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Development of a Two-Way Evacuation Route Database Based on Interviews Conducted with Historic Preservation Area Residents

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ABSTRACT

It has been determined that two-way evacuation routes that connect houses to evacuation sites should be developed to protect residents of historic preservation areas from future disasters. These routes are required because traditional buildings and other historic spatial elements are located close to each other. It is important to understand residents' perceptions of evacuation routes that connect their houses to temporary safe places to develop evacuation system strategies that include effective two-way evacuation routes. This paper describes a procedure used to construct a two-way evacuation route database designed to preserve two study areas that was based on an interview survey conducted with area residents. The resulting database contained residents' perceptions of evacuation routes. The database contains categorized spatial problems related to these routes that can be used for future research.

Key words*: Disaster prevention, Historic area, Evacuation routes, Residents' perceptions, Evacuation Planning Database.*

1. INTRODUCTION

1.1 Background of Study

Historic preservation areas are particularly vulnerable to disasters because many people reside close together in wooden houses. Because the historic value of these areas must be protected, to protect its historic value, it can be difficult to widen narrow streets in an effort to prevent future disasters. Therefore, in some historic preservation areas in Japan, two exits for each house are required by law to prevent possible fire-related disasters. In addition, it has been recommended that residents determine two-way evacuation routes to connect their houses to temporary safe places to which residents can

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evacuate and take cover immediately after disasters because secondary street-side exits cannot be completely secured in historic preservation areas. During large disasters, streets may become blocked. Yet, no current laws require that evacuation routes be secured. Thus, finding ways to secure two-way evacuation routes is a crucial issue for individuals who reside in historic preservation areas.

With respect to disaster prevention for historic preservation areas, only a limited number of studies have focused on ways to determine two-way evacuation routes and on residents' perceptions of these routes. The goal of this study was to develop a method that could be used to create a basic database that analysts or strategy developers employed by research agencies or companies could access to develop evacuation plans for historic preservation areas. This database would include information related to problems encountered during the determination of two-way evacuation routes for historic preservation areas.

1.2 Aim of Study

This paper describes a procedure used to construct a basic database of two-way evacuation routes that could be used to preserve two selected historical preservation areas. This study was based on data collected during an interview survey of residents to discover problems related to the determination of evacuation routes in the study area.

1.3 Literature Review

Current research focused on evacuation route planning can be divided into several categories: behavioral analyses of evacuees, residents' perceptions, algorithms and programming methods, evacuation times, and evacuation databases. Behavioral analyses of evacuees examined the effects of a variety of different behavioral and managerial factors on evacuations [1-2], evacuees' speeds while ascending or descending stairs [3], and the effects of merging that occurs on staircases, as well as ways to ease or prevent merging under a variety of conditions [4]. Surveys have been conducted to analyze residents' perceptions of volcanic hazards [5], to clarify the risks of and reasons for evacuation [6], and to assess tourists' perceptions of hurricanes, based on forecasts [7]. Algorithms and programming methods were created to generalize optimal evacuation plans (e.g., models used to analyze building evacuability [8], to develop mathematical modeling to simulate evacuation problems [9], to develop GIS-based mapping of evacuation choices during earthquakes [10], to develop a new multiagent system (SimTread) that calculates the shortest walking times [11], and to develop an evacuation simulator [12]). Studies have evaluated evacuation times to determine optimal routes. Decision support systems have been implemented during evacuation planning. Previous studies included an evaluation of an evacuation plan by the use of a microscopic simulation model [13], an analysis of smoke exhaustion and evacuation times in the arcade of a traditional Korean market [14], the development of a heuristic method with an incremental data structure that relies on real-world scenarios [15], and a network optimization approach to address problems with evacuation planning that occur with short notice [16]. Finally, a number of studies have developed evacuation databases to be used in planning [17].

