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PEDESTRIAN TRANSPORT PLANNING

- PLANNING SIGN SYSTEM BASED ON BEHAVIORAL ANALYSES -

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PEDESTRIAN TRANSPORT PLANNING

- Planning Sign System based on Behavioral Analyses -

by

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With

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Preface

Recent innovations in communication technology have given rise to a range of navigation tools to assist the general public and system providers. This is much different from historical times when pilgrims had to rely on word of mouth or follow knowledgeable guides (for example to Santiago de Compostela in Europe; Mecca in Middle East and Ise-mairi in Japan). Some of these sites are even more popular and accessible now and there are many who elect to perform the pilgrimage the old-fashioned way. In essence, providing an adequate system of signs to manage pedestrian flows are important for users as well as administrators of large crowd attractors such as recreational parks and cultural venues. Similarly, sign systems are an integral part of management of pedestrian flows in localized properties including transport hubs, shopping complexes, employment hubs, educational centers and, hospitals.

Importance of pedestrian circulation is not well understood among system planners including transport professionals. Signage system design is reliant on little scientific foundations. Signage systems are expressly necessary at every area where a lot of persons visit with various purposes, for example, famous tourist areas, busy central areas of large cities and so on.

Recently many persons use GPS navigation system especially in younger generations. Such system is very convenient and plays an important role to give precise information to visitors. On-site sign system composed of several types of sign boards can offer suitable information on attractions tourists wanted to visit, at the same time, the system can give all passengers a better understanding of structure of the areas. On-site sign system discussed in this document and GPS navigation system have different characteristics and are of importance together.

Signage systems are important in both of ordinary times and emergency times. Signs for ordinary times play an important role to decrease getting lost, and at the same time, encourage circulation at the surrounding area. On the other hand, the emergency system is focused on getting out of danger. Therefore, it may be appropriate to discuss them separately. This project team adopts the former as the issue to be discussed, and the following two subjects have been selected:

i) A world heritage site as a typical tourist area, and
ii) A large transport hub as a typical busy area of a large city.

The characteristics of sign system of the former is guidance in a two-dimensional network, on the other hand, the latter sign system guides passengers mostly in a three-dimensional network.

There are many visitors to famous tourist areas including persons who are not familiar with the area. Therefore, route guidance information is important to them. However, supplying excessive amount of data may not be always helpful to the users. The information system design has to pay attention to the appropriate amount of information and layout of sign system. The primary objective of the sign system in a tourist area is to satisfy the user expectation to visit desirable attractions and use the available time productively without getting lost.

Large scale historical parks visited by many tourists usually have pedestrian sign systems which are likely gradually improved. Sign improvement makes tourists easy to find suitable routes to their destinations, therefore number of getting lost is expected to be decreased. On the other hand, improved sign system supports tourists to visit other sites, which may generate new way finding behavior as a result.

Visitors to tourist areas including historical precincts rely on the on-site direction sign system as the primary aid for self-navigation. To discuss a suitable sign system and its evaluation system at the above-mentioned subject i) (a world heritage site as a typical tourist area), the authors adopt Nara Park in Japan in which several UNESCO heritage sites exist, and its sign system has been improved. The field surveys have shown that modifications to the sign system have resulted in a quantitative increase of the sight-seeing experience for visitors while enhancing the level of satisfaction with navigation aids. Nara Park attracts about 13 million visitors a year. A development project for modification of the sign system was carried out leading up to 2010 as part of preparation for the 13th Centenary celebrations, considered one of the most significant historical milestones for the nation and an opportunity to showcase this heritage area.

This study adopts Nara Park where couple of UNESCO World Heritages for the area to be discussed. Therefore, it looks like only case study in limited a limited area in Japan. However, since large tourism areas often include UNESCO World Heritages inside, the findings in this study have a possibility to offer a useful information for similar large tourism areas.

As for the above-mentioned subject ii), the authors adopt Osaka Transport Hub, Osaka City. Osaka City is the third largest city in Japan, next to Tokyo and Yokohama, from a population point of view. Osaka Transport Hub consists of seven stations operated by four railway companies. The total number of passengers in this transport hub is about 2.4 million persons a day (2015).

Indeed, main facilities in large transport hubs are several railway stations, but most large transport hubs include shopping complexes such as department stores and shopping malls in underground level. Therefore, visitors to the transport hubs, consist of various persons with different purposes, including familiar and unfamiliar persons with the areas. It is apparent that sign system is indispensable for unfamiliar persons with areas, however, such system is useful for familiar visitors, because most transport hubs are composed of multistory complex structure. Visitors to such large transport hubs have to choose a suitable route in three-dimensional network, when they get to their destinations.

Many people including children and elderly visit such large transport hub every day. In addition, unfamiliar passengers such as tourists and business tourists from different regions often visit there. When they visit large transport hubs with complex structure, they sometimes might not be able to go to their destination smoothly. To improve this situation, it is necessary to identify the characteristics of passenger movements and offer them suitable guidance systems.

When we investigate pedestrian sign system, it is very important to analyze pedestrian behavior, especially pedestrian route choice behavior. Therefore, the project team gives description of “Pedestrian Route Choice Behavior one chapter” at Chapter 2.

Chapter 1. Introduction

1.1 Background

Walking as a means of mobility has been important since the beginning of the human evolution. Today, walking is an unavoidable element in most passenger transport systems. To cater for walking, planners have to provide safe and user oriented pedestrian facilities. Also, in the modern day, importance of walking has increased as we strive to establish low-carbon emission cities to reorient the society toward ecological sustainability. Addition to this, our society is now going to an unprecedented aged one in some countries. Under the circumstances, understanding characteristics of pedestrian behavior is an indispensable issue.

In general, when people visit unfamiliar areas, they need guidance information about accessing specific destinations within the local area network. This is particularly true for visitors to tourist areas or large transport hubs. Therefore, an effective information system is an important infrastructure issue to be discussed to attract more visitors and enhance their level of satisfaction. However, excessive information on sign systems is not the convenient for visitors. There are number of guidance systems available, but the primary method used worldwide to provide directions is to use permanent signboards erected at the roadside, often near intersections. There are other methods such as paper maps and GPS enabled devices suitable for personal use to supplement the primary information system available for public. The method of analyzing the functional effectiveness of a system of static roadside signs however, is not well understood.

Considering such situation, this project analyzed pedestrian route choice behavior without sign systems before discussing effects by sign systems. It is necessary to investigate pedestrian movements in different network, including two-dimensional ones and three-dimensional ones.

Mobile phones and smart phones using GPS (global positioning system) are gaining in popularity as navigation tools and some researchers have taken the opportunity to discuss differences among navigation methods based on GPS technology, paper maps and on-site signs. For example, Ishikawa et al. (2008) and Field et al. (2011) explored differences between paper map-based and GPS-based navigation. There experiments appear to indicate that GPS-based navigation system was less effective compared to paper map-based navigation. These studies suggested that sign systems based on personal devices are not always effective for visitors in an unfamiliar area. Therefore, effective installation of traditional sign systems in such sites is still an important issue to be discussed.

GPS navigation for tourism often offers pedestrian specific maps and multimodal navigation that combine walking directions with all available modes of transportation and even routing in indoor environments. GPS navigation requires more complex maps and algorithms to provide an adequate navigation experience than road navigation which is a simpler, much more predictable and contained environment. Examples of such applications include Journey Pro by Navitime: Journey which is pedestrian navigation application for iPhone and Android, Ovi Maps: Nokia free navigation solution that supports pedestrian navigation in the Walk mode, and Google Maps: Google free map solution that supports pedestrian navigation including public transportation (https://gssc.esa.int/navipedia/index.php/Pedestrian_Navigation)

This study is mainly concerned with identifying the impact of a roadside sign system on visitor movement experience at a historical park and a large transport hub.

As for the former case, this study adopts Nara Park as one of the popular large historical parks. Sign systems in large tourist areas such as Nara Park are important to ensure positive visitor experience with such areas. Administratively, Nara Park is the area constructed and managed by Nara Prefecture (Nara Local Government) in central Japan. Though Nara Park does not include their surrounding historical areas owned by religious properties such as Todaiji Temple, Kofukuji Temple and Hasuga-taisha Shrine, most tourists consider such surrounding areas also as a part of the Nara Park. Furthermore, it appears that most tourists do not distinguish between nearby Nara-machi Area and Nara Park as officially designated. From the view point of the public, all areas described above fall within 'Nara Park', and this study has adopted the wider definition of the public for current analysis. Over previous 10 years, this site has attracted about 14 million tourists in average per year, including overseas visitors. It is famous for its mix of heritage sites and harmony with the surrounding woodland area. Visiting this site is of great cultural importance to Japanese of all ages, from school children to elderly.

Nara was developed as the capital of ancient Japan in the year 710, which was "Heijo-kyo". Heijo- kyo was the capital of Japan until 784 when the capital moved to Nagaoka-kyo (The capital moved again in the year 794 to Kyoto (Heian-kyo)). As year 2010 was the 1300 anniversary since the establishment of the former capital, series of spectacular events were planned to commemorate the centenary. As a result, lot more visitors were expected during that period to come from all parts of Japan and beyond. This prompted Nara Prefecture to embark on a project to upgrade the sign system to a simplified and readily understandable system for both first timers as well as repeat visitors. A development project for modification of the sign system managed by Nara Prefecture was carried out leading up to 2010 as part of preparation for the 13th Centenary celebrations, considered one of the most significant historical milestones for the nation and an opportunity to showcase this heritage area.

Religious properties mentioned above are separate jurisdictions and signs installed in their properties could not be interfered with by the park authorities. Also, the most signs in Nara-machi, a popular mixed retail shopping and residential area, were not changed as they were managed by a different administrative authority, Nara City. Under these circumstances, there are four areas with different sign system ownership arrangements:

(a) Areas with signs owned by Nara Prefecture - most of these signs are improved in 2011,
(b) Areas with signs owned and maintained by relevant landlords - these older style signs have remained unchanged,
(c) Areas with a mixture of signs, near property boundaries for example, where new signs were installed by Nara Prefecture without changing or removing with signs constructed by landlords, and
(d) An area where the sign density is relatively low in the neighborhood, for example a boundary area of different owners.

There are large multistory transport hubs in which there are various large shopping complexes, including department stores and shopping malls in underground level, in addition to several railway stations. Visitors to such large transport hubs have to choose a suitable route in three-dimensional network, when they get to their destinations.

Lack of signs in pedestrian intensive networks degrades the quality of service of such systems by increasing walking distances, journey times and stressful conditions caused to users. Facility operators also suffer from having to place extra resources to handle lost and delayed users of the facility in addition to extra congestion caused by those who were unable to find an efficient path through the network of corridors.

Many people including children and elderly visit such large transport hub every day. In addition, unfamiliar passengers such as tourists and business tourists from different regions often visit there. When they visit large transport hubs with complex structure, they sometimes might not be able to go to their destination smoothly even if they use the guide maps. In order to improve this situation, it is necessary to identify the characteristics of passenger movements and offer them suitable guidance systems. Since Osaka Transport Hub is a typical example of the large transport hubs, this study adopts Osaka Transport Hub for the latter case.

As described above, indeed this monograph lays emphasis on pedestrian sign system, but understanding pedestrian route choice behavior is very important to discuss pedestrian sign systems. From this point of view, we mention our previous studies on pedestrian route choice behavior at the beginning of the monograph.

1.2 Previous studies

(1) Pedestrian route choice models

It is very important to understand route choice behavior of pedestrians. It is important not only to pedestrians in efficiently reaching the destination, but also to planners in identifying how to allocate resources. Traditional methods based on shortest path criterion, implying an all or nothing assignment. In real networks where there are multiple shortest paths this method is clearly deficient.

There are lots of previous attempts to identify characteristics of pedestrian route choice behavior.Garbrecht (1970, 1971) studied pedestrian behavior at a grid type network where the pedestrians know the location of their destination and they can be seen though the point. Therefore in his calculation, the probabilities of going straight and turning movement are the same. As an early attempt should be mentioned is Kamino and Funahashi (1974) which investigated pedestrian flow at railway station. Another early attempts to identify variables involved in pedestrian route choice behavior have been reported by Mori and Tsukaguchi(1979). This work has explored behavioral elements involved in the pedestrian route choice process. The pedestrians observed were traveling to and from a railway station. This work has shown that pedestrian route choice is affected by the relative orientation of the destination, but their research remained a qualitative analysis. Funahashi (1991) has investigates pedestrian route choice behavior in rectangular grid streets and then found that several routes located near diagonal line between the origin and destination, or boundary routes were frequently used. Vandebona and Yossyafra (1999) have developed a modeling framework extending conventional location theory strategies to analyze pedestrian efforts required when the destination search process is carried out in a completely random manner as when the pedestrian is navigating an unfamiliar network which has no directional signs to assist. They assumed going straight probability is 0.5 and those of turning right and lift are 0.25 respectively. The simulation model presented adopted the random walk theory as the mathematical framework. See Cohen (1992) for example for details of the random walk theory.

