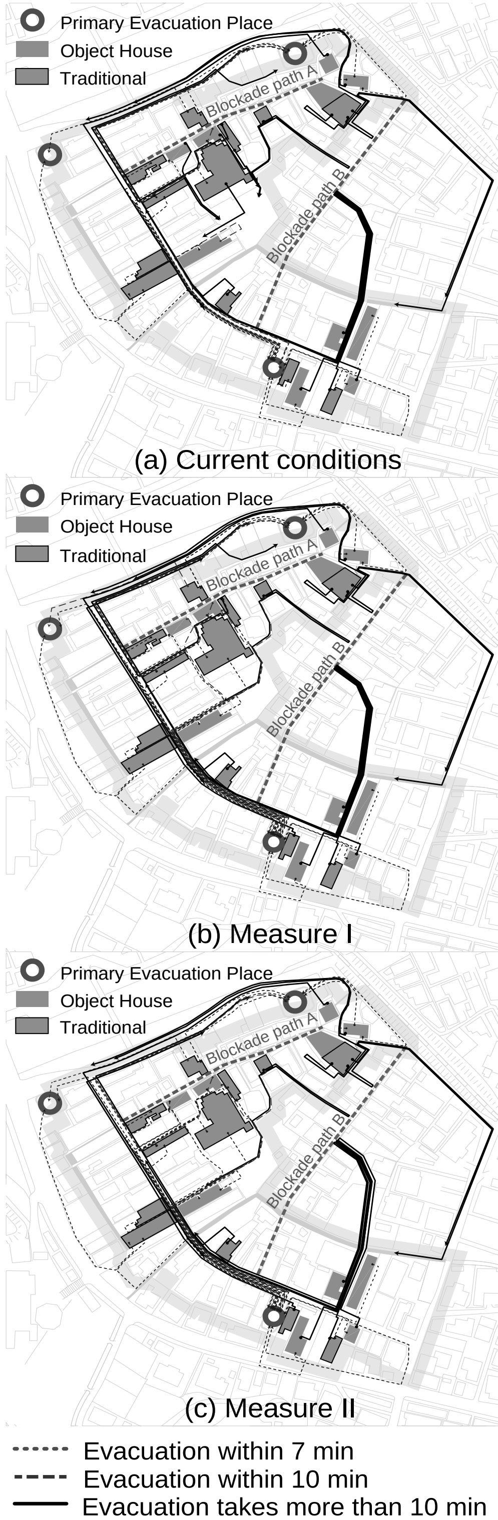

Fig. 14 Simulation results for other routes with blockade of paths A and B

ACKNOWLEDGMENT

We have been studying the town since before its designation as an important preservation district, and have been playing an active part in its development. Therefore, we were able to obtain permission to interview residents and city authorities.

We sincerely appreciate the help of a local nonprofit organization (known as “Hizenhamashuku mizu to machinami no kai”) in the district, the residents of the study area, and Kashima City authority for assistance with the surveys.