However, historic preservation areas are locations that are particularly vulnerable to disaster because many elderly people live close together in wooden houses. A number of previous studies examined disaster prevention plans for the protection of traditional buildings located in Kanazawa City, Japan [18], and assessed increased local safety because of the shortening of evacuation routes located in Senbon-syaka-do in Kyoto, Japan [19]. Street widths in these areas might be narrower than 4 m. Thus, it can be difficult to widen these streets and maintain their historic value. These streets can easily become clogged or blocked during large disasters, such as great earthquakes and large fires that might destroy buildings and block exits. If preferred evacuation routes become blocked, residents must evacuate by other routes. Therefore, the determination of two-way evacuation routes for each house is one of the most critical aspects of disaster prevention for historic preservation area residents. However, this must be achieved in addition to the maintenance of the narrow path widths. A prior study investigated the effectiveness of historic wooden back doors in Kyoto [20]. In addition, in another study [21], we assessed evacuation routes used in a Japanese historic preservation area by conducting intensive interviews with its residents. Based on our results, we proposed the use of a procedure to determine evacuation route planning for that study area. Our results indicated that maintenance of the open space located at the center of the study area was a useful method that could be used to improve evacuation routes that connected the houses to primary evacuation sites [25]. However, it can be difficult to create a database of residents' perceptions for use in two-way evacuation route planning. Therefore, it is important to analyze residents' perceptions, as well as problems related to evacuation routes.

2. METHOD OF STUDY

2.1 Study Areas

2.1.1 Characteristics of study areas: Our study areas consisted of two important historical preservation districts comprised of traditional buildings that were designated under the Act on Protection of Cultural Properties in 2007. The areas are located close to one another and are situated on either side of the Hama River in Kashima City, Saga Prefecture. Both areas functioned historically as station towns located along the Nagasaki Road that was built in Edo era to connect Kokura and Nagasaki. One area is known as Hamashozu Machi Hamakanaya Machi (hereafter, Area A). It has been preserved as a local town that contains straw-roofed and tile-roofed wooden townhouses built alongside narrow streets (see Figure 1). The second area is known as Hamanaka Machi Happongi Shuku (hereafter, Area B). It has been preserved as a sake-producing town that contains both tile-roofed wooden storehouses and sake factories built close together (see Figure 2). Therefore, these two areas are more vulnerable than other historic preservation areas or other dense urban areas filled with wooden structures.

2.1.2 Relaxation Ordinance: In 2010, the Kashima City

authorities enacted a relaxation ordinance to compliment the building standards laws that aimed to preserve the historic characteristics of the two study areas. It released the quasi-fire prevention areas by encouraging changes in city planning. This ordinance led to relaxed regulations for roof structures and reduced restrictions on street construction activities on streets. This was achieved by the adoption of alternative methods, such as the provision of two exits for each traditional house to prevent future fire disasters. Additionally, two-way evacuation routes that connected the houses to designated final evacuation sites (e.g., Hama elementary school) were considered because large-scale disasters require street blockades. However, these routes were not recommended in the ordinance.

Fig. 1. Study Area A.
Hamashozu Machi Hamakanaya Machi preserved as a local town. Straw-roofed houses alongside streets were built close together.

Fig. 2. Study Area B
Hamanaka Machi Happongi Shuku preserved as a sake-producing town. It contains tile-roofed wooden storehouses.

2.2 Flow of the Study (see Figure 3.)

2.2.1 Interview Survey: The primary method used in this study was an interview survey conducted with residents of the two study areas. The goal was to determine residents' perceptions of the determination of two-way evacuation routes for each house during large disasters.

The interview survey was conducted between October 2009 and November 2009. Useful data was collected from 21 residents in Study Area A and 35 residents in Study Area B (see Figure 4). During the interview survey, we asked interviewees to describe evacuation routes that connected their homes to temporary safe places based on the procedure shown in Figure 3. The first question asked interviewees to describe their choices of temporary safe places. The second question asked interviewees to describe evacuation routes that connected their houses to temporary safe locations, and, in particular, to describe exits and routes to these temporary safe locations. We asked interviewees to continue until they were unable to find any other evacuation routes. We summarized the results of these interviews on a data sheet (see Figure. 5). The data sheet consisted of a map and photographs of evacuation routes. The map showed exits for houses, route paths, temporary safe places, and route obstacles.

The interviewees provided a variety of answers, such as, "For the first route, I would use the main exit that goes to the front street. For the second route, I would evacuate through the back door and go to my neighbor's garden by walking between the buildings." We categorized all responses into exits, temporary safe places, and the paths located between them. We used the terms, "from," "to," and "through," and classified them respectively in Table 1, based on areas and building types. In this case, building types were categorized as several traditional buildings, single traditional building, and nontraditional building.