Tsukaguchi and Matsuda (2002), Tsuakaguchi, Takegami, and Matsuda (2005), Takegami and Tsukaguchi (2006) introduced new factors, including angle of orientation and angle related to turning movement (the details will be described in Chapter 2) and developed pedestrian route choice model on ground level street network. Based on the same concept, Tsukaguchi and Ohashi (2007) modeled pedestrian route choice behavior in underground shopping streets. The authors have analyzed pedestrian route choice behavior in street networks located on the ground and underground. However, these researches are limited in the pedestrian movements of the ground or underground level.

In these studies, pedestrian movements in two-dimensional network, street networks on ground level or underground level, were analyzed. As for the germ of pedestrian route choice behavior in three-dimensional network, we can adopt Kamino and Funahashi (1974) mentioned above which studied pedestrian movements between ticket wickets of a subway station and the platform. However, strictly speaking, their study is not three-dimensional analysis, though up-and-down movements were analyzed. Tsukaguchi, H., Shibata, H., Hirata, H., and Ahn, Y. (2013) developed a model on three-dimensional pedestrian route choice behavior in a large transport hub.

As for pedestrian route choice behavior in transport hubs, Cheung *et al.* (1998) studied pedestrian route choice behavior related to escalators and stairways in stations. Zacharias *et al.* (2005) simulated pedestrian behavior in shopping environment. Zacharias et al. (2005) describe both of familiar and unfamiliar pedestrians with the study area. Certain networks may have an inherently large proportion of familiar users, such as in a network near a railway station.

On the other hand, other networks may have a large proportion of unfamiliar users, such as in association with tourist destinations. Besides that the planners may face situations where the pedestrian composition may vary for a short but significant duration such as when an adjacent land use hosts a special event.

Hoogendoorn and Bovy (2004) analyzed route choice behavior by minimizing the activity load of pedestrians. Zacharias et.al. (2005) and Zacharias (2006) analyzed pedestrian route choice behavior in a shopping center. Also, they have analyzed pedestrian route choice behavior in street networks located on the ground and underground.

(2) Pedestrian sign systems
Sign systems for pedestrians can be divided into two different categories such as those used in emergency times and those in ordinary times. The former systems play indispensable when people put into high grounds to escape tsunami or put into grounds to escape from underground shopping malls in emergency times. The latter systems guide people who visit an unfamiliar area. Even though people have some information about the area, their familiarity is limited when the area consists of complex network. The latter systems are important in these situations. Anyway, sign systems in emergency and ordinary times are challenging issue for sign system planners.

There is little in terms of recent literature that specifically relate to this topic area. Recent efforts of researchers in this area have been devoted to improvement of signs on escape routes related to Tsunami and natural disasters, for example as reported by Chanson (2010). A tourism-oriented sign improvement project has been reported by Osaka City Government (2003). That work has investigated problems of the old system for visitors and has set out to develop a visitor-friendly environment. Color coding signs was the theme of the short article by Misty (2002), reporting an improvement scheme carried out in a popular holiday destination in the USA.

Also, there are few studies focused on behavioral change by sign system arrangement and improvement in ordinary times. For example, we can show the following studies on the issues. Chiyoda (2006) studied the effect of temporally arranged public signs in Matsuyama City, Japan. Reagin (2002) discussed the effect of improved sign system in Vali, a ski resort in Colorado, USA.

The category of signs considered in this monograph aims to deliver correct way finding information to potential destinations for visitors who may or may not be unfamiliar with the area. As mentioned above, there is another category of signs, with the objective of maximizing evacuation efficiency installed for handling emergency or disaster situations. Such study treated that aspect as beyond the scope of the current study.

In a large transport hub located in the city center of a metropolitan area, there are railway terminals, commercial establishments and public facility on different floors of multistory layout. Transport hubs rely on sign system to provide directions in an understandable and convenient way for users. Continuity and unification are the most important factors for effective sign system. Addition to these, comprehensibility is another leading factor.

Previously, sign systems have been studied with the focus on analyzing the relationship with destination and/or route choice behavior. For example, Yokota *et al.* (1997) studied basic conditions on sign system from a view point of spatial recognition to plan an understandable underground shopping arcade, because space recognition should be studied in advance. Kim *et al.* (1990) discussed sign planning including arrangement, design and management of pedestrian signs. Ogata *et al.* (1995) discussed arrangement of pedestrian signs. Vandebona and Yossyafra (1999) studied efficiency of pedestrian sign system by simulation approach on grid type network. Mori and Iida (1997) analyzed pedestrian behavior to construct pedestrian sign system.

As mentioned above, there are many studies on pedestrian movements and signs for pedestrians. However, there is still a room to improve methodology followed in the planning process to determine the best way to arrange signs for pedestrians in large transport hubs based on analysis of pedestrian characteristics.

1.3 Purpose and methodology of the project

Principal components of discussion on pedestrian sign system may include: i) how to construct effective pedestrian sign system, and ii) how to estimate the sign system. For this purpose, analysis on pedestrian route choice behavior is of importance.

This monograph consists of four chapters excluding "Introduction" and "Conclusion", including

- Chapter 2 describes characteristics of pedestrian route choice behavior, as a basic knowledge for pedestrian sign system construction,
- Chapter 3 describes basic concept of sign system structure,
- Chapter 4 discusses getting lost and circulation characteristics of pedestrians which are major components of sign system evaluation, and
- Chapter 5 discusses the effects of pedestrian sign system on pedestrian route choice behavior.

In Chapter 2, pedestrian route choice characteristics without any information of destination and those with some information of destination are discussed. In the former situation, the project team carried out observation survey to confirm the assumption in Vandebona and Yossyafra (1999). In the latter situation, we focus on the two characteristics such as keeping a straight movement tendency and pedestrian tendency that he/she likely chooses a route to minimize the angle between the route and line OD. The route choice logit model developed here is based on this concept.

In Chapter 3, basic concept of sign system structure is discussed. The major methods in this chapter is the route choice model and entropy concept. The network studies here is a grid type to make discussion easier, expansion to other type network is possible.

In Chapter 4, way finding and route guidance methods within popular tourist zones need periodic review to ensure they meet requirements of visitors as well as various operators related to the tourism activity. In Japan where this project was conducted, pedestrian direction signs at tourist zones have traditionally received negative comments from social media sites as well as certain travel guide literature. Terms such as garish are liberally used in internet sites to describe feelings toward such signs. Often these signs are number of direction arrow boards mounted on a single post, haphazard in the manner the boards are attached to the post. Although the information given may be correct, the presentation is comical, and these signs often require a full circle walk around the post to review the information. This rustic appearance may have been appropriate in the past but lacks the symmetry and professionalism of signs public have become used to in general traffic streams. It is generally agreed that many historical zones in the region need improvements to the sign systems. The research problem covered in this project is about the methods available to quantify the outcomes from a sign improvements scheme.

This project has paid attention to investigate changes that has occurred to the circulation pattern, number of attractions visited and the phenomenon of visitors experiencing difficulties finding their way. A before and after analysis method has been adopted here as it allows review of tangible benefits as well as change of perceptions and satisfaction. This method involves conducting field surveys at different points in time using identical survey instruments. In the project reported here, it has been possible to identify a higher level of satisfaction with the sign system from the opinion survey conducted after the system modification. It is also observed that the amount of attractions visited per visitor has increased following the modification.

The sign system improvement in Nara Park raises the average number of attractions, on the other hand, it has not influence to reduction of getting lost. Therefore, to make clear the effectiveness of sign system improvement, it is necessary to investigate the sign system more deeply. The purpose of this study is to investigate reasons for getting lost events to provide guidance to design of effective sign systems. This study can propose practical ways to improve the current sign system in Nara Park.

This study focuses on events of individual tourists getting lost and the nature of sign boards available in surrounding area. All signs in Nara Park constructed by Nara Prefecture, Nara City and temples or shrines become the object of this study. As mentioned above, the authors carried out four times questionnaire surveys. Addition to these, a face to face interview survey was carried out in 2015 (Wu et al. (2016)). This booklet uses the result of the survey in 2008 as the before improvement and the surveys in 2010, 2011, and 2013 as the after improvement. The survey result of 2015 is used to derive recommendations related to reducing way finding errors.

Researchers who have compared the use of paper maps and way finding method based on latest communication technology have observed that despite its popularity methods do not improve the spatial knowledge. For now, authorities of leisure activity centers such as Nara Park have to modernize the traditional static way finding system to minimize the level of inconvenience and enhance visitor experience. The primary objectives of this research work are (1) to propose practical sign system design, and (2) to monitor its impacts on performance of traffic on the road network of the site.

Chapter 5 describes the effects of pedestrian sign system on pedestrian route choice behavior in two different situations. One is pedestrians visiting Nara Park, and another is pedestrians visiting a large transport hub (Osaka Transport Hub). The project team has confirmed whether sign system has an influence on pedestrian route choice behavior.

Most large transport hubs consist of plural busy railway stations and large shopping complexes. Persons visiting these transport hubs include familiar and unfamiliar persons with the area. Therefore, in order to grow more active and manage smooth pedestrian flow, sign system is indispensable in ordinary times, and also the sign system is very important in emergency times. As mentioned before, this project discusses the former issue.

Since large transport hubs function as busy transport terminals and active shopping areas, the sign system in these hubs should have the following two characteristics, from functional point of view. The sign system has to guide passengers who use railway stations, and persons visiting there for shopping purpose. Addition to this, the sign system of large transport hubs should consider passenger's route choice behavior in three-dimensional network. Understanding these characteristics of the sign system in large transport hub, this project consists of the following contents.

(a) Analysis on pedestrian route choice behavior in three-dimensional network
(b) Assessment of productivity of signs in an indoor pedestrian network
(c) Evaluation of pedestrian sign system in a shopping and business complex
(d) To develop a practical method to assess sign system in large transport hubs.

The approach followed in the proposed methodology attempts to make use of the static sign system to minimize the randomness of walking paths through the network for all passengers walking between a given origin and destination pair. This methodology is particularly helpful when there are number of minimum distance paths between the origin and destination pair, as often found in built environments. The methodology also makes a conscious attempt to make the guide paths be similar to the one selected by most users who are well familiar with the network layout and make route choice decisions at intersections according to observed pedestrian choice probabilities. This method has deviated from the common temptation to find the solution with the minimum number of signs, which often let users walk to the far end of the corridor (i.e. to the edge of the network) before directing them to turn. The proposed methodology respects the human (hunting) instinct to make an earlier turn when they know the location of the prey within the network.

The study was designed as a before and after analysis to identify lessons for transport planning and management purposes. The study team had to account for number of jurisdictional issues and simultaneously account for different level of guidance information required by first time visitors as well as repeat visitors. The focus of the analysis has been the changes to circulation patterns and getting lost behavior of visitors. There was an opportunity to use the transition matrix method and the route choice model to analyze visitor's behavioral changes.

1.4 Workshops

IRG-22-2013, Integrated Sign Systems for Non-motorized Transport and Transit Users, held a seminar on Friday, 19 May 2017, at CIBE Building Room 101/102, Institut Teknologi Bandung (ITB). The title of the symposium was "Non-motorized Signage and Way-finding Systems in Asian Countries". The seminar was held by subsidy ICRA-A.

Researchers, Hiroshi Tsukaguchi (Ritsumeikan Univ.), Upali Vandebona (UNSW), Widyarini Weningtyas (ITB), and Tri Basuki Joewono (UNPAR) made following presentation.
Upali Vandebona: Introduction and purpose of the seminar, and general concept of pedestrian signage system
Hiroshi Tsukaguchi: Nara Park sign system improvement -before and after comparison
Widyarini Weningtyas: Bandung City wayfinding and signage for cycling activity
Tri Basuki Joewono: Friendly and useful pedestrian (UNPAR)
After these presentations, round table discussion was held where the moderator of discussion was Dr. Sony Sulaksono Wibowo.
Master course students of Transportation Eng., and System and Highway Eng. of ITB were joined the discussion. Total number of participants were 70.

Chapter 2. Pedestrian Route Choice Behavior

Before discussing pedestrian sign system, it is necessary to investigate characteristics of pedestrian route choice behavior, because pedestrian sign system has likely effects on pedestrian route choice behavior. This chapter describe the issues from two points of view. One situation is pedestrians without any information about location of destinations, and the other is pedestrians with information about the approximate direction of their destinations.

2.1 Basic concept of modeling pedestrian route choice

Traffic engineering variables, such as route length, street width, level of vehicular traffic, availability of sidewalks, and amenities along a street, contribute to pedestrian route choice behavior. Takeuchi (1977) and Fukami (1977) proposed pedestrian route choice models using such variables. However, in general, these pedestrian route choice models lack high reproducibility and worldwide application potential. Most previous models placed too much emphasis on the effects of such factors in relation to the walking environment along a street. This approach may reduce the applicability of the models to other sites. Therefore, this study places emphasis on shape of street network and the angles approaching a destination.

