Research Paper

Improvement strategy of open space at the center of a traditional lowland town with narrow paths for securing persons in need of aids viewing from evacuation time

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ARTICLE INFORMATION

ABSTRACT

This paper aims to discuss improvement strategy of an existing open space at the center of a traditional lowland town, in which local spatial heritage including narrow paths should be preserved. We calculated evacuation times not only of normal persons but also of persons in need of aids on the assumption of street blockades in narrow paths might occur by disaster such as large earthquake also with big fire. In the study area, we thought that the weedy vacant space at the center worked as an efficient evacuation route for residents. Yet, the calculation results showed that the evacuation time of person in need of hard aids was more than we expected in the case of street blockades, although the others could. It means that it is useful to maintain the vacant space at the center in the town in order to secure evacuation without damage of the traditional meanings of the area in lowland, but that the other measurements are also necessary especially for person in need of hard aids.

1. Introduction

1.1 Background of study

Conservation of man-made heritage such as traditional towns is recently one of the most significant strategies for local cities. They have own original meanings of the area and still remain as living culture. Such local heritage properties including traditional towns are exposed to natural and man-made disasters that threaten their integrity and may compromise their values (UNESCO World Heritage Centre). Especially traditional towns are also facing to conflict between preservation of living originality and residents who are with vulnerability to natural and man-made hazards such as big fire, earthquake, and heavy rain. Besides, the residents in such local towns are aging. While the residents want to make their living conditions safe, the traditional towns themselves are living witnesses to tell us their local culture. Even though the disaster prevention is crucial, we should consider not to hurt originalities and cultural values of the local towns. One of the most important issues to be solved for traditional towns is to save lives of the residents who live in such vulnerabilities to disaster.

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In case of traditional lowland towns, old buildings are standing close along narrow streets in flat area with little difference in level that is more comfortable to live than hilly area. Yet, the condition of the close standing old buildings is very vulnerable to fire disaster, even though both of the buildings and the narrow streets have historic and cultural value to protect. Therefore, as for disaster prevention of traditional lowland town, we should discuss evacuation route planning in preservation of both traditional building and narrow streets not only against flood disaster but also against big fire disaster may also caused from large earthquake. We also suggest that open space at center of town should be useful for evacuation at big fire (Mishima, et al., 2014). Especially in lowland town, there are sometimes open spaces such as wetland without buildings because of its bad condition to live. Yet, we have to also know how the open space works in the difference of persons.

1.2 Aim of study

To establish evacuation route planning against big fire disaster in consideration both preservation of cultural value and secureness of person in need of aids in traditional lowland town is neither clear nor easy, as mentioned above. It is, nevertheless, necessary to make a comprehensive planning of evacuation routes. Thus, this study aims at clarifying necessity of improvement of open space in the center of a traditional lowland town with narrow paths where its population is getting older, considering probability of street blockade in the paths.

1.3 Previous study

Most of the traditional towns are such as dense cities with wooden buildings, where disaster vulnerability is one of the problems. Disaster problems of dense city with wooden buildings have been studied from several aspects, such as fire prevention, simulation of fire spread, street blockade by building collapse, and evacuation.

As per fire prevention, Hamada (1951) is one of the pioneers who studies velocity of fire spread to consider wooden building. Horiuchi (1994) proposes velocity of fire spread especially for fireproof wooden building. Based on these studies, many researchers study fire spread at dense city with wooden buildings. Itoigawa et al. (1988, 1989 and 1997) study fire spread behavior in case of urban area and develop its simulation methodology to find fire prevention method. Physics-based urban fire spread model is also developed (K. Himoto and T. Tanaka, 2006, 2008). To make urban improvement plan for prevention from urban fire spread at large earthquake, Kato et al. (1999a, 1999b, 2000) study theoretical

technology using percolation model and develop an evaluation methodology that they apply to real data of urbanized area. Abe et al. (2003 and 2004) also study and propose an idea of fire spreading network to find appropriate urban improvement planning using real data. The author studies also a proposal and its evaluation of fire spreading prevention for a historic area considering traditional building style of the model area (Mishima and Taguchi, 2011).

