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 contains 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
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 complement 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.

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.

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.

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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 | From                  | Primary route to Through | Second route From To Through | Third route From To Through | Fourth route From To Through |
|------------------------|----------|-----------------------|--------------------------|-------------------------------|-----------------------------|-----------------------------|
| **Several Traditional Buildings** | 1 Temple Joju | The main exit of the main building | The open space on the riverside | The main exit - Nagasaki Road | - The engawa - The Goat wetland | - The restroom window - The Goat 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 yard | - Between the buildings - The engawa - The Goat wetland | - - - |
| | 4 | The main exit The neighbor’s parking lot | Along the path from the high window | - The second-floor window - The neighbor’s house Via the roof | - - - |
| | 5 | The back door of the The Goat 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 door 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 - Temp 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 entrance to the neighbor’s parking lot | - The side windows - 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 - The neighbor’s vacant lot | - 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 door - The parking space | Beyond the street The side window - Nagasaki Road | The temple approach The bathroom approach The neighbor’s garden | - - |
| | 16 | The main exit Nagasaki Road | - The engawa - The front yard of the temple | - The back door - Nagasaki Road | The temple | - - |
| | 17 | The front exit Nagasaki Road | - The side door - The parking space | - The back door - The Goat wetland | - - - |
| | 18 | The main exit Nagasaki Road | - The engawa - Road 207 | - The back door - The neighbor’s lot | - Another back door | - - |
| | 19 | The main exit The front vacant lot | - The high window - The back vacant lot | - - - - |
| | 20 | The main exit The front vacant lot | - 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 | From                  | Primary route to Through | Second route From To Through | Third route From To Through | Fourth route From To Through |
|------------------------|----------|-----------------------|--------------------------|-------------------------------|-----------------------------|-----------------------------|
| **Several Traditional Buildings** | 1 | The shop exit The front street | - The back door - The back door | - The open space on the riverside - The buildings | - The Goat wetland | - The front street |
| | 2 | The main exit The street | - The kitchen door - The parking lot | - Between the buildings | - The second floor - The Goat wetland | - - - |
| | 3 | The main exit The street The shop | - The back door - The kitchen door | The parking door lot | - - - - |
| | 4 | The shop The elementary The front store | The back door of the The Hama river | - The side door | The neighbor’s | - - |
| Sample  | Traditional Building |
|---------|----------------------|
| 5       | From the main exit   |
| 6       | The main exit        |
| 7       | The main exit        |
| 8       | The shop exit        |
| 9       | The main exit        |
| 10      | The back door        |
| 11      | The main exit        |
| 12      | The main exit        |
| 13      | The shop exit        |
| 14      | The back door        |
| 15      | The main exit        |
| 16      | The main exit        |
| 17      | The back door        |
| 18      | The main exit        |
| 19      | The main exit        |
| 20      | The main exit        |
| 21      | The main exit        |
| 22      | The main exit        |
| 23      | The main exit        |
| 24      | The main exit        |
| 25      | The main exit        |
| 26      | The main exit        |
| 27      | The kitchen door     |
| 28      | The main exit        |
| 29      | The main exit        |
| 30      | The kitchen door     |
| 31      | The main exit        |
| 32      | The main exit        |
| 33      | The main exit        |

| Nontraditional Building |
|-------------------------|
| 5                       | From the main exit   |
| 6                       | The main exit        |
| 7                       | The main exit        |
| 8                       | The shop exit        |
| 9                       | The main exit        |
| 10                      | The back door        |
| 11                      | The main exit        |
| 12                      | The main exit        |
| 13                      | The shop exit        |
| 14                      | The back door        |
| 15                      | The main exit        |
| 16                      | The main exit        |
| 17                      | The back door        |
| 18                      | The main exit        |
| 19                      | The main exit        |
| 20                      | The main exit        |
| 21                      | The main exit        |
| 22                      | The main exit        |
| 23                      | The main exit        |
| 24                      | The main exit        |
| 25                      | The main exit        |
| 26                      | The main exit        |
| 27                      | The kitchen door     |
| 28                      | The main exit        |
| 29                      | The main exit        |
| 30                      | The kitchen door     |
| 31                      | The main exit        |
| 32                      | The main exit        |
| 33                      | The main exit        |

International Journal of Contents, Vol.9, No.2, Jun 2013
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.

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

This research was supported by Grants-in-Aid for Scientific Research (representative: Assoc. Prof. N. Mishima) and the Program for the Promotion of Methodological Innovation in Humanities and Social Sciences by Cross-Disciplinary Fusing (representative: Prof. K. Kitagawa). In addition, we are thankful for the support and cooperation provided by the Kashima City Authority and by individuals who resided in the study areas.

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