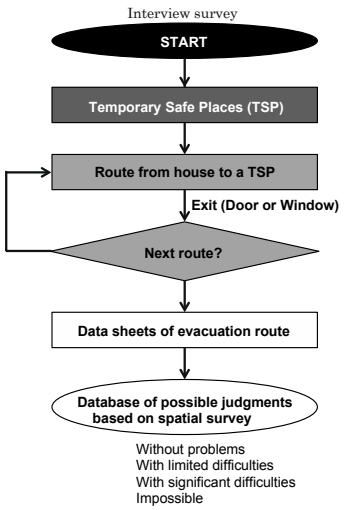

Fig. 3. Flow of study to build database.

2.2.2 Judgments of Possible Evacuation Routes: To create the evacuation route database, we realized that judgments of possible evacuation routes were important. We based our judgments on residents' responses to the interview survey, as well as on the results of a spatial survey. Possible evacuation routes were categorized into the following classifications: "no problems," "with limited difficulties," "with significant difficulties," and "impossible."

A route that contains no problems would be a route that contains a normal exit and path. An example of an evacuation route with limited difficulties would be a route that contains limited gaps, such as a low window and or an engawa (a type of veranda typically included in Japanese houses that is generally located between the garden and the guest room), or a

route that requires travel through another building. An example of a route with significant difficulties would be a route that contains a high window or a wide stream, or a route that requires travel between buildings. In other words, an impossible route would be too difficult for vulnerable people to travel on. For example, an impossible route would require an individual to exit from a second floor window.

2.2.3 Method of building database and analyzing: We list the results of all possible judgments in Table 1. Therefore, the value of Table 1 is a database that contains evacuation routes with a variety of difficulties for a historic area that includes residents' perceptions. Based on Table 1, we calculated the number of evacuation routes and listed the results in Table 2. We considered the categories of possible judgments, problems inherent in each route, the order of evacuation routes mentioned by residents, and building types. These calculations can reveal the quantitative realities of study area evacuation routes (e.g., whether primary and other routes were problem-free.

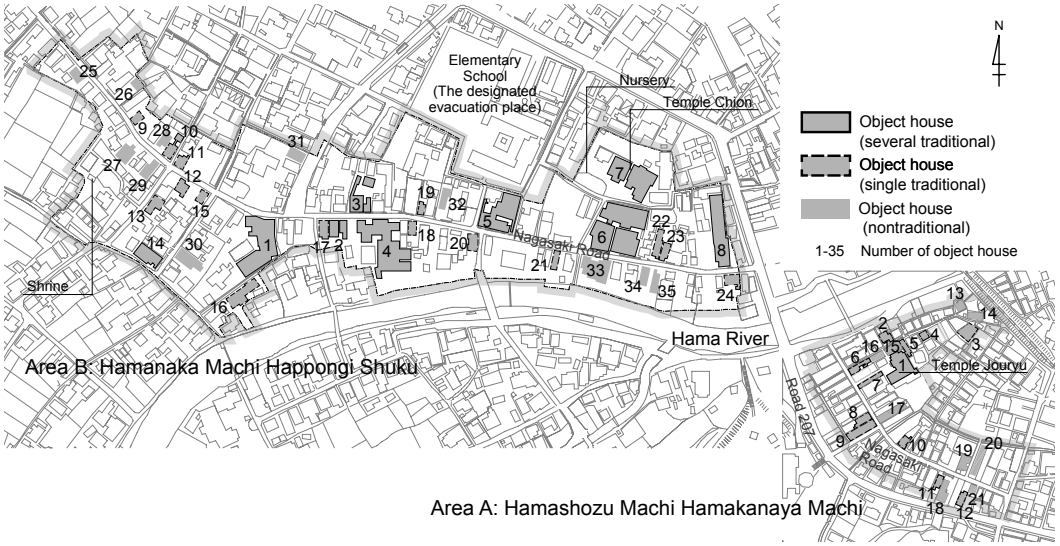

Fig. 4. Object houses of the study area.