As per street-blockade at earthquake, Ieda et al. (1997) study the case of Hanshin Earthquake in 1995 and point out its influence on disaster relief activities. Imaizumi and Asami (2000) develop a model to estimate probability of street blockade caused by building collapse and propose a method to evaluate urban improvement policies for disaster prevention. Ichikawa et al. (2004) analyze accessibility to spaces for disaster refuge considering danger of street-blockades caused by collapse of buildings on evacuation routes. They make a model of building collapse to analyze street blockades. Regarding historic city, Ogawa and Tsukaguchi (2006) extract important streets for cultural heritage in Kyoto to prevent from disaster and propose monitoring system. Kamei et al. (2009) evaluate accessibility to cultural heritages in road blockade caused by earthquakes in Kyoto City proposing a simulation model to estimate detailed attributes of each building by combining multiple data sets. Ahn et al. (2011) assess disaster risk viewing from cultural heritage disaster mitigation in historical cities. They evaluate the routes connecting fire stations and cultural heritages based on the condition of buildings along the roads and the spread blockade rate.

Evacuation at disaster is very important research field to study (Roussel, 1980). Numerous researchers study on evacuation from different aspects. As per evacuation decisions, Doheny and Fraser (1996) develop a modeling tool of decisions that people make in emergency situations in offshore environments. Kim et al. (2007) study evacuation route planning. Regarding historic area to be preserved, Toyoda et al. (2009) propose possibility of increasing safety by opening a shrine that centers in his study area in Kyoto as an emergent evacuation place. The authors commit a series of studies on evacuation route for a historic town with traditional buildings (Mishima et al. 2012, 2013a, 2013b, 2013c, 2014). In the previous study, the authors indicate that an essential problem of historic area could be solved through maintaining an open space in the center viewing from current condition (Mishima et al 2014). On the other hand, the authors compare two measures, maintenance of the centered open space (Fig. 1) and improvements of high windows only focusing on persons in need of aids (hereafter PNs), and indicate that the measures are

efficacious with limitation for vulnerable people who cannot walk (2013a). Yet, considering the preservation of traditional town, it is necessary to make clear how useful the maintenance of the centered open space is at large disaster in which streets are blocked by rubble of broken buildings, and then we can say the methodology of spatial evacuation route planning for the traditional town has been established.

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Several researchers also study urban disaster problems in lowland area such as flood, storm, and transportation. Adib et al. (2011) propose flood inundation modeling for flood management by combination of 2D hydrodynamic model and flood mapping. I-soon et al. (2011) analyze hazard risk level of storm surge risk and evaluate potential evacuation in Bangkok using GIS. Also, Iamtrakul and Hokao (2012) study on urbanization pattern to evaluate road safety.

The authors commit a series of studies on evacuation route for a historic town with traditional buildings (Mishima et al. 2012, 2013a, 2013b, 2013c, 2014). In the previous study, the authors indicate that an essential problem of historic area could be solved through maintaining an open space in the center viewing from current condition (Mishima et al 2014). On the other hand,

Fig. 1. An example of open space to be maintained for evacuation at disaster such as large earthquake also with fire. This open space is called "Gaboi wetland" located in the center of the study area (see Fig. 3) as a vacant space without buildings because it is often flooded when heavy rain. (Mishima et al. 2013a).

the authors compare two measures, maintenance of the centered open space (Fig. 1) and improvements of high windows only focusing on persons in need of aids (hereafter PNs), and indicate that the measures are efficacious with limitation for vulnerable people who cannot walk (2013a). Yet, considering the preservation of traditional town, it is necessary to make clear how useful the maintenance of the centered open space is at large disaster in which streets are blocked by rubble of broken buildings, and then we can say the methodology of spatial evacuation route planning for the traditional town has been established.

2. Methodology

2.1 Study area

We set a study area to discuss the problem as a model mentioned above. The area is a traditional local lowland town called Hamashozumachi Hamakanayamachi (hereafter, HaH), which has been supported by the Japanese government since 2007 as an important preserved district of traditional buildings under Cultural Properties Protection Law of Japan, especially evaluated its characteristics as a local town lined with thatched houses and tile-roofed houses as shown in Figs. 2 and 3. The area is 2.0ha.

This area is a part of Hizenhamashuku (hereafter, HaS.) as named by local leaders for revitalization of the area, which is located in the south of Kashima City, Saga Prefecture, Japan. The lead author has worked for HaS as both an advisor and a planner to promote its preservation, cooperating with the city authorities and representatives of the residents since 1999, for example, conducted surveys of traditional buildings, renovation of the buildings, innovation of the town,

In the center of the study area, there is a big open space that is called "Gaboi wetland." The reason why there is no building standing is that the place is historically often flooded by water comes when heavy rain. We have set this open space in the center of the area as a temporary safe place also in the previous study. Then, although we have also discussed its possibility with Kashima city authority, it has been not realized yet because all residents of the area including the land owner of the open space should accept the idea, Therefore, it is crucial to show the possibility and limitation of using the open space as a temporary safe place, even though the open space is a wetland of the lowland town.

