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No.428

京都市における非常住者人口を考慮した避難計画の分析と提案

An Analysis and a proposition of Evacuation Plan Considering Non-Resident People in Kyoto City

今年度は，京都市の昼夜間人口分布とパーソントリップ調査結果のデータベースを整備し，都心5 区（上京区・中京区・下京区・東山区・南区）における帰宅困難者と徒歩帰宅者の推計，および帰宅流動シミュレーションを行った。

帰宅困難者は都心部と京都駅周辺に集中することを明らかにした。また，震災時においては，市内の観光地に滞在している観光客は宿泊地に全員帰ると設定し，京都市観光調査年報に基づき，都心部に帰る観光客数の合計は約 14 万人という推計結果を得た。さらに，道路データを作成し，徒歩帰宅者約 52 万人と観光客数約 14 万人と合わせて流動シミュレーンを行い，流動が集中する箇所を描出した。

研究成果はコペンハーゲンで開催された国際学会で発表したので（下記参照），次ページ以降にその内容を添付する。

Kaoru Matsumiya, Saki Okamura and Kiyoaki Oikawa

Estimation of nonresidents and the stranded commuters in the Center Area of Kyoto City

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Estimation of nonresidents and the stranded commuters in the Center Area of Kyoto City

Kaoru Matsumiya, Saki Okamura, Kiyoaki Oikawa

***Abstract*—**Kyoto is one of the most popular tourist destinations in Japan and is visited by many tourists as well as nonresidents. Severe traffic congestion caused by natural disasters may cause many commuters and tourists to be stranded ("stranded travelers" hereafter). In urban disaster prevention planning, there is a need for measures to help them return home or safely evacuate them to temporary shelters.

In this study, we aim to estimate the population away from homes during the day and the distribution of tourists in various destinations within Kyoto, perform a traffic simulation of people returning home, and quantitatively analyze the traffic patterns and characteristics of people traveling long distances. This will enable us to obtain basic data that can be used to implement measures for stranded commuters.

The results show that the flow of pedestrian evacuees is extremely concentrated and may lead to significant chaos.

***Keywords*—**stranded commuters, person trip survey, disaster prevention planning, Kyoto city

I. INTRODUCTION

A. Background and purpose of this research

THE Tohoku earthquake that struck Japan on March 11, 2011 originated in the Pacific Ocean off the coast of the Tohoku region. The earthquake caused many casualties, affected victims, and terrorized the entire country. With a seismic intensity of 5, the Tokyo metropolitan area experienced significant traffic congestion due to a shutdown of public transportation and regulations aimed at ensuring public safety and preventing direct damage by the earthquake. Because the disaster occurred during the daytime on a weekday, many commuters became stranded in the metropolitan area. According to the announcement by the Cabinet Office, a total of 5.15 million people were unable to return home on the day of the earthquake in the metropolitan area, including Tokyo, Kanagawa, Chiba, Saitama, and Ibaraki Prefectures. This accounted for 28% of the people who were outside their homes at the time of the earthquake. In urban disaster prevention planning, there is an urgent need for measures to help them return home on foot or to safely evacuate them to temporary shelters.

In this study, we aim to estimate the number of persons who are away from their homes during the day and the distribution of tourists at various destinations within Kyoto, perform a traffic simulation of people returning home, and quantitatively analyze the traffic patterns and characteristics of tourists traveling long distances to return to their homes. By doing so, we hope to obtain basic data that can be used to implement measures for stranded commuters.

Each year, more than 50 million tourists visit Kyoto, which is one of the most popular tourist destinations in Japan. Many companies and schools are located downtown, and there is a significant difference between daytime and nighttime populations due to a large number of commuters. If a disaster occurs in Kyoto and causes significant traffic congestion similar to the Tohoku earthquake, many persons may become stranded, including tourists who are not familiar with the city.

B. Positioning of this research

Previous studies have analyzed the patterns of stranded commuters on the basis of personal trip surveys (PT surveys). Assuming the occurrence of a major disaster in the Tokyo metropolitan area, Akimoto et al. estimated the number of stranded commuters, performed a behavioral simulation of people returning home, and statistically summarized traffic and the characteristics of tourists traveling long distances to return to their homes.