Vandebona and Yossyafra (1999), and Takegami and Tsuakguchi (2006) studied pedestrian behavior based on the concept described above. The former study analyzed the behavior of pedestrians without any information about the area, and the latter study analyzed the behavior of pedestrians with some information about the area. This project advances these previous studies.

2.2 Route choice without any information about the destination

Vandebona and Yossyafra (1999) assumed that the probabilities of going straight, turning right, and turning left are 0.6, 0.2, and 0.2 when they simulated random walk in grid type network. The pedestrians here were unfamiliar at the area.

The turning movement probability varies on the level of information that unfamiliar pedestrian has. It is better for us to make clear by an observation survey. However, it is not easy to show the level of familiarity, therefore this study conducted the following experiment in which the subjects required to search the destination which they did not have any information about the destination.

In order to establish the basis of the turning movement probability, an experiment was carried out in four days in November 2009. The survey area illustrated in Figure 2-1 is part of the CBD of Kyoto City, a historical city in Japan. The surveyed area has a grid type street network. The length of the area is about 440 meters from south to north, and 330 meters from east to west. Subjects of this experiment were 19 students of Ritsumeikan University. Routes of subjects were precisely tracked, since each subject carried a GPS logger.

The subjects were guided to the starting point and were asked to walk around the area and reach the destination. The black circle indicates the starting point, and the white circle indicates the destination which the subject did not know (Figure 2-1).

The conditions of the experiment were as follows:

(i) The starting point and the destination were determined, but the subject does not know the location of the destination.

(ii) The subjects were guided to the starting point from the nearest railway station. The route was illustrated in Figure 2-1. In the process, subjects were not given any precise information where he/she was.

(iii) Subjects knew the boundary of experiment, but they did not have other information.

(iv) Subjects were informed that there was only one destination in the study area. He/she did not know the location, but he/she could find the location when he/she reached the point. The sign of the destination could be seen only when he/she visited the exact point.

Figure 2-1 Experimental area with grid type street network

Source: Google map (maps.google.com)

There are four types of intersections in a grid type street network as shown in Figure 2-2. Results obtained from the experiment are shown in Table 2-1 by the four intersection types. As for type (a), the choice rate of “going straight” was about 60%, and the choice rates of “turning left” and “turning right” were almost the same. As for type (b), the choice rates of “turning left” and “turning right” were almost the same. As for types (c-1) and (c-2), the rate of “going straight” was somewhat small compared with straight through movements in type (a). The results of experiment do not deviate the assumption by Vandebona et al.

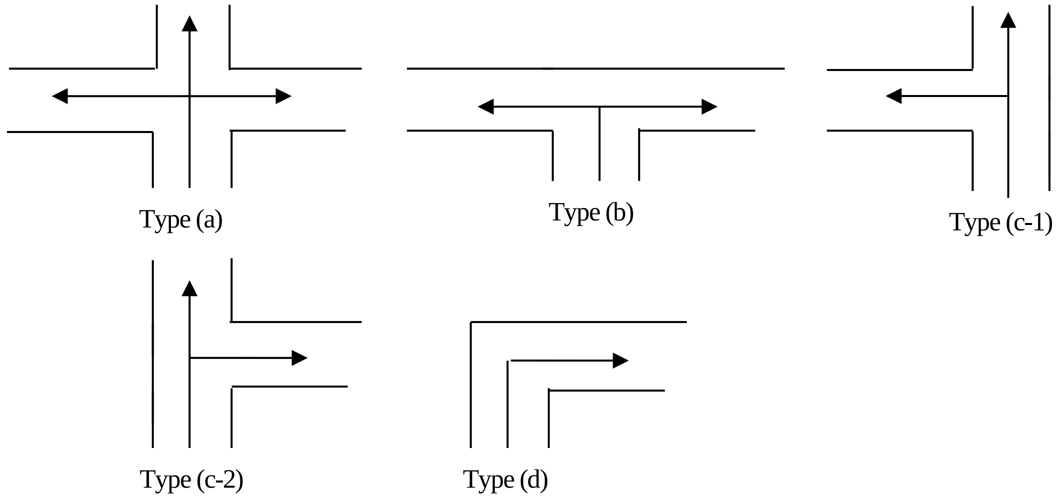


Figure 2-2 Intersection types in the experimental area

Table 2-1 Turning probability obtained by the experiment

	Going straight	Turning left	Turning right	U turn
(A)	0.560	0.197	0.229	0.014
(B)	----------	0.471	0.494	0.034
(C-1)	0.533	0.453	--------	0.013
(C-2)	0.526	--------	0.461	0.013
(D)	0.966	--------	--------	0.034

Based on the experimental results, percentages of subject's behaviors such as "going straight", "turning left", and "turning right" are obtained as Table 2-1. This table shows that if there is no information on the location of the destination, pedestrians select "going straight" with probability of about 60%, and "turning left" and "turning right" are selected by about 20% respectively in the case of grid type network. Though the results are obtained by an experiment in a grid type network, these findings, preference of going straight when there is no information, seem to be useful information for analyzing movements of unfamiliar visitors.

2.3 Route choice with some information about the destination

Most tourists visiting unfamiliar areas are likely to have some information about attractions in this area. Although they did not have detailed information at the starting point, they try to make a rough guess of the direction of their attractions. Therefore, this study develops a route choice model under the condition in which visitors know the approximate direction of their destination.

There are several studies considering such situation from similar methodological point of view. For example, Garbrecht (1970, 1971), Mori and Tsukaguchi (1979), and Tsukaguchi, Vandebona and Matsuda (2003). However, these studies deal with grid networks only.

To discuss pedestrian sign system effects on pedestrian behavior in the following chapters, this project introduces here pedestrian route choice models applicable to various networks including grid type and non-grid type. The model can be used for various types of street networks including grid and non-grid types and assumes that pedestrians tend to choose a straight route over a branched route of similar distance. This behavioral tendency is like inertia in physics. The model also assumes that pedestrians prefer to minimize the geometric angle between the current movement vector and the imaginary vector that connects the present location to the destination. Thus, the assumptions related to the pedestrian route choice mechanism in this study include:

1) Tendency keeping a straight movement: Pedestrians have a particular probabilistic distribution of turning movements. Typically, the straight-through movement, including relatively straight movement in non-grid networks, is the most favored action at an intersection where alternative paths are of similar length.
2) Minimizing the angle of orientation: Pedestrians are aware of the angle between their current movement vector and the vector to their destination. Typically, they choose a route to minimize the angle between the route and line OD.

The study also recognizes the effect of street environment on pedestrian route choice behavior but emphasizes the above-mentioned characteristics and examines whether those characteristics alone can explain pedestrian route choice behavior.

Suppose pedestrians are unaware of the location of the desired destination. If there are no signs, pedestrians have to determine the suitable direction without guidance information at each intersection. The route selection from the origin to destination consists of a series of turns at each intersection in the network. If the pedestrian does not have any information, the person has to select direction at random. On the other hand, if the approximate direction to the destination is known, alternative directions to select can be limited. As mentioned before, previous studies have indicated that a route longer than 1.2 times than the shortest route is rarely considered (Takeuchi(1977), Takegami and Tsukaguchi (2006)).

Assume that a pedestrian is approaching node O illustrated in Figure 2-3. His/her destination is node D. Assuming the pedestrian knows approximate direction of the destination, alternative links at each node may be two in most cases, when U-Turn movement is ignored. Takegami and Tsukaguchi (2006) developed route choice models successfully which follow the same situation mentioned above. The models are based on observation surveys in twenty districts with deferent street networks in Keihanshin (Kyoto, Osaka and Kobe) area, Japan. Therefore, the modeling concept, allowing two alternative links to select at the node is reasonable, if the pedestrian can guess the approximate direction of the destination.

At the node O in Figure 2-1, there are two links, on left side (S_L) and right side (S_R). We can also identify two vectors, origin vector and destination vector. The origin vector is the extension of approach vector, and the destination vector is the vector connecting node O and destination D. Considering the two links and two vectors, the following angles can be defined:

Θ_{OL}: angle between the origin vector and the left side link,
Θ_{OR}: angle between the origin vector and the right side link,
Θ_{DL}: angle between the destination vector and the left side link, and
Θ_{DR}: angle between the destination vector and the right side link.

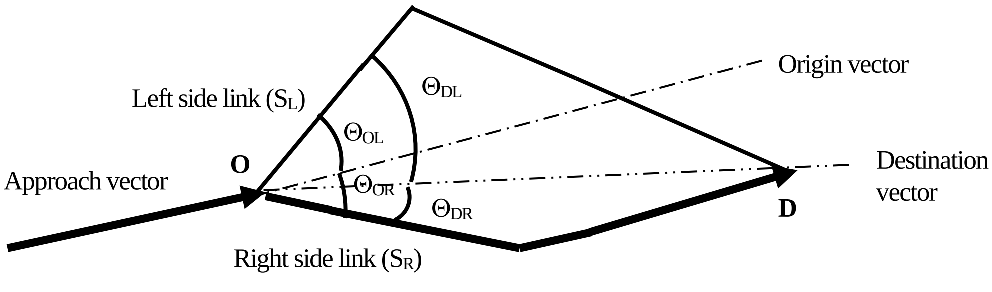


Figure 2-3 Angles related to pedestrian turning movement at an intersection

Route choice of pedestrians often depends on two behavioral intentions. Pedestrians tend to choose a straight route over a branched route of similar distance. This behavioral tendency is similar to inertia in physics. For example, if Θ_{OR} is smaller than Θ_{OL}, the pedestrian likely selects the right side link drawn by thick lines. Also pedestrians prefer to minimize the geometric angle (Θ_{OR}, Θ_{OL}) between the origin vector and the destination vector that connects the present location to the destination. For example, when Θ_{DR} is smaller than Θ_{DL}, pedestrians likely select the right side link.

Considering these characteristics, authors selected the following route choice model. The choice probabilities of the left side link and right side link are expressed as:

$$P_L = \frac{e^{V_L}}{e^{V_L}+e^{V_R}},\ P_R = \frac{e^{VR}}{e^{VL}+e^{VR}} \qquad (2\text{-}1)$$

where,

$$V_L = \omega_1\, \Theta_{OL} + \omega_2\, \Theta_{DL}, \quad \text{and} \quad V_R = \omega_1\, \Theta_{OR} + \omega_2 \Theta_{DR} \qquad (2\text{-}2)$$

ω_1 and ω_2 are coefficients associated with Θ_{OL} or Θ_{OR}, and Θ_{DL} or Θ_{DR}.

There two parameters in the equation (3) such as the parameter of minimizing the angle of orientation expressed by the angles between their current movement vector and the forward paths (ω_2), and the parameter of tendency keeping a straight movement expressed by the angles between the imaginary vector to their destination and the forward paths (ω_1).

These parameters can play an important role to investigate pedestrian route choice behavior. Here, let's introduce the following index, parameter ratio.

$$\text{Parameter ratio} = \frac{\text{Parameter on minimizing the angle of orientation}}{\text{Parameter on tendency keeping a straight movement}} \qquad (2\text{-}3)$$

When the parameter ration is smaller than 1.0, tendency keeping a straight movement is superior to minimizing the angle of orientation. On the other hand, when the parameter ratio is larger than 1.0, minimizing the angle of orientation is superior to tendency keeping a straight movement.

If there is no effective information of the destination, visitors are likely to come to their attraction based on the behavior described at (1) in this section. If there is some information of the destination, their behavior to approaching the attraction is likely to change according to the level of information. The findings at (2) in this section plays an important role to evaluate the effectiveness of sign system in tourist areas.

In order to investigate pedestrian route choice behavior and estimate the above-mentioned parameters, observation surveys were carried out at twenty districts in Kei-han-shin Metropolitan Area (Kyoto, Osaka and Kobe) whose networks are shown in Figure 2-4. The selected twenty districts include various types of street networks. A shadowing technique was adopted to perform the observational survey. The surveys were performed by several investigators who discretely followed pedestrians from the origin, including temporary origins, to the destination in the networks. About one hundred subjects were observed in each district. The survey subjects were selected at random excluding parsons who looked to be getting lost.

Using these field observation data, the necessary angles at every intersection between the origin and destination pair were measured to verify the study assumptions. Similar method has been also reported by Zacharias et.al. (2005) in a survey within shopping center in downtown Montreal. Based on these field observations, the following route choice models shown in Table 2-2 has been developed (Takegami and Tsuakguchi. (2006)).