To preserve the preservation area, Kashima City enacted the relaxation ordinance of building standard law.

As an alternative, it is obligated to provide two exits for each traditional house. Two-way evacuation routes from each house to a designated final evacuation place are not determined but should be advisable considering large-scale disasters that bring street blockades.

Here, near this area, a fault called Sae Fault (3.5km length and low activeness) was found. Handa (2011) pointed out that the low-resistivity belt was found in Sae Fault. So, the area is facing to potential dangerousness of earthquake in a little less than seismic intensity of 7.

Fig. 2. Thatched houses in the study area. The area is preserved as a local town lined with thatched houses and tile-roofed houses.
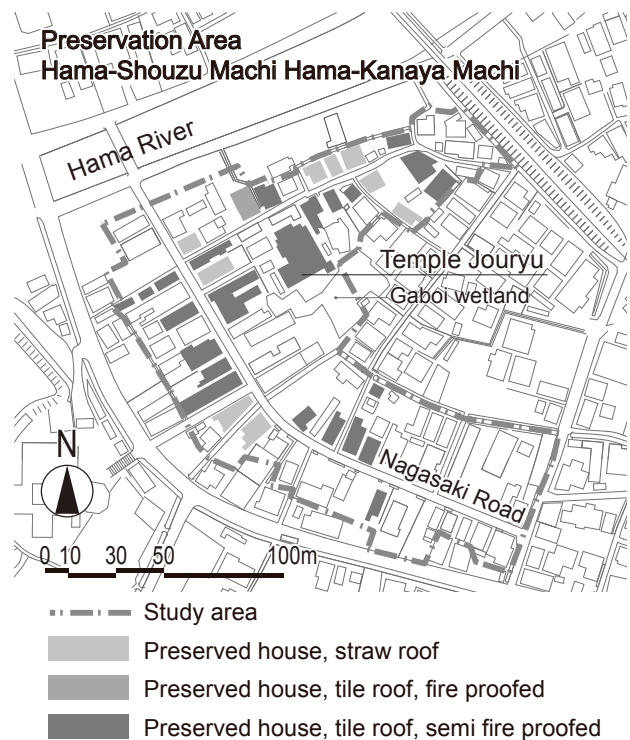
Fig. 3. Preserved houses in the study area (Mishima et al. 2014).

2.2 Framework and flow of analysis

To achieve the aim of study, we analyze the current condition of vulnerability of model area. Then, we discuss how to consider the improvement of the open space at the center of the study area. Here, we show a framework and flow of the analysis as shown in Fig. 4:

Target: *To shorten evacuation time without damage to historic value*

Probability of street blockade

Setting street blockades
to check evacuation routes

Simulation of evacuation route
using Sim Tread

Comparison of evacuation time

Normal persons (NPs)
Persons in need of aids I (PNs I)
Persons in need of Aids II (PNs II)

Current condition

Nonstreet blockade

Blockade Path A

Blockade Path B

Blockade Path A and B

Measure: Maintenance of open space at the center

Nonstreet blockade

Blockade Path A

Blockade Path B

Blockade Path A and B

Within 7 min, within 10 min, or over 10 min.