This study is different from previous studies in that we have focused on Kyoto, a tourist destination, to understand the flow of traffic and have included not only stranded commuters but also tourists.

II. ESTIMATION OF POPULATION AND ITS HOURLY DISTRIBUTION CHARACTERISTICS

A. Daytime population distribution and estimates from the personal trip survey

Figure 1 shows that the daytime population of Kyoto is concentrated in five central wards: Kamigyo, Nakagyo, Shimogyo, Higashiyama, and Minami-ku. In this study, we have limited our analysis to these five wards.

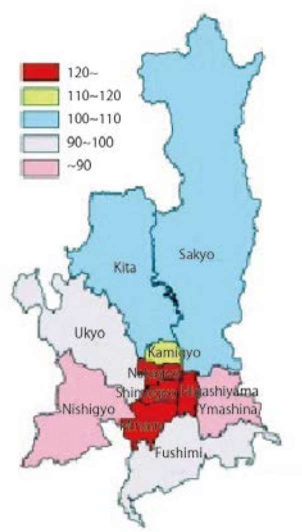

Fig.1 Breakdown of daytime and nighttime populations

Further, we have used the PT survey for the estimation of population. Because the OD matrix of the PT survey was collected for each district, the five central wards were divided into districts and streets. Also, the buffer zone spanning 20 km from the five wards was divided into the smallest possible units of towns and

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wards. The population was prorated on the basis of the number of commuters and daytime population. In addition, the OD matrix of the PT survey was divided on the basis of the purpose of the trip, such as commuting for school, work, pleasure, and business. The pleasure and business populations were prorated only on the basis of the daytime population.

B. Hourly population characteristics

1) Nighttime population

We represent nighttime population based on where people sleep at night. The nighttime population of Kyoto is approximately 1.46 million. The population densities of Kamigyo, Nakagyo, and Shimogyo-ku exceed 10,000. We observed that the population is concentrated in these three wards. Table 1 shows that the influx of the population from outside the city because of commuters is higher than the outflow.

Table 1 Nighttime populations, population influx, and outflow of Kyoto

	Nighttime population	Area (km²)	Population density (/ km²)	Population outflux	Population influx	Net population flux
Kytoto	**1,460,688**	**827.9**	**1,764**	**118,297**	**240,589**	**122,292**
Ward						
Kita	123,747	94.92	1,304	5,646	16,968	11,322
Kamigyo	82,765	7.11	11,641	4,397	15,916	11,519
Sakyo	167,933	246.88	680	9,842	20,591	10,749
Nakagyo	101,518	7.38	13,756	7,080	32,504	25,424
Higashiy	42,096	7.46	5,643	2,639	10,777	8,138
Yamashir	136,277	28.78	4,735	12,267	10,239	2,028
Shimogy	73,706	6.82	10,807	5,828	39,483	33,655
Minami	98,055	15.78	6,214	8,248	30,138	21,890
Ukyo	196,112	291.95	672	11,836	16,678	4,842
Nishikyo	153,460	59.2	2,592	16,963	8,612	8,351
Fushimi	285,019	61.62	4,625	33,551	38,683	5,132

2) Daytime population and ratio of daytime and nighttime populations

The nighttime population after the influx and outflow due to commuting is called the daytime population.

Table 2 shows that the total daytime population of Kyoto exceeds its nighttime population. In particular, the daytime populations of the five central wards are much higher than their nighttime populations.