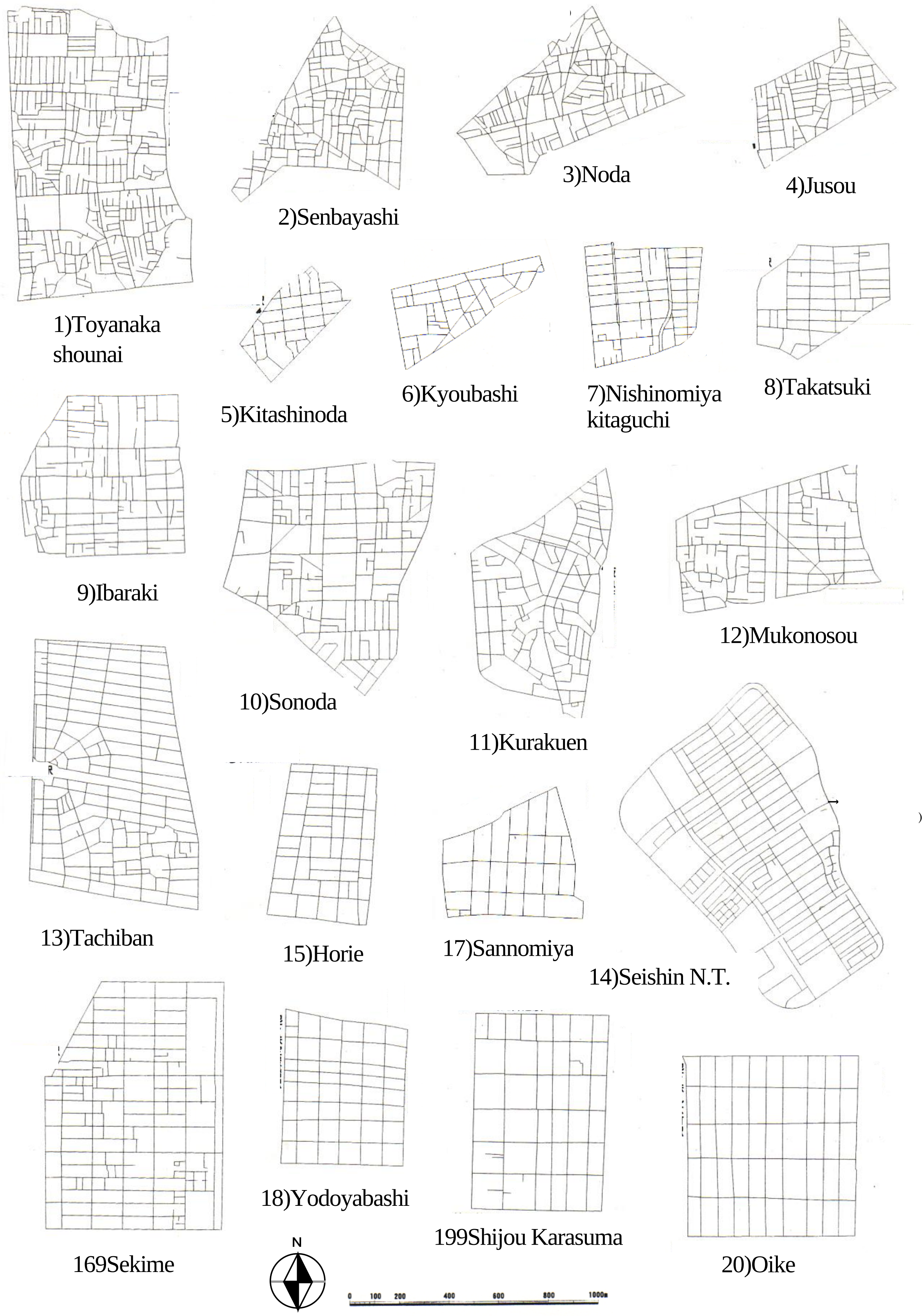


Figure 2-4 Street network in the experimental area

Table 2-2 Pedestrian route choice models

District surveyed	Parameter value		Likelihood Ratio	Reproductivity Ratio (%)	Parameter Ratio
	Angle of orientation (degree)	Angle related to turning movement (degree)			
1)Toyonaka shounai	-1.0948×10^{-2} (-4.39**)	-8.4517×10^{-3} (-7.07**)	0.1122	67.7	1.30
2)Senbayashi	-2.0742×10^{-2} (-5.48**)	-1.0515×10^{-2} (-5.58**)	0.2551	73.4	1.97
3)Noda	-1.5607×10^{-2} (-5.56**)	-4.7303×10^{-3} (-2.62**)	0.1206	68.5	3.30
4)Jusou	-1.5006×10^{-2} (-4.88**)	-1.6303×10^{-2} (-9.81**)	0.2554	76.2	0.92
5)Kitashinoda*	-1.5063×10^{-2} (-5.12**)	-1.3200×10^{-3} (-1.91)	0.0615	56.9	11.41
6)kyoubashi*	-8.2513×10^{-3} (-2.97**)	-2.1222×10^{-3} (-1.44)	0.0292	58.8	3.89
7)Nishinomiya kitaguchi	-1.4497×10^{-2} (-6.03**)	-8.3489×10^{-3} (-6.99**)	0.1467	67.0	1.74
8)Takatsuki	-2.1021×10^{-2} (-7.88**)	-1.0992×10^{-2} (-7.45**)	0.2497	76.8	1.91
9)Ibaraki	-1.7626×10^{-2} (-6.51**)	-1.1483×10^{-2} (-7.97**)	0.2092	72.7	1.53
10)Sonoda	-1.4385×10^{-2} (-3.45**)	-1.1527×10^{-2} (-5.96**)	0.1449	66.3	1.25
11)Kurakuen	-1.9527×10^{-2} (-4.74**)	-1.1596×10^{-2} (-5.23**)	0.2428	76.3	1.68
12)Mukonosou	-8.9146×10^{-3} (-2.16*)	-7.6625×10^{-3} (-3.57**)	0.1418	70.9	1.16
13)Tachibana*	-6.3260×10^{-3} (-2.18*)	-5.0265×10^{-3} (-3.48**)	0.0406	60.2	1.26
14)Seishin N.T.*	1.4458×10^{-2} (4.86**)	-1.7385×10^{-2} (-8.04**)	0.4220	82.8	-0.83
15)Horie	-1.5761×10^{-2} (-4.83**)	-6.5367×10^{-3} (-4.31**)	0.1173	65.9	2.41
16)Sekime*	-8.3414×10^{-2} (-3.50**)	-3.9003×10^{-3} (-3.53**)	0.0380	61.0	2.14
17)Sannomiya	-1.1639×10^{-2} (-3.46**)	-1.0331×10^{-2} (-6.48**)	0.1504	69.4	1.13
18)Yodoyabashi	-1.6152×10^{-2} (-5.58**)	-7.4621×10^{-3} (-5.88**)	0.1621	70.2	2.16
19)Sijyou Karasuma	-1.7892×10^{-2} (-5.41**)	-9.4816×10^{-3} (-7.44**)	0.1704	70.3	1.89
20)Oike	-1.1175×10^{-2} (-2.61**)	-1.0209×10^{-2} (-5.67**)	0.1321	69.0	1.09

There are a great number of shortest paths for the same OD pair in grid networks. Since all these paths are feasible for use by pedestrians, they must be considered when analyzing pedestrian route selection behavior. For non-grid networks, feasible paths must be chosen in the initial phase of the analysis. Takeuchi (1977) made it clear that paths 1.2 times longer than the shortest one are seldom used by pedestrians based on an observational survey. The observational survey conducted in this study also confirmed the tendency. Therefore, this study considers only paths that are shorter than 1.2 times longer than the shortest path as feasible paths (Takegami, N. and Tsuakguchi, H. (2006)).

Table 2-2 shows that appropriate route choice models can be developed in fifteen districts out of twenty districts. In the districts 5), 6), 13), 14) and 16) with * in Table 2-2, appropriate models cannot be developed. However there are reasonable reasons such as existence of exceedingly attractive roads comparing other roads in the districts. Therefore it can be said that the concept of modelling mentioned above is appropriate. If the data of fifteen districts together, the following model can be developed as Table 2-3.

Table 2-3 Integrated pedestrian route choice model

Parameter value		Likelihood Ratio	Reproductivity Ratio (%)	Parameter Ratio
Angle of orientation (degree)	Angle related to turning movement (degree)			
-1.5304×10^{-2} (-19.42**)	-9.5872×10^{-3} (-24.69**)	0.1661	70.0	1.60

Here, let's pay attention to parameter ratio. This value is worth notice, because it is larger than 1.0 when an appropriate model can be developed. For example, the value is 1.60 in the integrated model. The parameter ratio being larger than 1.0 means that minimizing the angle of orientation is superior to tendency keeping a straight movement. In the data collection, passengers getting lost were carefully excluded, therefore the subjects here can be regarded as familiar persons in the district, at least they knew the approximate direction of their destination. Findings of Section 2.2 is that going strait movement are preferred when no information is offered. Therefore, there is a possibility to use this index to evaluate effectiveness of sign system installation.

2.4 Pedestrian route choice behavior in three dimensional network

Most large transport hubs in large cities have not only transport function but also commercial function. Then, most large transport hubs have three-dimensional structures, which force travelers to three-dimensional movements. This chapter aims to develop a three-dimensional route choice model for pedestrians in large transport hubs, based on observational survey.

2.4.1 Overview of pedestrian route choice behavior among many floor

To achieve the purposes, this study adopts Osaka Transport Hub including a large shopping complex to be discussed. Osaka, the third largest city in Japan, next to Tokyo and Yokohama, had 2.7 million population in 2018. In the CBD of Osaka City, there is a large multiple transport hub which consists of seven railway stations including JR Osaka Station, JR Kita-shinchi Station, Hankyu Railway Umeda Station, Hanshin Railway Umeda Station, and three stations of Osaka Municipal Subway (Subway Umeda Station, Higashi-Umeda Station, and Nishi-meda Station). The total number of passengers is about 2.4 million per day (2015). In the underground level of the transport hub there is a large underground shopping arcade with several independent shopping centers. The details will be discussed in Chapter 5.

This study classifies three-dimensional movements into three categories based on locations of origin and destination. According to the survey at Osaka Transport Hub, when movements have one level difference between the origin and destination, the movements are classified into type (A). When there are more than two levels differences, the movements are classified into type (B). And movements whose origin and destination are in the same level, the movements belong to type (C). Note that origins and destinations of type (C) are located in the same level, but some of type (C) include up-and-down movements between the origin and destination. Figure 2-5 illustrates the type (A) movement is 40 %, the type (B) is 39%, and the type (C) movement is 20%.

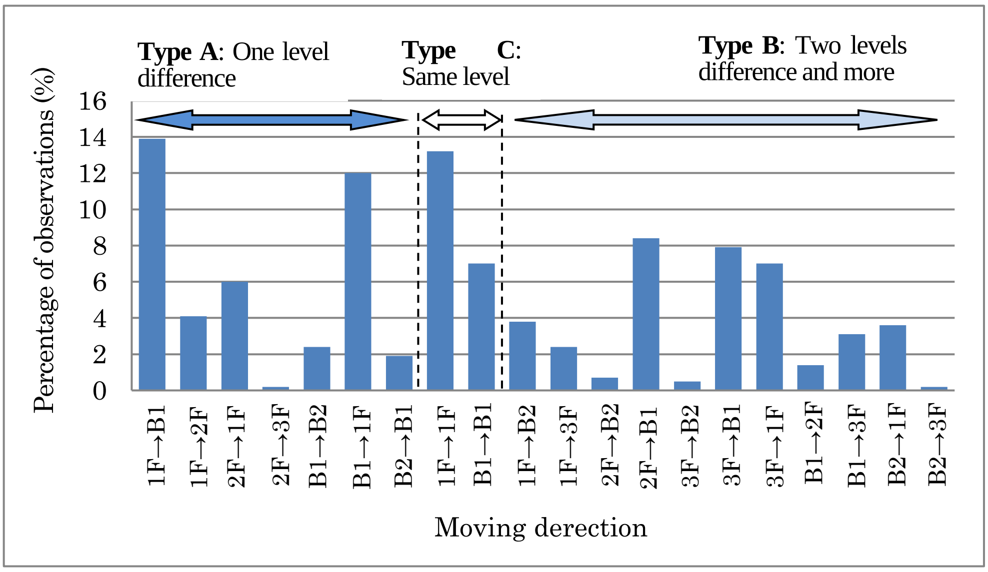


Figure 2-5 Movements observed in Osaka Transport Hub
(Hanai, Tsukaguchi, and Ahn (2012))

These three-dimensional movements can be presented from different view point as shown in Table 2-3. As for movements ‘from ground to underground’, one-level difference is about 45%, and two-level difference and more is about 55%. As for the movements ‘from underground to ground’, one-level and two-levels difference are about 55% and 45% respectively. There is not so much difference between the two movements.

On the other hand, movements 'from ground to ground' consists of 44% of two level difference, and movements from underground to underground' consists 88% of no level difference. The distinguished pedestrian route choice movements in Osaka terminal is also shown in the right column of Table 2-4.