This paper

Conclusion of the previous study: Effect of maintenance of the open space that exists at the center in the study area
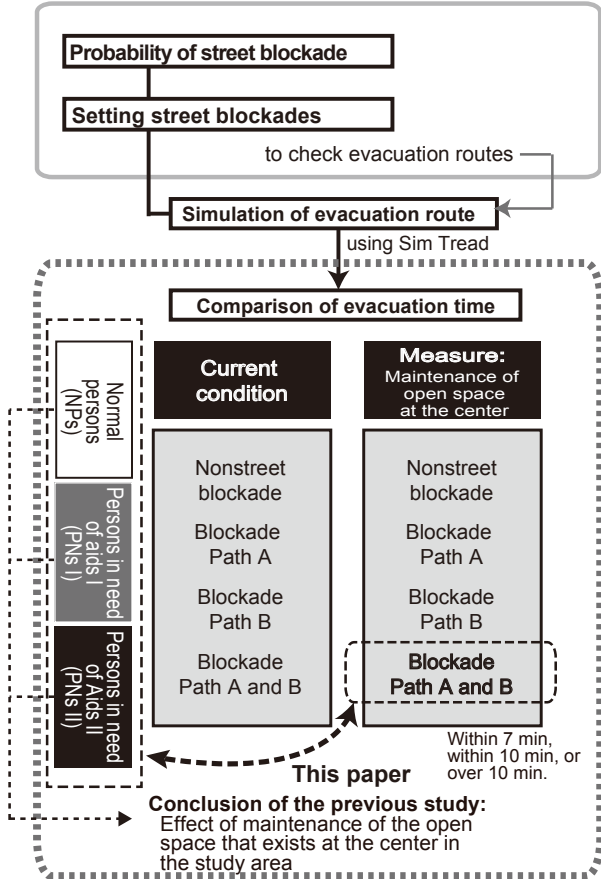
Fig. 4. Framework of Analysis in the study. Here in the paper, we set street blockades of path A and B, simulate evacuation time of normal persons and persons in need of aids, and evaluate.

1) First, we survey street blockade considering the structure of traditional buildings to set the probability of street blockade (hereafter, PSB) in the study area as the detail is mentioned below. Considering the result, we set the street blockades for simulation of walking. Here, we set two street blockades (Path A and B).

2) Second, we simulate walking time from each house to an evacuation place set by residents in case of after maintenance of the centered open space, comparing among normal person and persons in need of aids (possible and impossible to walk, hereafter PNs).

3) We evaluate the walking time, based on the time in which fire engine can reach the study area after alarm

within 10 min. Hopefully, people are expected to arrived at a temporary evacuation place within 7 min. Considering the time, we set the evaluation time of evacuation routes such as within 7 min, within 10 min, and over 10 min.

3. Street blockade

3.1 Direction of rubble flow

Here, we set direction of rubble flow to calculate PSB considering collapse of Japanese traditional building by earthquake arise from Sae fault in the study area.

Sakata and Teraki (2009) studied a simulation for road blockage considering direction of rubble flow, but they did not consider structure of traditional building. Regarding street blockade by collapse of traditional building, direction of rubbles based on structure of traditional building should be considered.

Normally, Japanese traditional town house takes wooden frame structure, which has stronger direction and weaker direction of wall. Namely, the side facing to the main street is generally weaker than the other side, because the main side has entrance and window. What the other side is largely covered with earth wall makes stronger as shown in Fig. 5.
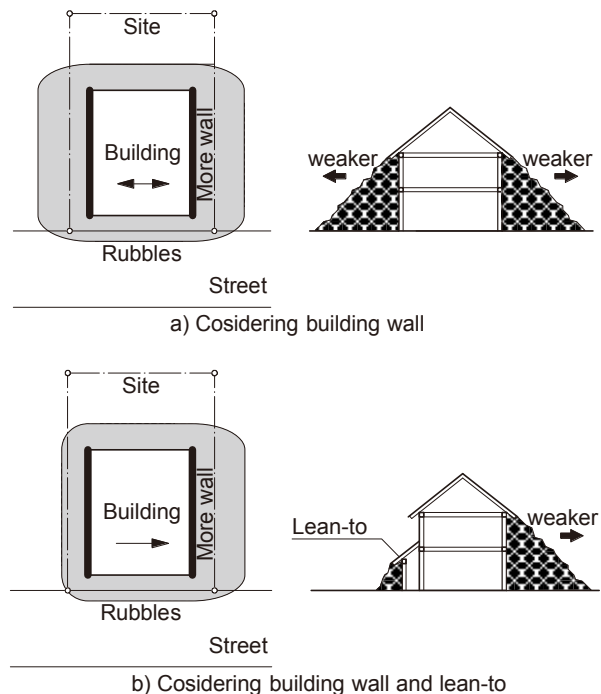
a) Cosidering building wall

b) Cosidering building wall and lean-to

Fig. 5. Direction of rubble flow considering traditional wooden frame structure.

3.2 Probability of street blockade (PSB)

PSB is according to the table on probability of fully collapse of wooden buildings issued by Cabinet Office, Government of Japan (See Table 1).