Table 2 Daytime population and ratio of daytime and nighttime populations

Ward	Daytime population			Ratio of daytime
	Total	Male	Female	
Kyoto	**1,582,980**	**766,815**	**816,165**	**108.4**
Kita	128,308	61,039	67,269	103.7
Kamigyo	98,864	47,009	51,855	119.5
Sakyo	170,961	81,649	89,312	101.8
Nakagyo	159,055	80,885	78,170	156.7
Higashiyama	58,184	22,824	35,360	138.2
Yamashina	117,623	53,811	63,812	86.3
Shimogyo	140,624	70,753	69,871	190.8
Minami	140,119	83,265	56,854	142.9
Ukyo	182,207	86,416	95,791	92.9
Nishikyo	119,382	51,297	68,085	77.8
Fushimi	267,653	127,867	139,786	93.9

3) Hourly population characteristics

The combined daytime population of the five central wards (600,000) is 1.5 times that of its nighttime population (less than 400,000). On the other hand, the combined population of the other six wards decreases by approximately 200,000 during the day, as shown in Figure 2.

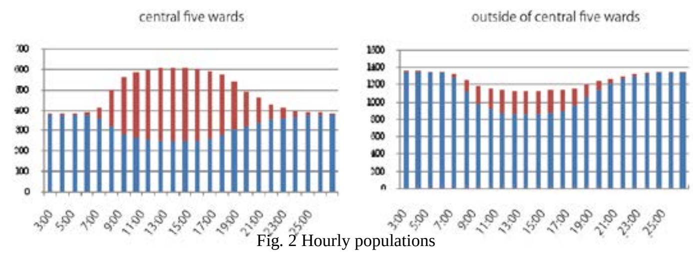

Fig. 2 Hourly populations

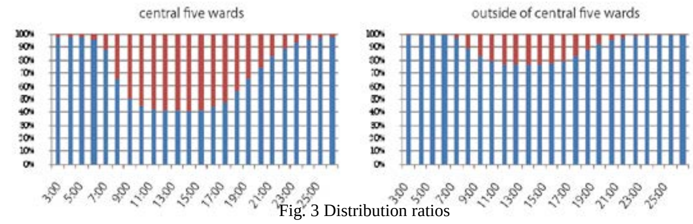

Fig. 3 Distribution ratios

Figure 3 shows that more than 50% of the population in the five central wards between 9 am and 6 pm are nonresidents, which may give rise to stranded commuters in case of a major disaster.

III. Estimation of Stranded Commuters and Flow of Pedestrian Traffic Returning Home

A. Estimation method of the number of stranded commuters and flow of pedestrian traffic returning home

According to the Cabinet Office, stranded commuters are defined as those who stay or move a certain distance away from home. In this paper, we assumed that within an area of 10–20 km away from home, every kilometer away from home decreases the pedestrian traffic returning home by 10%. In addition, from the results of the PT survey, people staying or moving were added together without distinction, and the population returning home from the five central wards (approximately 720,000 people) was regarded as the staying population.

When creating the OD matrix, the street-level population was regarded as the leaving population, and the arriving population was distributed according to the nighttime population. In addition, the distance from home was estimated by the distance between the centers of gravity of the origin and destination street polygons.

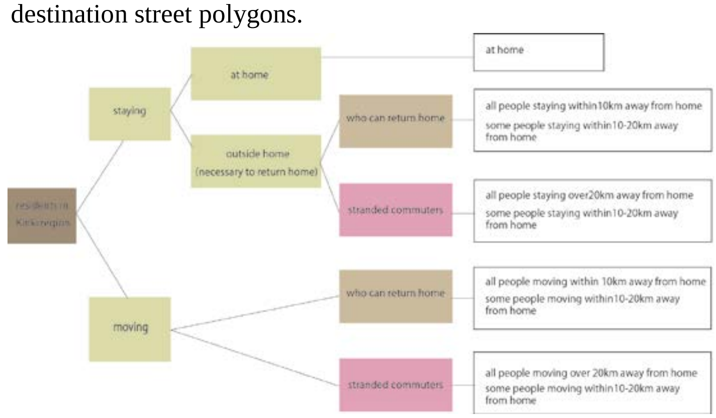

Figure 4 Definition of stranded commuters and travelers

B. Distribution of stranded commuters

The estimation results show that there were 200,000 stranded commuters, and the total number of pedestrians returning home was 520,000 in the five central wards. The population density distribution of the stranded commuters was concentrated around Karasuma Oike, which has many companies (Figure 5). In the areas around Kyoto Station and Shijo Karasuma, which are expected to have a large number of stranded commuters, measures are required to secure temporary waiting areas and buildings that can serve as shelters for those who cannot stay in the buildings.