Table 2-4 Percentages of two up-and-down movements and more in Osaka Transport Hub

	Location of origin and destination	Percentages of each number of times of up-and-down movement			Distinguished movements in more than twice up-and down movement
		0	1	2 or more	
Osaka terminal	Ground→Underground	-----	45%	55%	3F→B1
	Underground→Ground	-----	55%	45%	B2→1F, B1→3F
	Ground→Ground	27%	29%	44%	3F→1F
	Underground→Underground	88%	10%	2%	

2.4.2 Route choice behavior in three-dimensional networks

This research analyzes the characteristics of points where pedestrians conduct up-and-down movements in their route choice behavior. According to our previous study (Tsukaguchi and Ohashi (2007)), routes which are 1.4 times longer than the shortest path are not used in general. Therefore, the sample which does not have an alternative path within 1.4 times is excluded from the analysis. Also, to analyze pedestrian route choice behavior, this study selects samples which have more than two up-and-down movement points in their path.

As a result, 147 samples in the Osaka transport hub are selected in this section. This study divides 'total walking distance' into two parts, namely 'distance of the ground street' and 'distance of the underground street'. Figures 2-6 illustrates up-and-down movements. Here, 'ground street ratio' is calculated by the following equation.

Ground street ratio = walking distance of the ground street / total walking distance

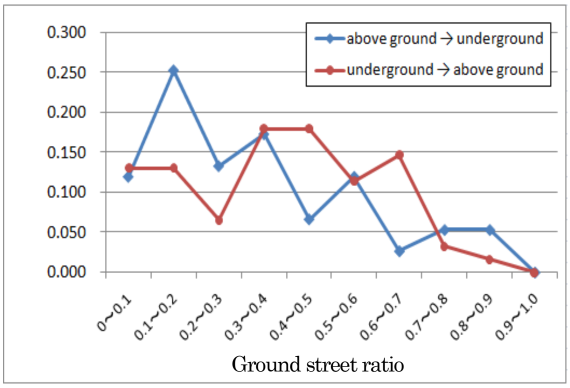


Figure 2-6 Up-and-down movements in Osaka Transport Hub (Tsukaguchi, Shibatal, Hirata, and Ahn (2013))

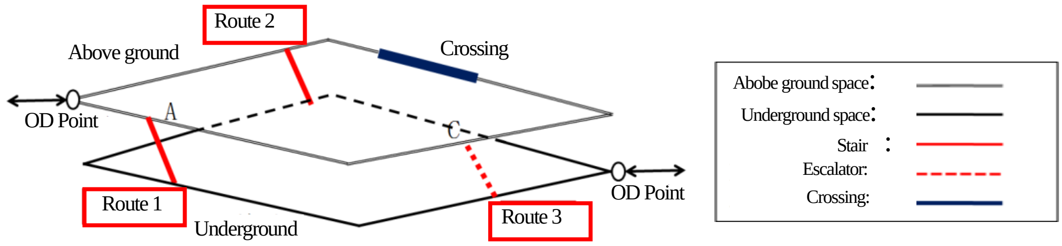
There is a tendency which pedestrians prefer the route in which walking distance in the ground street is shorter than that in the underground street.

This study develops pedestrian route choice behavior model in three-dimensional networks. The study focuses on the movements between the ground (1F) and the underground (B1) shown in Figure 4-1. The data used this section are 103 samples.

There are several points for up-and-down movements in a large transport hub. This study compares the following three alternatives characterized by the location of up-and-down position. Here, α is the distance from the origin to the up-and-down position divided by the total distance. Each route is expressed as follows;

Route 1: 0.00≦α<0.33,   Route 2: 0.33≦α<0.66,   Route 3: 0.66≦α≦1.00.

If there are more than three routes, a route whose α is close to the middle value of α in each rank was picked out as an alternative route. The image of each route is shown in Figure 2-7.



Route 1 : 0.00≦α<0.33   Route 2 : 0.33≦α<0.66   Route 3 : 0.66≦α≦1.00

Figure 2-7 Image of alternative route in three-dimensional network

The model is a logit model with three choices, including Route 1, Route 2 and Route 3. When the utility function of each route is shown as V_1, V_2, and V_3, the choice rate of Route i, i.e. P_i is estimated by the following formula.

$$Pi = \frac{\exp(Vi)}{\exp(V1)+\exp(V2)+\exp(V3)} \quad (i= 1, 2, 3) \qquad (2\text{-}4)$$

Explanatory variables in the utility functions are total walking distance, walking distance in the ground street network, and kind of up-and-down facilities which is expressed as a dummy variable. As for the dummy variable, in the case of stair is 0, and escalator is 1.

Parameter estimation results are shown in Table 2-5. Considering indices as t value and likelihood ratio of the model, it can be said that these models are acceptable for pedestrian route choice behavior model in three-dimensional networks. This model is an example of sub-model (a) described in section 2.1.

.

Table 2-5 Location choice model of up-and-down movements
(Hanai, Tsukaguchi, and Ahn (2012))

Explanatory variable	Parameters value	t value
Total distance	-3.30E-02	-4.5050**
Above ground distance	-5.81E-03	-4.0940**
Kind of up-up-down facilities	1.07E+00	2.8390**
Likelihood ratio	0.3542	
Reproducibility	71.84 = 77 / 103	

(**:1% significant, *: 5% significant)

The model demonstrates that the passengers prefer the underground streets to the ground streets. There may be several reasons for their decision, including the fact that passengers need to cross major streets with heavy traffic when they choose the ground streets. Also, the models make clear that escalators play an important role for pedestrian movements in three-dimensional networks.

The following is an example of sub-model (b) described in Section **2.2**. The choice rate of the Routes 1 and 2 shown in Section **2.1** are expressed as:

$$P_L = \frac{e^{V_L}}{e^{V_L+e^{V_R}}}, \; P_R = \frac{e^{VR}}{e^{VL+e^{VR}}} \quad (2\text{-}5)$$

where,

$$V_L = \omega_1 \Theta_{OL} + \omega_2 \Theta_{DL,} \quad \text{and} \quad V_R = \omega_1 \Theta_{OR} + \omega_2 \Theta_{DR} \quad (2\text{-}6)$$

ω_1 and ω_2 are coefficients associated with Θ_{OL} or Θ_{OR}, and Θ_{DL} or Θ_{DR}.

Equations (2-5) and (2-6) are the same as equations (2-1) and (2-2). The details of the model were already described in Section **2.2**.

The parameters estimated in this study are shown in Table 2-6. Considering indices such as t value, likelihood ratio ρ^2 and reproducibility of the model, it can be said that we can develop pedestrian route selection model using only two variables including the angle of orientation and the angle related to turning movement.

Table 2-6 Route choice model at the same floor (Tsukaguchi, Shibatal, Hirata, and Ahn (2013))

Area	Angle of orientation (degree)		Angle related to turning movement (degree)		Parameter ratio	Likelihood ratio ρ^2	Reproducibility of the model
	Parameter	t value	Parameter	t value			
Underground street	-0.0132**	-9.46	-0.00767**	-8.63	1.72	0.17	0.692
Aboveground streets	-0.0158**	-14.0	-0.00894**	-17.1	1.77	0.16	0.694

(**:1% significant, *: 5% significant)

This model is a sub-model (b) described in section 2.1. Sub-models (a) and (b) consist of the stepwise model for three-dimensional route choice described in the same section.

Chapter 3. Basic Concept of Sign System Structure

3.1 Introduction

It is very important to establish a concept of effective sign system structure. This chapter proposes a new method to construct such pedestrian sign system, though the network adopted to consideration is simple grid network.

Lack of suitable signs in pedestrian intensive networks similar to those found in certain transport interchanges degrades the quality of service of such systems by increasing walking distances, journey times and stressful conditions caused to people getting lost. Entropy based model for determination of direction signs in a pedestrian flow network has been presented in the paper. Pedestrian route choice behavior has been built into the model to evaluate the selection process for travel paths. A demonstration of the computation procedure to propose a sign system for the underground pedestrian corridor network of a large transport interchange, Osaka Transport Hub, has been included.

3.2 Analytical Methods

3.2.1 Path Selection to achieve minimization of randomness of flows

Suppose pedestrians are unaware of the location of the desired destination. If there are no signs, pedestrians have to determine the suitable direction without guidance information at each intersection. As mentioned in section 2.3, the route selection from the origin to destination consists of a series of turns at each intersection in the network. If the pedestrian does not have any information, the person has to select direction at random. On the other hand, if the approximate direction to the destination is known, alternative directions to select can be limited.

Suppose that there are n alternative links, namely Ai (i=1, n), potentially going to the destination at an intersection. Then the probability P_i of occurrence of A_i is, can be applied to express the uncertainty measure known as Entropy (H) in information theory. Entropy (H) is formulated by the following equation.

$$H = \sum_{i=1}^{n} P_i \times \log\frac{1}{P_i} = -\sum_{i=1}^{n} P_i \times \log P_i \quad (3\text{-}1)$$

3.2.2 Probability of link selection at each node

Section 2.3 described the model structure for link selection at each node.
Based on field observations, the following route choice model has been developed (Tsukaguchi, Shibata, and et al(2013)). The utility function is shown in Table 3-1

Table 3-1 Utility function in the route choice model

Coefficients		Likelihood ratio	Reproducibility of the model	Coefficient ratio (A/B)
(A) Angle of orientation (degree)	(B) Angle related to turning movement (degree)			
-1.5802×10^{-2} (-14.03*)	-8.9417×10^{-3} (-17.06*)	0.1604	69.4 %	1.767

Note: values within parentheses are t values and * indicates 1 % significance level.

Substituting P_L and P_R, shown in equation (2), to Pi values of equation (1), entropy measure H can be calculated. The next section explains the sign location selection process in a step by step manner.

3.2.3 Method for determination of sign locations

Pedestrians want to decrease uncertainty in general when navigating toward their destination. Therefore, the search process looks for the location where a sign can deliver the highest reduction of uncertainty and installs the next sign there. The search process can then be repeated until the complete path can be defined with all turns are sign posted to a given destination. The computation process can be summarized as follows:

1) Select an origin destination pair and a suitable cut-set arrangement.
2) Measure Θ_{OL}, Θ_{OR}, Θ_{DL}, and Θ_{DR} at all nodes.
3) Compute all turning movement probabilities at nodes (using the choice model) assuming there are no pedestrian signs provided yet in the network.
4) Calculate the initial Entropy (E_0) for the movement between particular origin destination pair without any signs.
5) Select a node as a potential sign location, recalculate Entropy (E_1) assuming all pedestrians relevant to the particular origin destination pair obey the sign.
6) Repeat Step 5 for all other nodes of the network.
7) Find the node i that maximizes $E_0 – E_i$. Locate the next sign at that node i facing the direction of the approach vector of pedestrian flow.
8) Repeat the process until the Entropy is zero.

It can be seen that this process follows a greedy algorithm character.
Route choice model presented in Section 2 combined with the entropy concept presented in Section 1 have been applied here to evaluate sign systems. The route choice model gives probability of route choice at each node using Equations (2) and (3). Substituting those probability values to Equation (1), the Entropy H in the network responding to the sign installment is easily calculated. Entropy minimization is then carried out to determine best locations for signs. The process is illustrated in Figure 3-1.