References

[1] L. E. Roussel, *Evacuation*. Bognor Regis: New Horizon, 1980.
[2] R. W. Perry, M. K. Lindell, and M. Greene, *Evacuation planning in emergency management*.Lexington, Mass: LexingtonBooks, 1981.
[3] H. D. Sherali, T. B. Carter, and A. G. Hobeika, "A location–allocation model and algorithm for evacuation planning under hurricane/flood conditions," *Transportation Research Part B: Methodological*, vol. 25, 1991, pp. 439–452.
[4] J. H. Sorensen, S. A. Carnes, and G. O. Rogers, "An approach for deriving emergency planning zones for chemical munitions emergencies," *Journal of Hazardous Materials*,vol. 30, 1992, pp. 223–242.
[5] B. M. Vogt and J. H. Sorensen, *Evacuation in emergencies: an annotated guide to research,* Oak Ridge National Laboratory; available from National Technical Information Service, Oak Ridge, Tenn. Springfield, Va., 1987.
[6] K. Dow and S. L. Cutter, "Crying wolf: Repeat responses to hurricane evacuation orders," *Coastal Management*,vol. 26, 1998, pp. 237–252.
[7] T. E. Drabek, "Understanding disaster warning responses," *The Social Science Journal*,vol. 36,1999, pp. 515–523.
[8] M. Nara, Y. Ohshima, and M. Watanabe, "Walking speed of people in refuge - Walking on stairs," *Bulletin of Japanese Association of Fire Science and Engineering*,vol. 45,1996, pp. 11–17.
[9] T. Sano, N. Takeichi, T. Kimura, Y. Ohmiya, Y. Yoshida, and H. Watanabe, "Characteristics of confluence of two occupant flows at staircase of high-rise building," *Journal of Architecture and Planning*,vol. 598,2005, pp. 51–56.
[10] D. K. Bird, G. Gisladottir, and D. Dominey-Howes, "Resident perception of volcanic hazards and evacuation procedures," *Natural Hazards and Earth System Sciences*,vol. 9,2009, pp. 251–266.
[11] D. M. Brommer and J. C. Senkbeil, "Pre-landfall evacuee perception of the meteorological hazards associated with Hurricane Gustav," *Natural Hazards*, 2010.
[12] C. Matyas, S. Srinivasan, I. Cahyanto, B. Thapa, L. Pennington-Gray, and J. Villegas, "Risk perception and evacuation decisions of Florida tourists under hurricane threats: a stated preference analysis," *Natural Hazards*, 2011.
[13] L. Chalmet, R. Francis, and P. Saunders, "Network model for building evacuation," *Fire Technology*,vol. 18, 1982, pp. 90–113.
[14] H. W. Hamacher and S. A. Tjandra, "Mathematical modeling of evacuation problems: A state of the art," *Pedestrian and Evacuation Dynamics*, 2002,pp. 227–266.
[15] C.-A. Tai, Y.-L. Lee, and C.-Y. Lin, "Urban disaster prevention shelter location and evacuation behavior analysis," *Journal of Asian Architecture and Building Engineering*,vol. 9,2010, pp. 215–220.
[16] T. Kimura, T. Sano, K. Hayashida, N. Takeichi, Y. Minegishi, Y. Yoshida, and H. Watanabe, "Representation of crowd in multi-agent model: Development of pedestrian simulation system SimTread," *Journal of Architecture and Planning*,vol. 74, 2009,pp. 371–377.
[17] W. Chiewchengchol, T. Koga, and K. Hirate, "Development of an evacuation simulator using a walkthrough system and research on evacuation behavior in the case of fire," *Journal of Asian Architecture and Building Engineering*,vol. 10,2011, pp. 101–108.
[18] M. Jha, K. Moore, and B. Pashaie, "Emergency evacuation planning with microscopic traffic simulation," *Journal of the Transport Research Board*,2004, pp. 40–48.
[19] T. Kim, B. S. Kim, and K. Kim, "Smoke movement and evacuation time in the arcade of a traditional market using numerical simulation," *Journal of Asian Architecture and Building Engineering*,vol. 6,2007, pp. 403–410.
[20] S. Kim, B. George, and S. Shekhar, "Evacuation route planning: scalable heuristics," in *Proc. 15th Annu. ACM International Symposium on Advances in Geographic Information Systems*, 2007.
[21] G. J. Lim, S. Zangeneh, M. R. Baharnemati, and T. Assavapokee, "A capacitated network flow optimization approach for short notice evacuation planning," *European Journal of Operational Research*,vol. 223,2012, pp. 234–245.
[22] T. Okubo, T. Ikemoto, M. Miyajima, M. Gotou, A. Murata, and Y. Suzuki, "A survey on disaster prevention planning of historical town preservation district Teramachi of Kanazawa city," *Disaster Mitigation of Cultural Heritage and Historic Cities*,vol. 4,2010, pp. 311–316.
[23] Y. Toyoda, S. Otsuki, and H. Kanegae, "A study on local safety increased by shortening of evacuation routes in case of Senbon-syaka-do made use of as an emergency evacuation site," *Disaster Mitigation of Cultural Heritage and Historic Cities*,vol. 3, 2009, pp. 259–266.
[24] M. Yamasaki, Y. Kurata, and H. Otsuki, "A study about the existence of emergency evacuation doors in the backyards of traditional townhouses in Kyoto," *Disaster Mitigation of Cultural Heritage and Historic Cities*,vol. 5,2011, pp. 69–72.
[25] N. Mishima, N. Miyamoto, and Y. Taguchi, "Evacuation route planning for a historic preservation area in large disasters," *Journal of Habitat Engineering and Design*, submitted for publication.
[26] S. Horiuchi, *Kenchiku Bouka,* Asakura Publication Co. Ltd., 1994.

Nobuo Mishima was born in Fukuoka, Japan, on May 11 1964. He graduated from the University of Tokyo, studied at the Technical University of Vienna from October 1990 to May 1992, and obtained his doctoral degree in engineering at the University of Tokyo, Tokyo, Japan, on July 13 1995. His major field of study is urban design and planning.

He has been Professor in the Graduate School of Science and Engineering, Saga University, Japan, since February 2013, where he previously held the position of Associate Professor (from December 1998 to January 2013). His current research interests are the contents and spatial design of urban spaces, townscape design and control, and preservation of historic areas.

Prof. Mishima is a member of the Architectural Institute of Japan and a member of the City Planning Institute of Japan. He was awarded a prize for best presentation at the 1st International Conference of ISHED.

Naomi Miyamoto was born in Kumamoto, Japan, on May 11 1984. She graduated from Saga University and obtained her Masters degree in engineering at Saga University, Saga, Japan, on March 24 2012. Her primary field of study is urban planning.

She is a member of staff at Land Brain Co., which is a consultancy office for city planning in Japan. Her current research interests are city planning and field surveys of historic areas.

Miss Miyamoto is a member of the Architectural Institute of Japan.

Yoko Taguchi was born in Gifu, Japan, on February 5 1975. She graduated from the Tokyo Institute of Technology and obtained her doctoral degree in engineering at the Tokyo Institute of Technology, Tokyo, Japan, in November 2006. Her primary field of study is architecture planning and design.

She has been a lecturer at the Graduate School of Science and Engineering, Saga University, from April 2011, where she previously held the position of Assistant Professor (from December 2008). Her current research interests include the design of urban space and field surveys.

Dr. Taguchi is a member of the Architectural Institute of Japan. She was awarded a prize for best presentation at the 1st International Conference of ISHED.