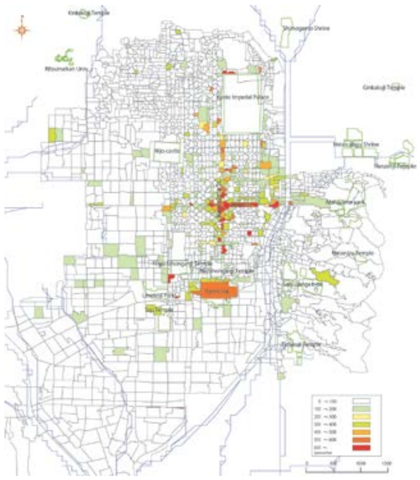

Fig. 5 Distribution of stranded commuters and travelers

C.. Simulation of pedestrian traffic returning home

On the basis of the created traffic data, we ran a traffic flow simulation of approximately 520,000 pedestrians returning home. We assumed that the shortest route was chosen for returning home and calculated the amount of flow for each day. Further, we did not consider the road capacity and assumed no speed decline due to congestion. Figures 6 and 7 show the distributions of the moving population (the population returning home) and the population after displacement (the population of the area to which commuters return). We found that the moving population as well as the stranded commuters are highly concentrated around Shijo Karasuma, whereas the pedestrian population returning home is uniformly distributed over the entire city. Thus, the city center has a combination of stranded commuters and pedestrians returning home.

The simulation results of the traffic flow returning home in Figure 8 show a large traffic flow between Shijodori Street and Kyoto Station, which is especially concentrated on the bridge over and the road along the Kamo River. Because the roads of Kyoto form a grid-like pattern, choosing any road can yield the shortest route home if the road capacity is not considered. Because the east–west movement requires travelers to cross the bridge, the traffic flow distribution is also concentrated on the bridge. In addition, the population of stranded commuters and the moving population returning home are concentrated around Shijo Karasuma, and the traffic flow tends to increase further south past Sanjo, Shijo, Gojo, Nanajo, and Kyoto Stations. This is because many people return home to southern Kyoto over long distances.

IV. Estimation and Traffic Flow Distribution of Tourist Evacuation

A. Tourist distribution and the OD matrix

On the basis of the Annual Report on the Kyoto Tourism Survey, we assumed that all tourists in major tourist attractions return to their accommodation[1)] and created an OD matrix for the returning routes. Accommodations were allocated on the basis of the ratio of the number of hotels in the five central wards. The total number of tourists was slightly below 140,000. Table 3 shows the leaving population.

Table 3 Number of tourists

Kiyomizu Temple	17177	Heianjingu Shrine	4685
Arashiayama	13101	Kyoto City Museum	3764
Kinkakuji Temple	9567	Chion-in Temple	3682
Ginkakuji Temple	7824	Kyoto Imperial Palace	2745
Nanzenji Temple	7446	Sanjusangendo	3255
Kodaiji Temple	5950	Nishihonganji Temple	2679
Yasaka Shrine	5950	Shimogamo Shrine	3781
Sagano	5096	Ryoanji Temple	2334
Nijojo Castle	5983	Nishiki Market	2088
Kurama, Kibune	4849	Fushimi Inari Shrine	2192
Ohara	4570	Higashi Honganji Temple	2581
Kyoto Station	4093	Seirenin	1890
Shijokawaramachi	4504	Tofukuji Temple	1808
Toji Temple	4405	Total	138000