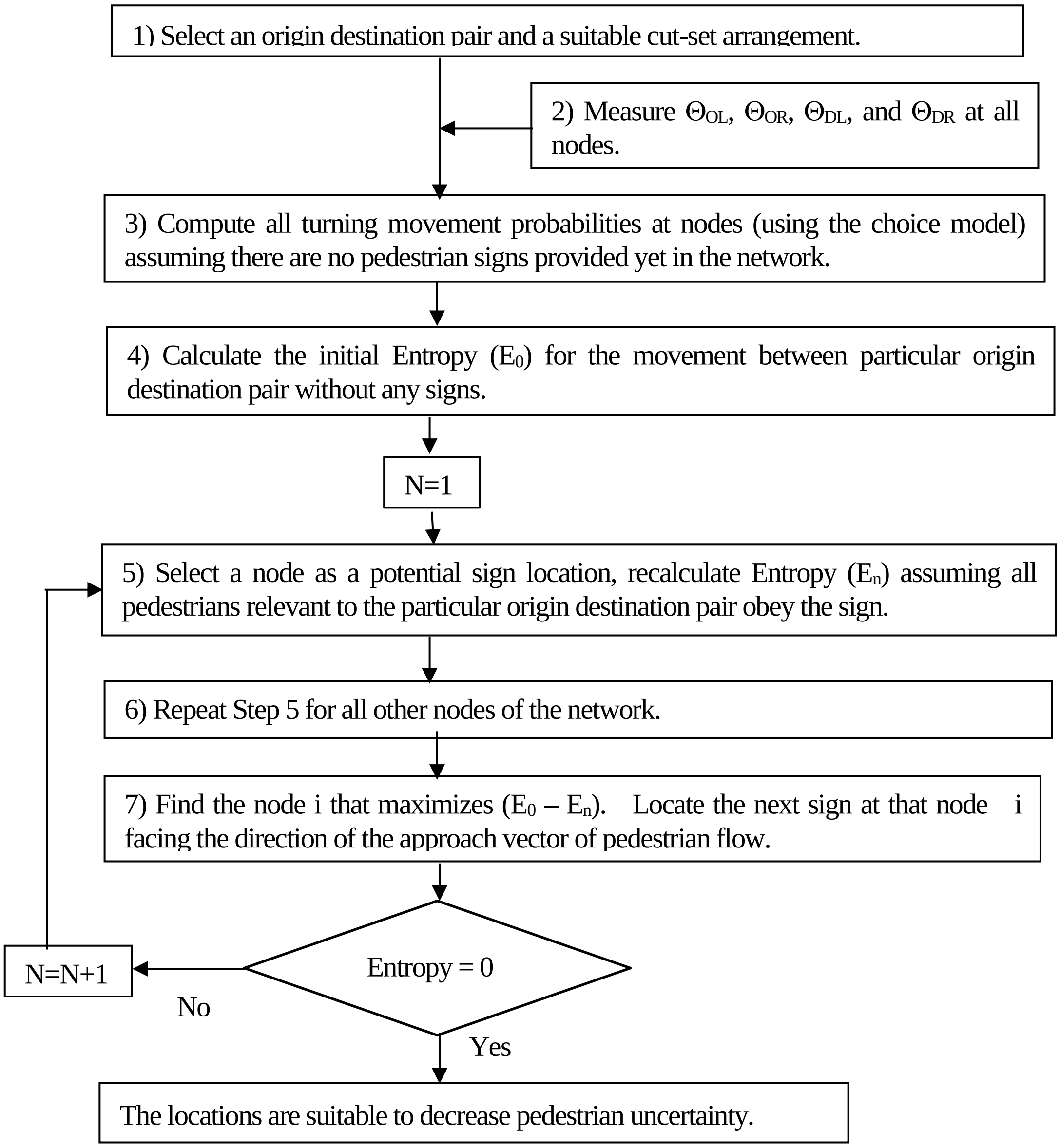


Figure 3-1 Flowchart of the computational steps

3.2.4 Simplification of sign location

As a result of the procedure mentioned above, the suggested plan of signs can be excessive and complicated. It could be simplified by the following manner. As mentioned earlier, pedestrians tend to choose a straight route over a branch route of similar distance, a behavioral tendency similar to inertia in physics. Hirata (2012) conducted a survey at grid-type network where subjects had no information of the destination location and that survey indicated that the percentage of going straight is 56%, and the percentages of turning right and lift are 20% and 23%. The result supports the validity of characteristics mentioned above. Considering this tendency, the signs placed on the nodes where pedestrians will go straight can be removed.

3.3 Sign arrangement example for a grid network

3.3.1 Characteristics of the grid network in this section

For ease of understanding the model application is shown for a grid network in the following section. All links are of equal length in the selected network (See Figure 3-2). However, the proposed sign allocation methodology can be applied to other types of street networks as well.

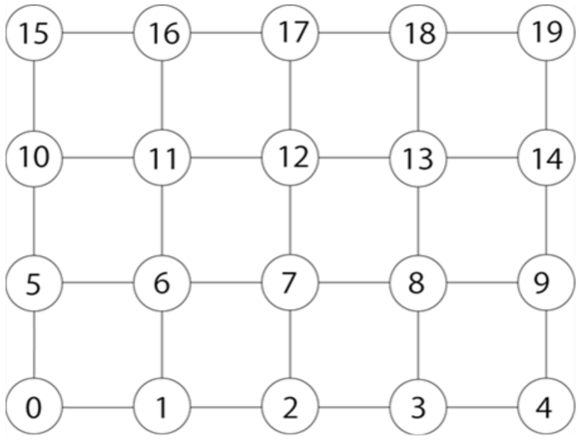


Figure 3-2 Example 4 × 5 grid network selected for the application.

At the beginning, there is no sign nominated for any node in the network shown in Figure 3-1. We assume that the origin is node 0 and the destination is node 19, when the passenger approaches the node 0 from the left side. Following conditions relate to the calculation performed:

a) Passengers do not know the route to the destination, but they know approximate direction to the destination, even if there is no sign in the network. Therefore, U-turns are not considered,
b) The two angles shown in Figure 2-3 are measured at all nodes (forks) in the network,
c) If a sign exists, all passengers obey the direction sign, and
d) If there is no sign at a node, passengers select their link according to the route choice model (equations (2) and (3)).

In the network shown Figure 3-1, a sign is added systematically, one by one. In each situation, entropy is calculated. The most suitable location for the next sign is determined by looking for the location that creates the largest amount of entropy reduction. This process repeats until the entropy becomes zero.

3.3.2 Calculation of the initial entropy

In this case, there is no sign installed in the network, therefore passengers have to rely on their own route choice behavior. Link choice probabilities obtained from Equation (2) and (3) are applied in the calculations.

As mentioned before, passengers approach node 0 from left side. Therefore, at the beginning, such passengers select link 0-5 with probability of 0.26 and link 0-1 with probability of 0.74. Probability values calculated at each node using the route choice model provides the link choice probability of all links as illustrated in Figure 3-3.

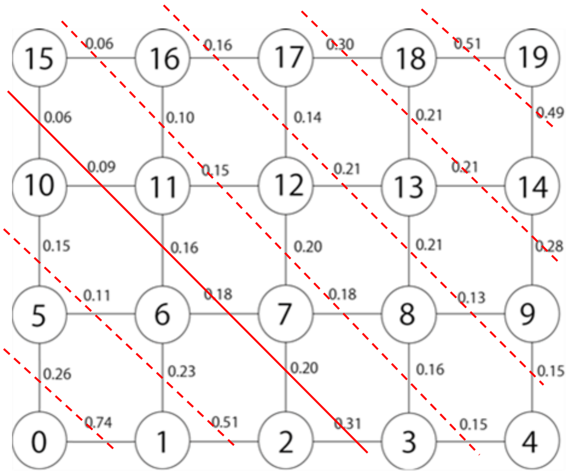


Figure 3-3 Link choice probability distribution without any sign

The obscurity of the network for unfamiliar persons can be expressed by the entropy concept. To obtain the value of entropy, cut sets as shown in Figure3-3 has been selected. There are seven cuts in this network. The entropy value for the cut set drawn by red solid line is calculated using Equation (1)

$$\mathrm{H} = 0.31 \times \log\frac{1}{0.31} + 0.20 \times \log\frac{1}{0.20} + 0.18 \times \log\frac{1}{0.18} + 0.16 \times \log\frac{1}{0.16} + 0.09 \times \log\frac{1}{0.09} + 0.06 \times \log\frac{1}{0.06} = 1.67$$

Entropy for the each cut set of the network is calculated by the same way mentioned above, and the results are shown in Table 3-2. Adding these values, the initial Entropy (E_0) of the network is obtained as 9.18.

Table 3-2 Calculation of network Entropy value

Cut	Entropy value
[0-5, 0-1]	0.57
[5-10, 5-6, 1-6, 1-2]	1.21
[10-15, 6-11, 6-7, 2-7, 2-3]	1.67
[15-16, 11-16, 11-12, 7-12, 7-8, 3-8, 3-4]	1.89
[16-17, 12-17, 12-13, 8-13, 8-9, 4-9]	1.78
[17-18, 13-18, 13-14, 9-14]	1.37
[18-19, 14-19]	0.69
Entropy of the whole network: 9.18	

3.3.3 Entropy minimization to determine sign locations

The objective here is to minimize randomness of pedestrian flows caused with the planned sign system. Randomness is reduced when a sign is introduced at any node in the network. The greedy optimization strategy adopted here is based on identifying the largest reduction of the entropy measure feasibly by introducing a sign at a single node. That node becomes most effective location for the next ideal sign.

(1) Network with a single OD pair

First example presented is for a one to one flow condition. Origin node is node 0 and destination node is node 19. At the node 0, passengers approach from the left side.

Firstly, let's find the most effective location when one sign is installed. If a sign is at a node, all pedestrians who pass the node follow the direction which the sign indicates. On the other hand, if there is no sign at a node, pedestrian movement is estimated by the route choice model in the same way as former section. Table 3-3 shows entropy values and reduction from the condition without any sign (here, Entropy is 9.18 calculated in Table 3-2), when one sign is installed. Since the entropy reduction is largest when sign is installed at node 0, the first sign is determined to install at node 0 as illustrated in Figure 3-4.

Table 3-3 Entropy calculation to select the guidance node 1

Node	Entropy	Reduction from E_0
0	7.44	1.74
1	8.27	0.91
2	8.63	0.55
3	8.71	0.47
5	9.03	0.15
6	8.68	0.50
7	8.74	0.44
8	8.91	0.27
10	8.94	0.24
11	8.68	0.50
12	8.92	0.26
13	8.80	0.38
Node selected	0	
Sign direction	Right	

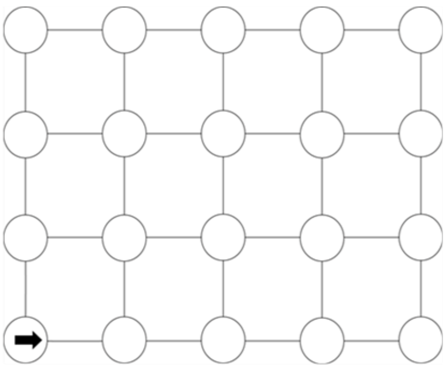


Figure 3-4 The first sign location

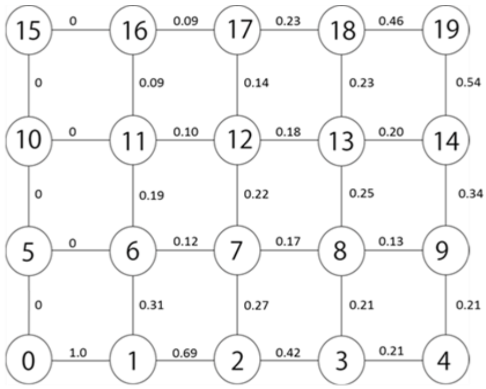


Figure 3-5 Link choice probability for Figure 3-4

Table 3-4 Effect of the first sign installation

Node	Entropy	Reduction from E_0
1	5.50	3.68
2	6.44	2.74
3	6.87	2.31
6	7.27	1.91

7	7.10	2.08
8	7.20	1.98
11	6.62	2.56
12	6.82	2.36
13	7.10	2.08
Node selected	0, 1	
Sign direction	Right	

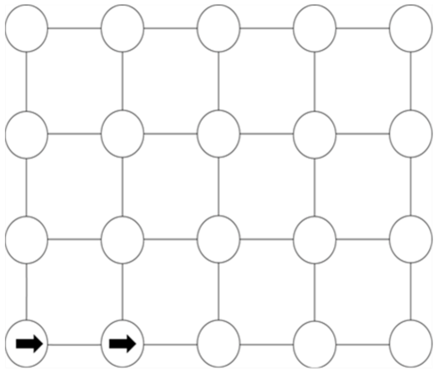


Figure 3-6 The first and second sign locations

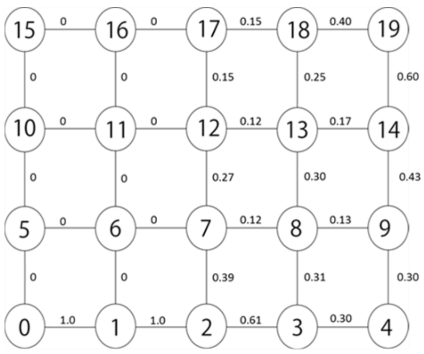


Figure 3-7 Link choice probability for Figure 3-6

Table 3-5 Effect of the first and second sign installation

Selected node for signs	Entropy
No sign	$H_0 = 9.18$
0	$H_1 = 7.44$
0, 1	$H_2 = 5.50$
0, 1, 2	$H_3 = 3.16$
0, 1, 2, 3	$H_4 = 2.18$
0, 1, 2, 3, 8	$H_5 = 1.24$
0, 1, 2, 3, 8, 13	$H_6 = 0.0$

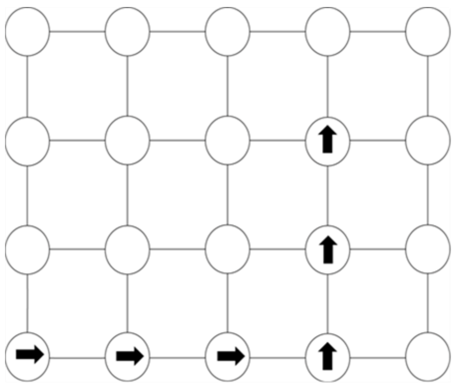


Figure 3-8 Sign locations when the entropy equals 0

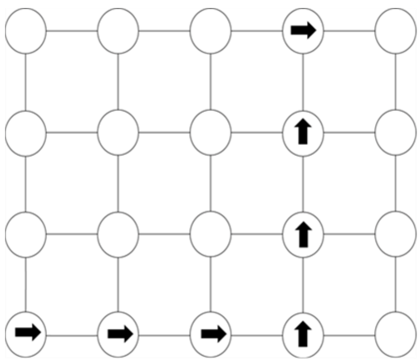


Figure 3-9 Final sign locations

When one sign is installed at node 0, the link choice probability is calculated as shown in Figure 3-5, using the same way we used in Figure 3-2. In this calculation, Entropy H_1 is 7.44. Since the entropy is not 0 at the sign location illustrated in Figure 3-4, we advance to the next step.