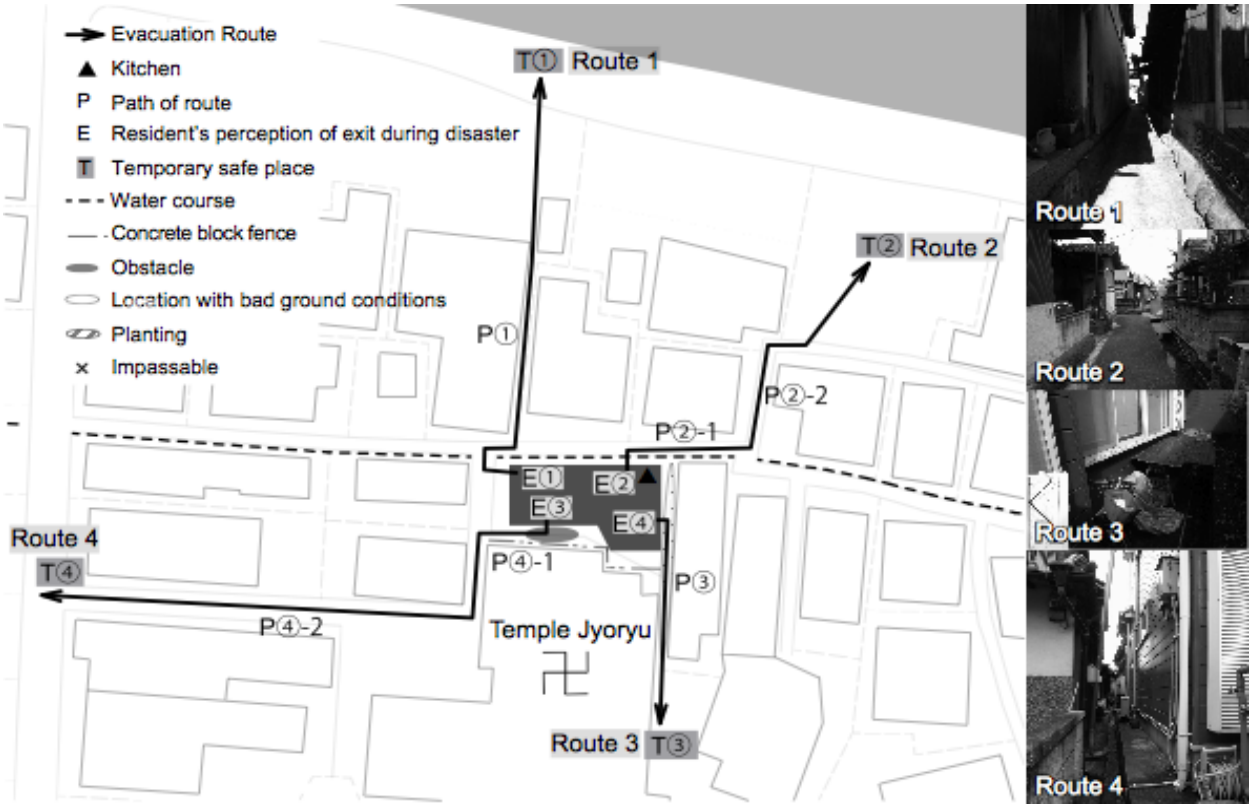

Fig. 5. Sample data sheet (Object House No. 15 located in Area A)