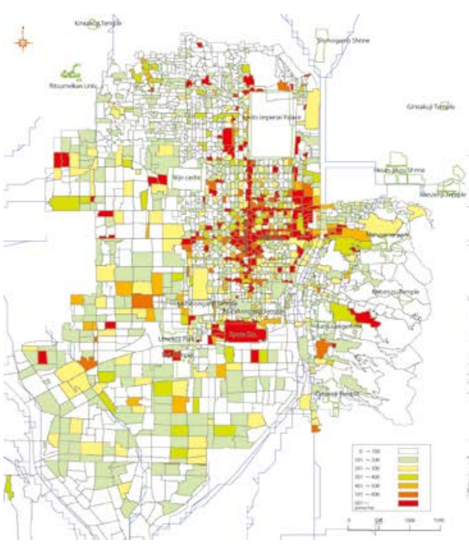

Fig. 6 Distribution of the moving population

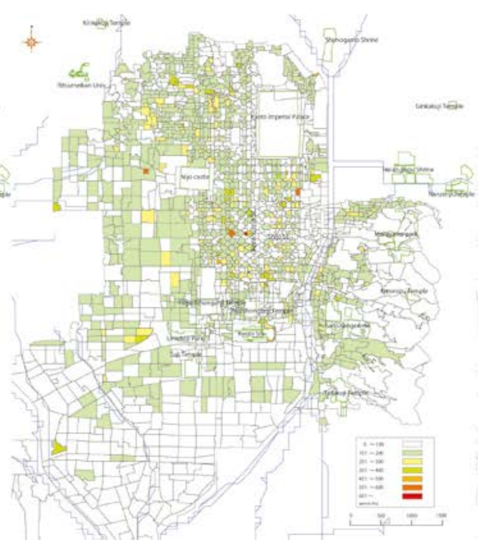

Fig. 7 Distribution of the population after

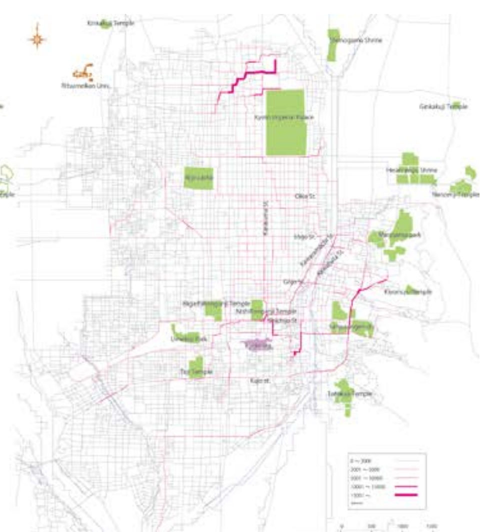

Fig. 8 Traffic flow returning home displacement

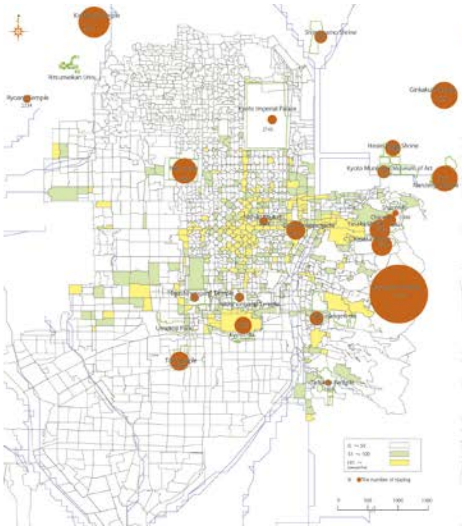

Fig. 9 Population distribution based on tourist arrivals

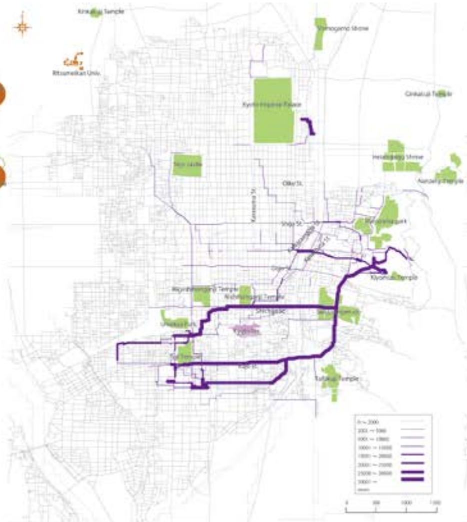

Fig. 10 Flow of tourist traffic

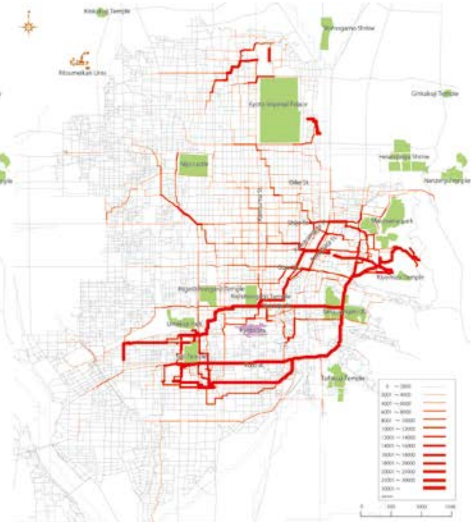

Fig. 11 Total traffic flow returning to accommodations

B. Simulation of the traffic flow returning to accommodations

The simulation results for the homeward-bound traffic flow in Figure 10 show that the traffic flow tends to concentrate on Nanajodori and Kujodori running west from Higashiojidori, which has many temples and shrines. This is because the flow of tourists is concentrated on the bridges to evacuate from Higashiyama Kiyomizu and surrounding areas toward the west. Because the flow is concentrated on all bridges south of Shijo, evacuation measures regarding the bridges over the Kamo River are a major issue.

C. Traffic flow simulation involving all evacuees

The combined flow of returning commuters and tourists in Section 3 is concentrated on the bridge over the Kamo River and the streets running east and west, which is consistent with both individual distributions (Figure 11). These results indicate the need to set up temporary waiting areas and systems that facilitate guidance and assistance along the Kamo River and around the Kyoto Station with a high concentration of pedestrian traffic returning home. Further, more public shelters are needed to prevent chaos due to many people simultaneously evacuating on foot. Because Kyoto has numerous temples and shrines that are easily accessible by tourists who are unfamiliar with the city, one possibility is to use them as temporary waiting areas to eliminate such chaos.

V. CONCLUSION