Figure 3-6 shows the new movement probability values when a direction sign is available at node 0. Table 3-4 shows the entropy calculation with trial signs introduced one at a time at the remaining nodes. The least entropy is observed when the next sign is added at node 1. Therefore, node 1 is selected as the second location for sign installation. Then Entropy H_2 is 5.50. Since the entropy is not 0 at the sign location illustrated in Figure 3-6, we will advance to the next step. With signs installed at nodes 0 and 1, the link utilization is calculated as shown in Figure 3-7.

We can repeat this process until the entropy value becomes zero. The results are indicated in Table 3-4. The sign location at this stage is shown in Figure 3-8.

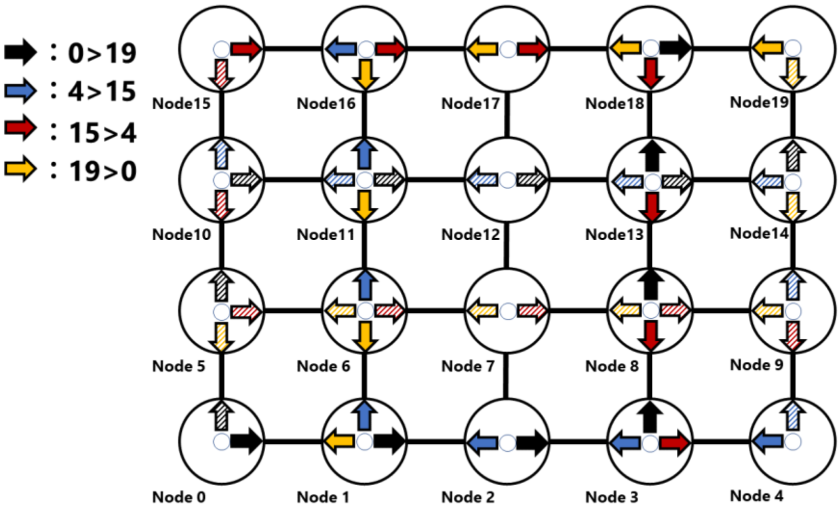


Figure 3-10 Sign locations for four OD pairs

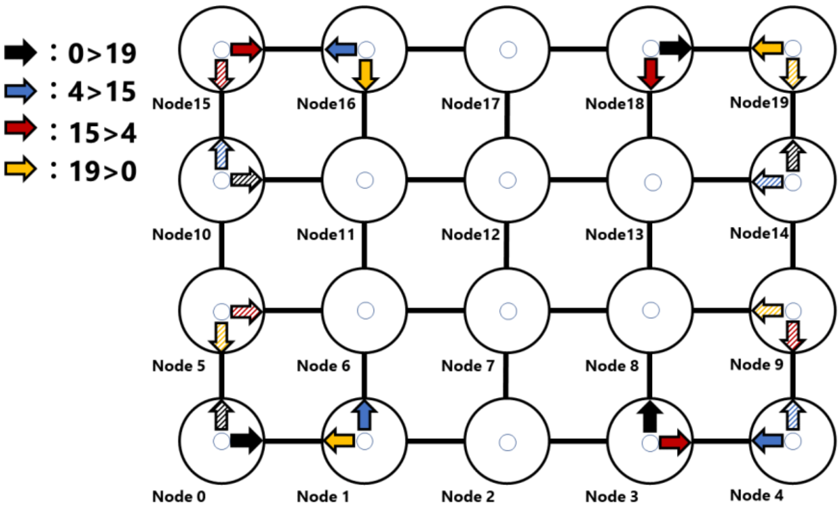


Figure 3-11 Simplified sign locations for four OD pairs

As shown in Table 3-4, when signs are installed at nodes 0, 1, 2, 3, 8 and 13, the entropy becomes 0. As the Entropy H_6 reaches 0, the calculation has been completed. In this sign system, U-turn is not considered. Therefore when the sign is installed at node 13, the route from node 13 to node 19 are determined. But in order to make the sign system certainly, this study add a sign at node 18.

(2) Multiple ODs

In a typical network there is a many to many origin destination pattern for the pedestrian flows. To recreate such a situation, it is possible to use following OD pairs for example. There are four origin destination pairs considered: from node 0 to 19, from node 4 to 15, from node 15 to 4, and from node 19 to 0. In each OD pair, there is two approach directions at the origin node as illustrated in Figure 3-10, such as horizontal and vertical directions.

Based on the methodology explained in the former section, suitable sign locations for the OD pairs described above are illustrated in Figure 3-9.

The plan of signs shown in Figure 3-10 is complicated. As mentioned in Section **2.2**, pedestrians tend to choose a straight route over a branched route of similar distance, a behavioral tendency similar to inertia in physics. Hirata (2012) confirms that the percentage of going straight is 56%, and the percentages of turning right and left are 20% and 23% at grid-type network where subjects had no information of the destination location, based on an observation survey. Considering this tendency, Figure 3-10 may be simplified as shown in Figure 3-11.

3.4 Case Study of Sign System Improvement in Osaka Transport Hub

Osaka Transport Hub is located in the central area of Osaka City. The population of Osaka, the third largest city in Japan, was 2.7 million in 2018. There are several large transport hubs in the CBD of Osaka City. The largest one is Osaka Transport Hub which consists of seven railway stations. JR Osaka Station, JR Kita-shinchi Station, Hankyu Railway Umeda Station, Hanshin Railway Umeda Station, and three stations of Osaka Subway (Subway Umeda Station, Higashi-Umeda Station, and Nishi-Umeda Station) are included in this transport hub. About 2.5 million of passengers per day use this transport hub.

In the underground level of the transport hub, there is a large underground shopping arcade with several independent shopping centers. The underground street network poses numerous orientation difficulties for passengers to find their way. This study investigates this the underground street network in Osaka Transport Hub to recommend a suitable sign system.

This study selects the area surrounded by the dotted line oval shape in Figure 3-12. It is located in the central part of Osaka Transport Hub. The underground street network in this area is illustrated in Figure 3-13.

Ahn and Tsukaguchi (2015), and Nakamura (2018) have estimated the OD matrix in this area as shown in Table 4-1. Using the data authors observed pedestrian flows at different 24 points, OD matrix was estimated. Ahn and Tsukaguchi (2015) explains the detailed method of estimation. Table 3-6 shows the pedestrian flows per one hour in the morning peak.

Table 3-6 makes clear the major OD pairs in this area. The OD pairs selected to develop sign locations in this study are:

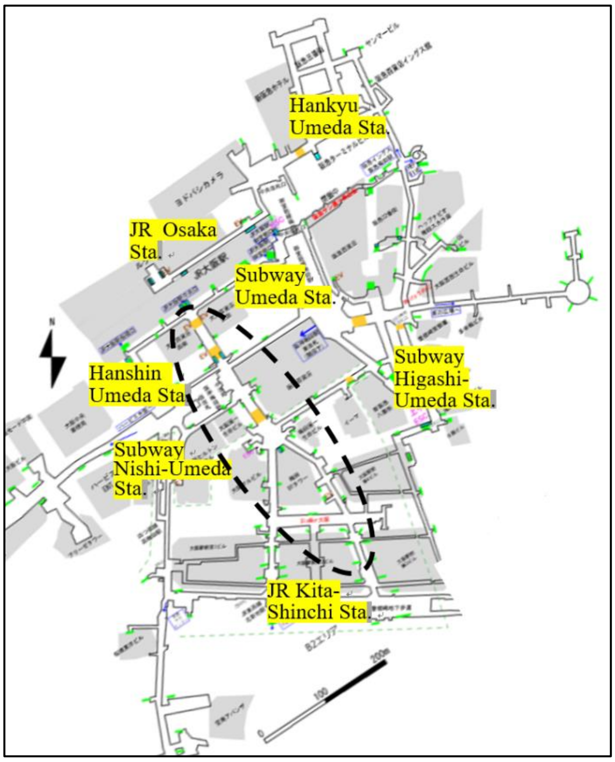


Figure 3-12 Main elements of the Osaka Transport Hub

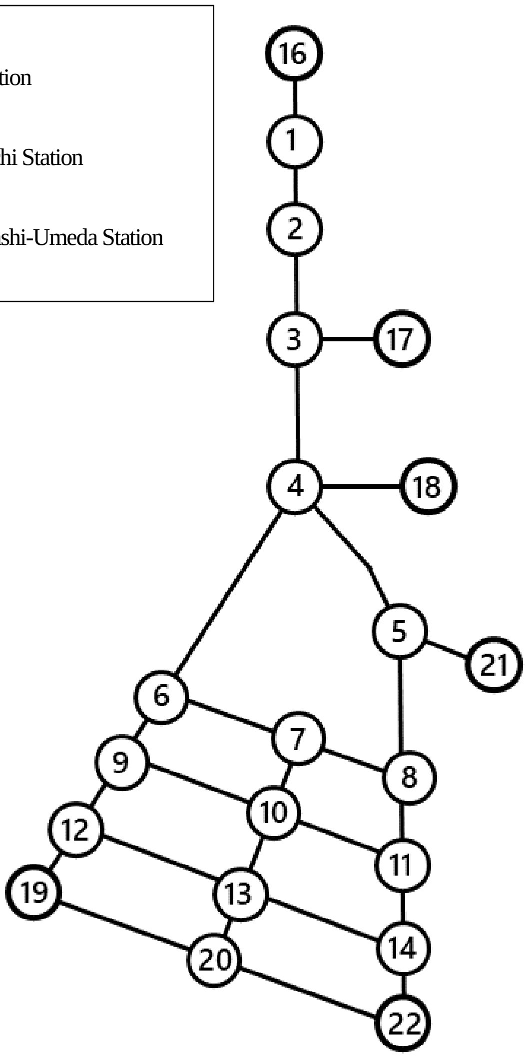
from node 16 to nodes 18, 19, 21, and 22,
from node 18 to node 19 and 22
from node 19 to nodes 16 and 22
from node 22 to node 19.

The traffic flows for these OD pairs are indicated by bold letters in Table 3-6.
The methodology described in the former sections can be applied to propose suitable sign locations for travelers among the OD pairs. For each OD, entropy values are calculated and the sign location in which (E_0 – E_n) are maximized is selected. Signs are added one by one until entropy value becomes zero. The results are illustrated in Figure 3-14.

Table 3-6 OD matrix in this area (Persons/hour)

O \ D	16 JR Osaka	17	18 Higashi Umeda	19 JR Kita-shinchi	20	21 Building No4	22 Building No3
16 JR Osaka	**-**	**526**	**564**	**2038**	166	**326**	**804**
17	9	-	8	29	2	5	11
18 Higashi Umeda	196	166	-	**642**	52	103	**253**
19 JR Kita-shinchi	**199**	168	180	-	53	104	**257**
20	43	37	39	142	-	23	56
21 Building No4	10	8	9	32	3	-	13
22 Building No3	87	74	79	**286**	23	46	-

Node 16
JR Osaka Station
Node 19
JR Kita-shinchi Station
Node 17,18
Subway Higashi-Umeda Station
Node 22



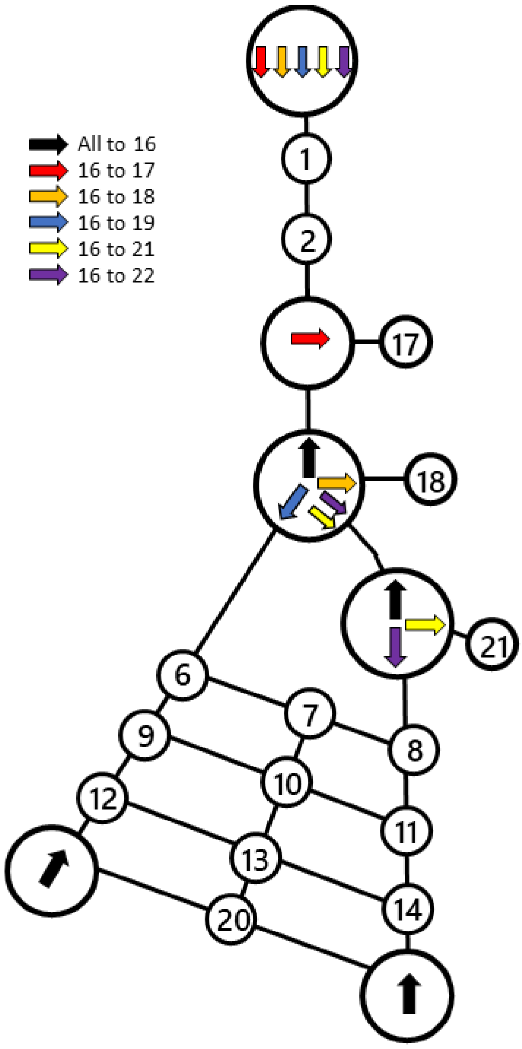


Figure 3-13 Network selected for analysis

Figure 3-14 Recommended direction sign locations

3.5 Concluding remarks

An entropy based model for determination of direction signs in a pedestrian flow network has been presented in this chapter. Pedestrian route choice behavior has been built into the model to evaluate the selection process for paths.