Table 1. Database of Residents' Determinations of Two-way Evacuation Routes

Area A: Hamashozu Machi Hamakanaya Machi

Building Type	House No	Primary route			Second route			Third route			Fourth route		
		From	To	Through	From	To	Through	From	To	Through	From	To	Through
Several Traditional Buildings	1 Temple Jouryu	The main exit of the main building.	The open space on the riverside	-	The main exit	Nagasaki Road	-	The engawa	The Gaboi wetland	-	The restroom window	The Gaboi wetland	-
Single Traditional Building	2	The main exit	Nagasaki Road or the road to the temple	-	The high window	The street behind	-	The high window	The neighbor's parking lot	-	-	-	-
	3	The main exit	The Hama River	-	The back door	The front	Between the buildings	The engawa	The Gaboi wetland	-	-	-	-
	4	The main exit	The neighbor's parking lot	Along the path	From the high window	The street of the Gaboi wetland	-	The second-floor window	The neighbor's house	Via the roof	-	-	-
	5	The back door of the kitchen	The Gaboi wetland	-	The main exit	Nagasaki Road or the road to the riverside	-	The side door	Nagasaki Road	The neighbor's property	-	-	-
	6	The main exit	The bridge or the front parking lot	-	The side door	The Hama River	-	From the back door	The front street	Between the buildings	-	-	-
	7	The front of the house	The bridge over the Hama River	-	The side door	The Hama River	The temple approach	Break	Go outside	The neighbor's wall	-	-	-
	8	The main exit	The front parking lot	-	The back door	The back yard	-	-	-	-	-	-	-
	9	The main exit	The front parking space	-	The back door	The neighbor's vacant lot	-	The second-floor window	Jump to the outside	-	-	-	-
	10	The main exit	The neighbor's vacant lot	-	The back door	The garden	-	The engawa	The garden	-	-	-	-
	11	The back door	The neighbor's vacant lot	-	The engawa	The neighbor's vacant lot	-	The main exit	The front neighbor's parking lot	-	The side window	The street	The neighbor's lot
	12	The back window	The opposite side of the street	-	The main exit	The neighbor's vacant lot	-	The engawa beside the main exit	The front street	-	-	-	-
Nontraditional Building	13	The main exit	The Hama River	-	The low window	The Hama River	-	Several high windows	May be used with difficulty	-	-	-	-
	14	The main exit	The street	-	The door	The back vacant lot	-	The engawa	The neighbor's garden	-	The side window	The open space near the Hama River	-
	15	The main exit to	The open space of the Hama River	The path	The kitchen door	The parking space	Beyond the street	The side window	Nagasaki Road	The temple approach	The bathroom window	The neighbor's garden	-
	16	The main exit	Nagasaki Road	-	The engawa	The front yard of the temple 1	-	The back door	Nagasaki Road	The temple	-	-	-
	17	The front exit	Nagasaki Road	-	The side door	The parking space	-	The back door	The Gaboi wetland	-	-	-	-
	18	The main exit	Nagasaki Road	-	The engawa	Road 207	-	The back door	The neighbor's lot	-	Another back door	The neighbor's vacant lot	-
	19	The main exit	The front vacant lot	-	The high window	The back vacant lot	-	-	-	-	-	-	-
	20	The main exit	The front street	-	The high window	The vacant lot	-	-	-	-	-	-	-
	21	The main exit	The front open space	-	The back door	The front street	-	The high window	The street	-	-	-	-

Area B: Hamanaka Machi Happongi Shuku

Building Type	House No	Primary route			Second route			Third route			Fourth route		
		From	To	Through	From	To	Through	From	To	Through	From	To	Through
Several Traditional Buildings	1	The shop exit	The front street	-	The back door	The back open space	The buildings	The storehouse door	The street	The path beside the house	The carport by opening the shutters	The front street	-
	2	The main exit	The street	-	The kitchen door	The parking lot	Between the buildings	The side engawa	The street	-	-	-	-
	3	The main exit	The street	The shop	The back kitchen door	The parking lot in front of the storage	-	-	-	-	-	-	-
	4	The shop	The elementary	The front store	The back door of the	The Hama river	-	The side door	The neighbor's	The garden	-	-	-