**Table 1.** Probability of fully collapse of wooden buildings. (http://www.bousai.go.jp/kaigirep/hakusho/h22/bousai2010/html/zuhyo/zuhyo017.htm)

Building year	Wooden		Non-wooden	
Seismic intensity	6-odd	7	6-odd	7
Before 1961	18%	80%	2.9%	19%
1962-1971	10%	60%	2.9%	19%
1972-1981	10%	60%	2.6%	15%
After 1982	1%	15%	0.6%	4.6%

Using these probabilities, we calculate PSB as followings. If there are two buildings, that is building A and building B, which collapse and the rubbles may pile up, the PSB by collapse buildings A and B (Pab) is:

$$Pab = 1 - (1 - Pa)(1 - Pb) \qquad [1]$$

where, Pa = PSB by collapse of building A, and Pb = PSB by collapse of building B.

We checked building year and structure of the existing buildings in the study area, then calculate PSB using the mentioned-above formula, to know the vulnerability of the study area at a large earthquake as shown in Fig. 6.
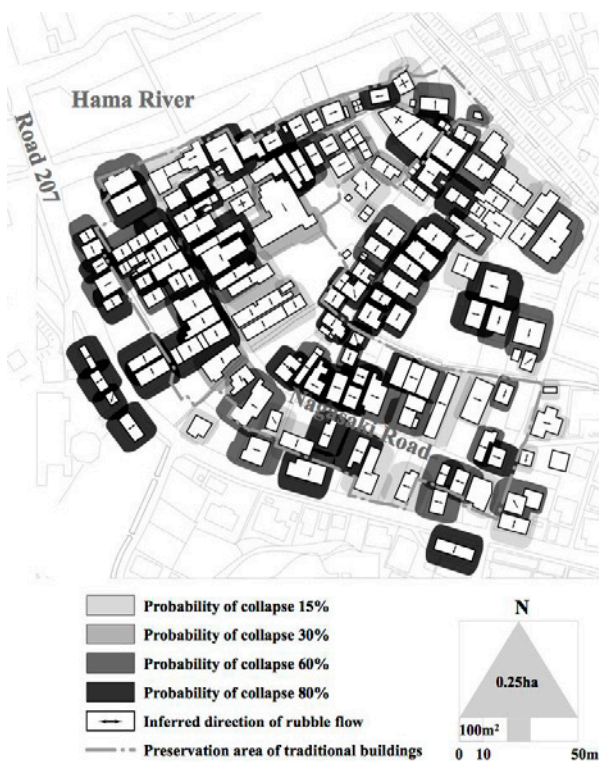
Fig. 6. Probability of street blockades (PSB) in the study area.

### 4. Analysis of evacuation time

4.1 Setting of analysis

For simulation of walking time, we surveyed temporary safe places and primary evacuation place based on residents' perceptions. A temporary safe place was a neighboring place or site where the evacuee could be temporarily secure against a disaster at his or her own house. A primary evacuation place was defined as a location where evacuees should come together for safety as soon as possible after a disaster happens. These were obtained by interview to the residents of the study area as shown in Fig. 7.

4.2 Setting of street blockade

Based on the PSB, we set street blockades for simulation of walking in the area, namely we supposed that two streets were blocked by rubble of broken houses as shown in Fig. 8. Both of them are the narrowest streets in the area. Using the set of the street blockade, we calculated the evacuation time from each house to a primary evacuation place.