In this study, we focused on nonresidents and tourists in central Kyoto to estimate the number of stranded commuters after a major natural disaster, perform a traffic flow simulation for pedestrian travelers returning home, and to identify problems that may occur with evacuation measures. As a result, we found that the pedestrian traffic flow may be extremely concentrated during evacuation. We also found that the streets with the most traffic flow were Higashiojidori, running north and south, as well as Gojodori, Nanajodori, and Kujodori, running east and west. The flow is especially concentrated on the bridge over the Kamo River, and all bridges south of Nijo have more flow than the surrounding streets. This is because it is necessary to cross the Kamo River to move east or west in Kyoto, causing the concentration of pedestrian traffic on the bridges. The pressing issue is to build temporary waiting areas and develop systems facilitating guidance and assistance along the Kamo River and around the Kyoto Station, with concentrations of pedestrian traffic returning home.

In recent years, evacuation measures for stranded commuters have been rapidly developed in Kyoto. In the future, we aim to analyze in depth the data for the entire city of Kyoto and perform simulations with higher accuracy.

NOTE

1) In actuality, not all tourists walk back to their accommodations; many tourists are expected to be stranded. Here we set simple conditions to obtain a rough estimate of the traffic flow.

REFERENCES

[1] Nobuhiro Akimoto, Noriyuki Izumi: An analysis on stranded commuters using PT survey data: For consideration of disaster mitigation measures, Research Activity Report, IBS Annual Report, 2011

[2] Keiichi Ogawa, Masahiko Kan, Takaya Maekawa, Hiroshi Tsukaguchi, Takahiro Yasu: A study on the travel behavior of tourists for evacuation planning in historical cities, Proceedings of the Disaster Mitigation of Urban Cultural Heritage, 5, 61-68, 2011

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