		school	house	store house				garden				
	5	From the main exit	The Hama river	-	The side office exit	The street	-	The back engawa	The elementary school	The garden	-	-	-
	6	The main exit	The front street	-	The back door	The temple square	-	The store-house exit	The outside	-	-	-	-
	7	The main exit	The elementary school	The street	The back door	The grounds of the nursery	-	The kitchen door	The square (graveyard)	-	The main hall exit	The square	Move to the main hall
	8	The shop exit	The outside	-	Jump from the second-floor window	The outside	-	The second-floor window	The neighbor's house	Over the roof	The second-floor window	Down to the street	The garage roof
Single Traditional Building	9	The main exit	The neighbor's square	-	The bathroom door	The neighbor's square	Between the buildings	The engawa	The garden	-	-	-	-
	10	The back door	The elementary school	-	The shop exit	The shrine	-	The bathroom window	The street	The side of the house	-	-	-
	11	The window	The parking lot	-	The main exit	The street next to the house	-	The back door	The parking lot	-	-	-	-
	12	The main exit	The front parking lot	-	The back door	The garden	-	The side window	The garden	-	-	-	-
	13	The shop exit	The front parking lot	-	The back door	The side street	-	The side window	The parking lot		The bathroom window	The parking lot	The garden
	14	The back door	The street beside the building	-	The main exit	The vacant lot in front of the house	-	The shop entrance	The front street	-	The window	The street	Between the buildings
	15	The main exit	The front street	-	The kitchen's back door	The neighbor's garden	Beyond the water-course	The engawa	The neighbor's garden	The garden	-	-	-
	16	The main exit	The front street	-	The kitchen door	The street	The back door	The innermost engawa	The street	The side of neighbor's house	The engawa beside main exit	The street	The neighbor's garden
	17	The back door	The parking lot next to neighbor's house	-	The main exit	The wide street	-	The side exit	The neighbor's garden	-	-	-	-
	18	The main exit	The front park	-	The back door	The Hama river	The garden	-	-	-	-	-	-
	19	The main exit	The front street	-	The window	The neighboring square	-	-	-	-	-	-	-
	20	The main exit	The front park	-	The kitchen door	The wide street	-	The side engawa	The park	-	The back engawa	The back square	The neighbor's site
	21	The main exit	The front parking lot	-	The back door	The square	-	-	-	-	-	-	-
	22	The main exit	The front street	-	The back door	The nursery	The shed	The second-floor window	Jump to the street	Along the roof	-	-	-
	23	The main exit to	The front street	-	The back engawa	The nursery	The garden	The bathroom door	The front of community center	-	-	-	-
	24	The main exit	The front street	-	The bathroom door	The neighbor's site	Beyond the block wall	-	-	-	-	-	-
Nontraditional Building	25	The main exit	The community center square	-	The back door	The back field	-	The kitchen door	The community center square	The neighbor's house	-	-	-
	26	The main exit	The front street	-	The front engawa	The community center square	-	The back door	The garden	-	-	-	-
	27	The kitchen door	The garden	-	The main exit	The square	-	The engawa	The street	-	The window	The square	-
	28	The main exit	The square	-	The back door	The street	The neighbor's back space	The innermost kitchen exit	The neighboring square	-	The engawa	The square in front of the house	Between the buildings
	29	The main exit	The community center square	-	The back engawa	The shrine	-	The kitchen door	The street	-	-	-	-
	30	The kitchen door	The street	-	The opening window to sweep	The street	-	The main exit	The square	-	-	-	-
	31	The main exit	The front street	-	The garage	The front street	-	The back door	The front street	-	-	-	-
	32	The main exit	The front street	-	The engawa	The elementary school	-	The window	The back garden	-	The window	The garage	-
	33	The main exit	The parking lot	-	The back door	The Hama river	-	The garage beside the	The front street	-	-	-	-

							house					
34	The main exit	The front street	-	The back door	The Hama river	-	The back engawa	The Hama river	-	The window	The street	-
35	The main exit	The community center square	-	The balcony	The square	-	The window	The square	-	-	-	-

2 The white character in black shows houses that do not currently possess two-way evacuation routes
Route A route without problems
Route A route with limited difficulties (e.g., a high step or a route that travels through another building)
Route A route with significant difficulties (e.g., requires exit from a high window, between buildings)
Route An impossible route (e.g., exit from the second floor via the roof)
- No answer from interviewee
Note: An engawa is a type of veranda that is typical of Japanese houses. It is generally located between the garden and the guest room.

3. ANALYSIS OF THE PRESENT SITUATION

3.1 Determination of two-way evacuation routes

We determined that two-way evacuation routes could not be established for ten houses because of several current conditions: Three single traditional houses and two nontraditional houses were located in Area A. One single traditional house and four nontraditional houses were located in Area B. Two-way escape routes could be established for the remaining 45 houses.

We attempted to determine residents' perceptions of temporary safe places (see Figure 6). We also attempted to evaluate the time required to reach final evacuation locations based on the locations of temporary safe places.

3.2 Residents' perceptions of evacuation routes

Based on Tables 1 and 2, our determinations of residents' perceptions of evacuation routes are listed below:

- Only two primary routes contained significant difficulties. The remaining 54 primary routes did not contain evacuation difficulties.
- With respect to secondary routes, five routes contained limited difficulties and ten routes contained significant difficulties. We determined that one route was impossible because it required an individual to exit from a second story window.
- With respect to tertiary routes, eight routes contained limited difficulties, ten routes contained significant difficulties, and five routes were impossible.
- With regard to quaternary routes, 40 residents had no routes, and only one route had no difficulties.