The houses we calculated evacuation time were the houses where we could conduct interview survey of the residents' perception on evacuation route when large fire occurred, as shown in Figs. 7 and 8.
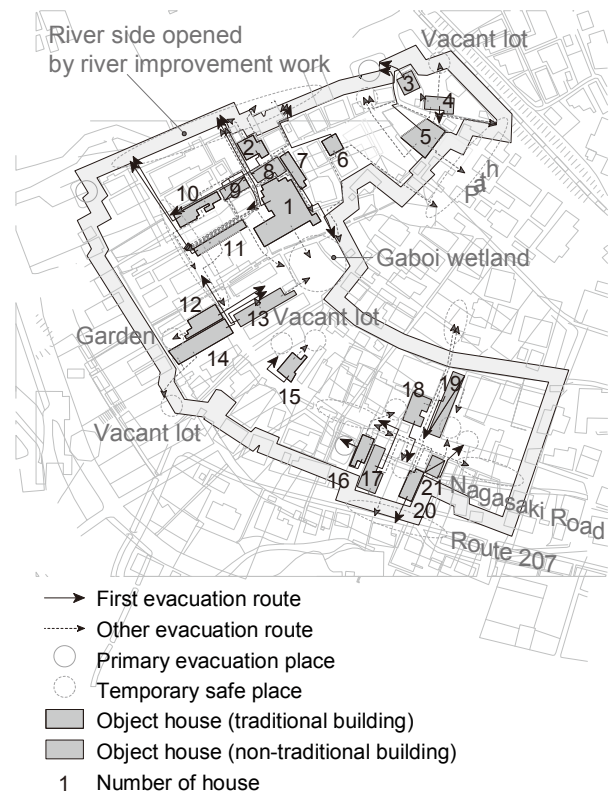
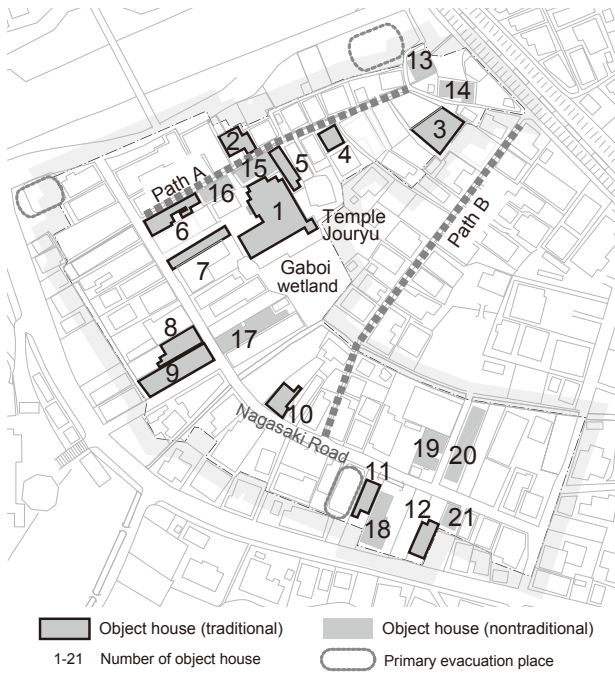**Fig. 7.** Temporary safe place and primary evacuation place (Mishima et al. 2014).

Fig. 8. Setting of street blockade for simulation.

4.3 Consideration of barriers in the study area

In the study area, there are several barriers beyond which it is difficult for persons to go, such as steps, high windows, weedy wetland and etc. We took fire drill to know the velocity in barriers on February 13, 2011. It was carried out in cooperation with the residents of the study area and Kashima City authority to identify problems with evacuation routes and to let the residents learn evacuation at disaster (see, Figs. 9 and 10).

In the fire drill, we could measure the differences in barrier among NPs, PNs I, and PNs II. According to the measurement, PNs I take 5 times and PNs II take 10 times as long as normal persons.

Fig. 9. Primary evacuation place (The photo of evacuation drill).

Fig. 10. A scene of evacuation drill in the study area (2011).

4.4 Walking velocity

We set walking velocities in normal persons (NPs), persons in need of aids I (PNs I), and persons in need of aids II (PNs II), respectively. As per velocity of NPs, we used 1.3m/s determined in Japanese verification methods for determining safe evacuation of a floor or building. The velocity of PNs I was deliberated to be the normal pace of older adult, and that of PNs II was considered to be the pace of those who have difficulty in walking like the physically handicapped or infants, as follows.

Table 2. Walking velocities in simulation.

Normal persons (NPs)	1.30 m/s
Persons in need of aids I (PNs I)	1.00 m/s
Persons in need of aids II (PNs II)	0.50 m/s

4.5 Result of simulation

We used a multi-agent system, namely walking simulation software "Sim Tread 1.0" for CAD "Vectorworks 11" sold by A&A Co., Ltd. to analyze the walking time using software that was on the market. The evacuation route was, in principle, from an exit or a window of a house to a primary evacuation place through

the temporary safe place mentioned above, in consideration of securing two-way evacuation routes as shown in Fig. 11.

The results of the simulation were as followings:

1.   The NPs could walk to a primary evacuation place almost within 7 min except only one route that goes through the open space "Gaboi wetland."

2.   The PNs I could almost walk to a primary evacuation place within 10 min except three routes that go through the open space "Gaboi wetland."

3.   Most of the PNs II took more than 10 min to a primary evacuation place, that was, not only routes through the centered open space but also roundabouts.