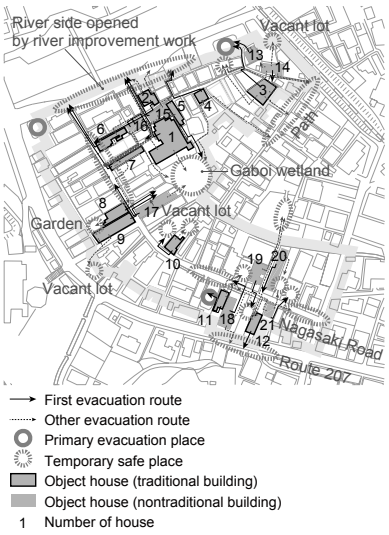

Fig. 6. Temporary safe places in Area A.

Table 2. Results of Calculations Performed on Results Shown in Table 1.

Building Type	Category	Problems	Primary route			Second route			Third route			Fourth route		
		Area	A	B	Total	A	B	Total	A	B	Total	A	B	Total
Several Traditional Building	Route	Route without problems	1	8	9	1	6	7	0	5	5	0	0	0
	Route	Route with limited difficulties	0	0	0	0	0	0	1	0	1	0	2	2
		from the engawa			0			0	1		1		2	2
		from low window			0			0			0			0
	Route	Route with significant difficulties	0	0	0	0	1	1	0	1	1	1	0	1
		from high window			0			0			0	1		1
		through between buildings			0		1	1		1	1			0
	Route	Impossible route	0	0	0	0	1	1	0	1	1	0	1	1
	-	No route	0	0	0	0	0	0	0	0	0	0	5	5
		Subtotal	1	8	9	1	8	9	1	8	9	1	8	9
Single Traditional Building	Route	Route without problems	10	15	25	7	12	19	3	5	8	0	0	0
	Route	Route with limited difficulties	0	0	0	1	0	1	2	3	5	0	2	2
		from the engawa			0	1		1	2	3	5		2	2
		from low window			0			0			0			0
	Route	Route with significant difficulties	1	1	2	3	4	7	2	3	5	1	2	3
		from high window	1	1	2	2	1	3	1	3	4	1	2	3
		through between buildings			0	1	3	4	1		1			0
	Route	Impossible route	0	0	0	0	0	0	3	1	4	0	0	0

	-	No route	0	0	0	0	0	0	1	4	5	10	12	22
		Subtotal	11	16	27	11	16	27	11	16	27	11	16	27
Nontraditional Building	Route	Route without problems	9	11	20	4	10	14	3	8	11	1	0	1
	Route	Route with limited difficulties	0	0	0	3	1	4	1	1	2	0	0	0
		from the engawa			0	2	1	3	1	1	2			0
		from low window			0	1		1			0			0
	Route	Route with significant difficulties	0	0	0	2	0	2	2	2	4	2	4	6
		from high window			0	2		2	2	2	4	2	3	5
		through between buildings			0			0			0		1	1
	Route	Impossible route	0	0	0	0	0	0	0	0	0	0	0	0
	-	No route	0	0	0	0	0	0	2	0	2	6	7	13
		Subtotal	9	11	20	9	11	20	9	11	20	9	11	20
		Total	21	35	56	21	35	56	21	35	56	21	35	56

4. CONCLUSION

We created a basic evacuation route database to categorize problems that occurred during the determination of two-way evacuation routes. The database was based on current conditions in the two study areas, as well as on residents' perceptions. This database provides basic information that can be used to determine two-way evacuation routes for each study area (e.g., the number of houses that possess two-way evacuation routes that do not contain problems, or the number of houses that possess routes that might be easily renovated without damaging the value of traditional houses.

Furthermore, based on this database, we calculated the evacuation time required to travel from each house to each designated evacuation location to determine the danger residents might encounter on each evacuation route.

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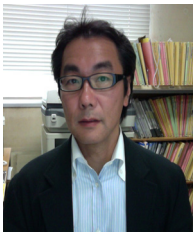

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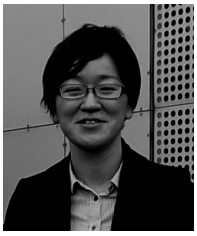

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