5.   Conclusions

The previous study shows that current problem of the study area is to maintain open space at the center of the area "Gaboi wetland", and that two measures for securing two-way evacuation routes, namely the maintenance of the centered open space and improvements of high windows, are efficacious with limitation for PNs II to evacuate from each house to a primary evacuation place. Nevertheless, viewing from, the calculation results of evacuation time this among NPs, PNs I, and PNs II in this study, the maintenance of the open space at the center of the area in lowland is one of the useful methods especially for NPs and PNs I. Comparing severe street blockade, the results tells us that the vulnerability of the study area is mainly the issue of persons in need of aids who cannot walk (PNs II). Therefore, the maintenance of the open space at the center of area should be considerable for the traditional town to prevent from disasters for NPs and PNs I strategically, because the wetland of lowland is difficult place for building. Besides, the other measurement for PNs II, for instance to grasp their whereabouts and to use the public aids, should be developed.

In this study, we have not simulated in all cases of street blockade, so we have not revealed all of the problems in the area viewing from street blockade and PNs. Moreover, we have just simulated only for one study area, so the results of this study is limited in the study area. Nevertheless, we have found the problems of the study area, e.g., PNs II cannot evaluate in good time and also limitations of measures for developing evacuation route planning in a traditional town. That is, a series of our study are considerable and helpful as a model to find a good method not only for securing evacuation route but also for pointing out any problems of traditional lowland towns with narrow streets and open spaces such as wetland at the center of the area.
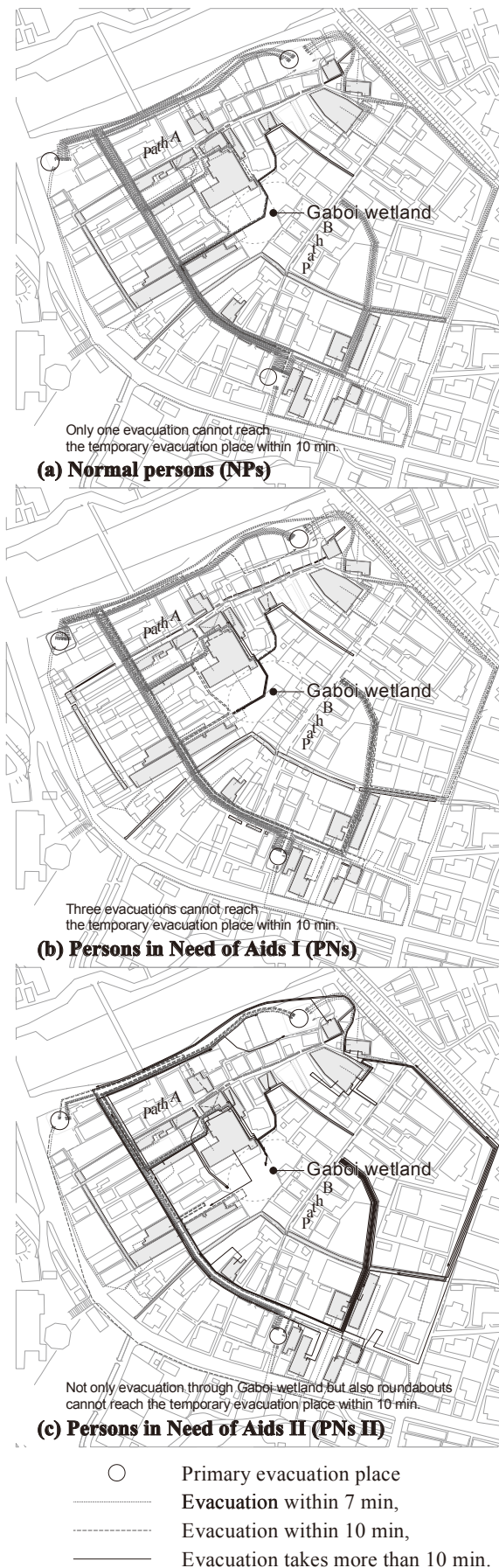

Fig. 11. Results of calculation of evacuation time.

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Symbols and abbreviations

HaH.	Hamashozumachi Hamakanayamachi
HaS	Hizenhamashuku
NPs	Normal persons
PNs	Persons in needs of aids
PSB	Probability of street blockade
Pa	Probability of street blockade by collapse of building A
Pb	Probability of street blockade by collapse of building B
Pab	Probability of street blockade by collapse of buildings A and B