Entropy calculation for a trial sign placement arrangement relies on network evaluation using the cut set technique. A greedy algorithm has been introduced to search for the minimum entropy condition that provides the best arrangement of signs. In addition to this, when the arrangement of signs is excessive and complicated, this study proposes a way to simplify the results based on pedestrian characteristics to choose a straight route, a behavioral tendency similar to inertia in physics.

A demonstration of the computation procedure to propose a sign system for the underground pedestrian corridor network of a large transport interchange, Osaka Transport Hub, has been included. Many to many demand pattern has been considered for this problem. The example network shows the sign system required to efficiently direct pedestrian flow paths among major demand nodes, i.e. among train stations and common entry/exit nodes.

Chapter 4. Getting Lost and Circulation Improvement

4.1 Case study of pedestrian sign system improvement in a UNESCO world heritage site

This project has paid attention to investigate changes that has occurred to the circulation pattern, number of attractions visited and the phenomenon of visitors experiencing difficulties finding their way. A before and after analysis method has been adopted here as it allows review of tangible benefits as well as change of perceptions and satisfaction. This method involves conducting field surveys at different points in time using identical survey instruments. In the project reported here, it has been possible to identify a higher level of satisfaction with the sign system from the opinion survey conducted after the system modification. It is also observed that the amount of attractions visited per visitor has increased following the modification.

The sign system improvement in Nara Park raises the average number of attractions, on the other hand, it has not influence to reduction of getting lost. Therefore, to make clear the effectiveness of sign system improvement, it is necessary to investigate the sign system more deeply. The purpose of this study is to investigate reasons for getting lost events to provide guidance to design of effective sign systems. This study can propose practical ways to improve the current sign system in Nara Park.

This study focuses on events of individual tourists getting lost and the nature of sign boards available in surrounding area. All signs in Nara Park constructed by Nara Prefecture, Nara City and temples or shrines become the object of this study. As mentioned above, the authors carried out four times questionnaire surveys. Addition to these, a face to face interview survey was carried out in 2015 (Wu et al. (2016)). This booklet uses the result of the survey in 2008 as the before improvement and the surveys in 2010, 2011, and 2013 as the after improvement. The survey result of 2015 is used to derive recommendations related to reducing way finding errors.

Researchers who have compared the use of paper maps and way finding method based on latest communication technology have observed that despite its popularity methods do not improve the spatial knowledge. For now, authorities of leisure activity centers such as Nara Park have to modernize the traditional static way finding system to minimize the level of inconvenience and enhance visitor experience. The primary objectives of this research work are (1) to propose practical sign system design, and (2) to monitor its impacts on performance of traffic on the road network of the site.

4.2 Selected study area

4.2.1 Nara Prefecture and Nara City

Nara, which was called Heijyo-kyo, was established as the capital of ancient Japan in the year 710 AD, and remained the capital for about 75 years until the capital moved to Nagaoka-kyo (mainly extended over Muko City and Nagaoka-kyo City) in 784 AD. The capital moved again in 794 AD to Heian-kyo in Kyoto City now, which continued about 1200 year. This epoch of Japanese history is known as the Nara Period. As year 2010 was the 1300 anniversary since the establishment of the ancient capital, series of spectacular events were planned to commemorate the centenary. The main site of the anniversary events was the exact location of the ancient capital, Heijyo-kyo, near Nara Park. Nara Park is located in Nara City which is the local capital of

Nara Prefecture, one of the 47 prefectures in Japan.

Administratively Nara City belongs to Nara Prefecture which is located in Kinki region (Area 4 indicated in Figure 4-1). The population in Nara Prefecture is 1,347,510, and that in Nara City is 356,746 in 2017.

Note: Modified from the map available at http://d-maps.com/carte.php?num_car=71883&lang=en

Figurer 4-1 Main islands of Japan

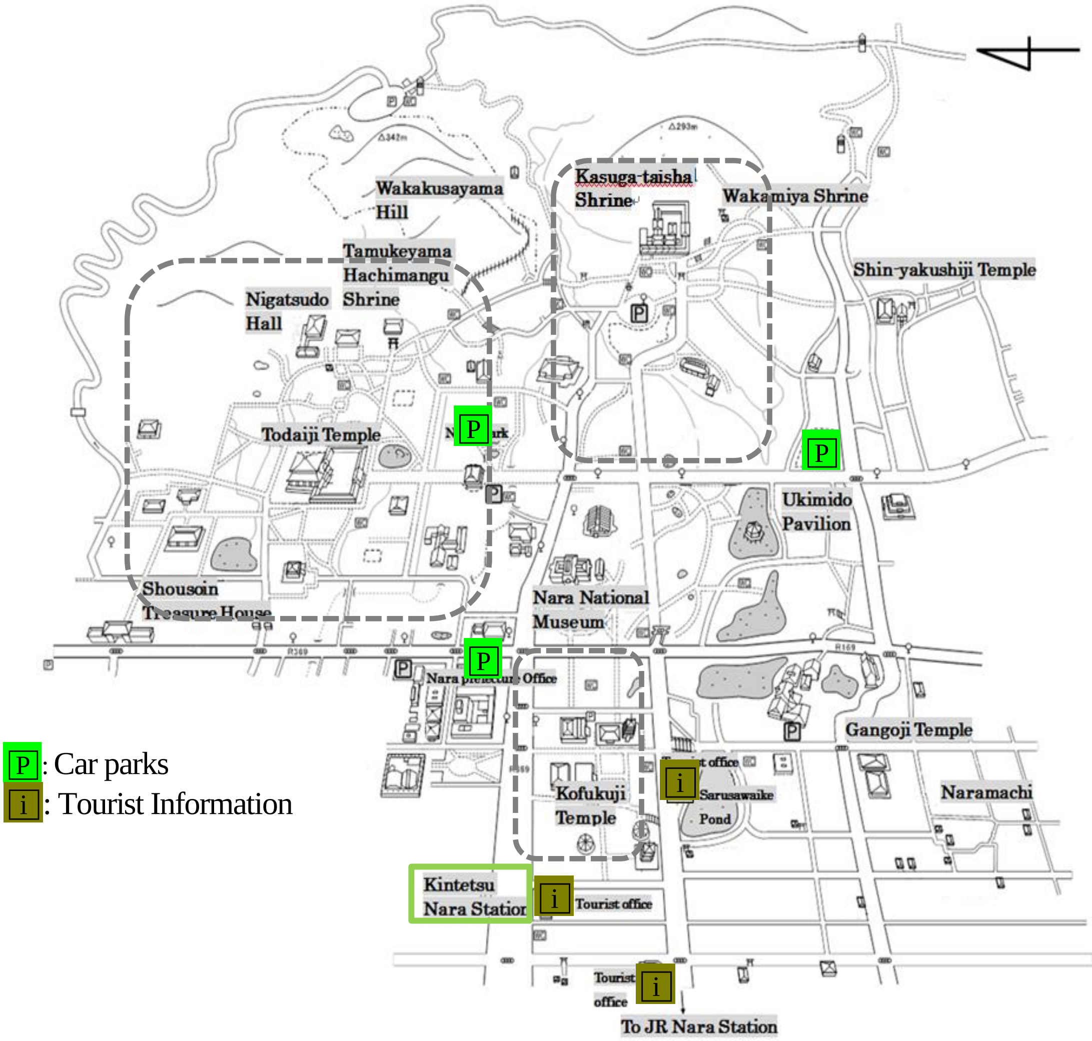
4.2.2 Brief explanation of Nara Park

City parks in Japan are classified as shown in Table 4-1 by Urban Park Act in Japan. Nara Park belongs to the large-scale parks. Nara Park was established in 1880 as an urban park managed by Nara Prefecture. There are four world heritage sites in this area named Todaiji temple, Kofukuji temple, Kasuga-taisha shrine, and Gangoji temple. This area, excluding Kasugayama virgin forest next to the park, was designated for "Historic Monuments of Ancient Nara" in1998. In addition to those sites of religious significance, the park contains a museum and green spaces as shown in Figure 4-2. Nara Park is an outstanding urban park in which cultural heritage and surrounding green spaces are well harmonized. Also, nearly 1200 wild deer have become a symbol of the park.

Table 4-1 Classification of urban parks

Types	Classification	Description
Basic parks for community use	City Block parks	Those which are to be placed for the use of most nearby residents; their standard area is 0.25 ha per park, and each will be intended to be used by residents who live within a certain area with radius of 250m.
	Neighborhood parks	Those which are to be placed for use by residents who live in the neighborhood; one neighborhood park will be provided in each neighborhood unit. Their standard area is 2 ha par park, and each will be intended for use by residents who live within a certain catchments area with radius of 500 m.
	Community parks	Those which are to be placed for use by those who live within walking distance; their standard is 4ha or more for specific district parks (Specified community parks) in certain municipalities that are not covered in urban planning areas.
Basic parks for city wide use	Comprehensive parks	Those which are to be placed for use by all residents in a city for various purposes, including rest, walking, playing and sport; their standard area ranges from 10 to 50 ha according to the size of the city.
	Sport parks	Those which are to be placed for use by all residents in a city mainly for athletic activities; their standard area ranges from 15 to 75 ha according to the size of the city.
Large scale parks	Regional Parks	Those which are placed for the purpose of satisfying area-wide weekend recreation needs of residents of more than one municipality. Their standard area is at least 50 ha and their recreational facilities are placed organically.
	Recreation Cities	Areas where a variety of recreation facilities are provided mainly in a large-scale urban park; these cities aim at meeting area-wide recreation needs of residents of large cities or other cities, which are constructed in accordance with a comprehensive city plan. Total area will be 1,000 ha.
National government parks		Large-scaled parks established by the government for use by residents of more than one prefecture; their standard area is at least 300 ha per park; in case these parks are constructed as the government's commemorative project, they should have facilities suitable for their objectives.
Buffer green belts	Specific Parks	Special parks, such as scenic parks, zoos and botanical parks, historical parks, cemeteries, etc. are set up in accordance with their objectives.
	Buffer Green Belts	Green belts intended to help prevent or reduce pollutions like air contamination, noises, vibrations and bad odors, or to prevent disasters in industrial complexes, etc. They are provided at locations where areas with sources of pollution or disasters and residential or commercial areas must be separated.
	Ornamental Green Spaces	Green Space provided to maintain and improve natural environment of a city and to better urban landscape, and their standard area is at least 0.1 ha per lot; when in an established city area there are existing woods, etc., or when green belts are provided to expand green belts by planting trees for a better urban environment, the standard area is 0.05 ha or more.
	Greenways	Green belts which are mainly composed of passages with tree plantings, pedestrian ways or cycling courses. They aim to secure escape roads in an emergency case. They naturally connect parks to houses, schools, shopping centers, etc.

http://www.mlit.go.jp/english/2006/d_c_and_r_develop_bureau/03_parks-and-green/index.html



Note: Areas surrounding by dotted line indicate rough sketch of are so-called "historic site". The precise boundaries of the area are illustrated in Figure 2-7.

Figurer 4-2 Locality map of the study area

There is a difference between the administrative definition and what is commonly accepted by public as the Nara Park. Administratively, Nara Park is the area managed by Nara Local Government and this area does not include separately owned religious properties such as Todaiji Temple, Kofukuji Temple and Kasuga-taisha Shrine. Nevertheless, the public considers such religious propertied also as part of the Nara Park. The area considered in this study has its boundary consistent with this public perception. The researchers had to be mindful of sensitivities of different landlords and negotiate with multiple owners to perform the necessary field work, particularly when gaining permission to do surveys at different locations at what is considered as one park.

Large number of visitors were expected to come from all parts of Japan and beyond during 1300 anniversary events. This prompted the Nara local government to embark on a project to upgrade the sign system to be a simplified and readily understandable system for both first timers as well as repeat visitors. After the 1300 anniversary event, it became clear that more than 3.6 million visitors came between April and November 2010 to the main site of the anniversary events. The total number of visitors to Nara Park that year amounted to 17.4 million visitors.

4.2.3 Sign system in Nara Park

(1) Concept of previous and improved sign system

Signs constructed by Nara Prefecture have been redesigned and renovated in 2010 to coincide with the 1300 anniversary events held that year. Those signs were simplified to a readily understandable system suitable for visitors. For the purpose of improving their sign system, park attractions were classified into four types, as Ranks A to D where A was for the most important and D was for the least important attractions according to (i) a public perception survey conducted earlier and (ii) a government registry of historical properties (Tanaka et al. (2009). The former sign system shown in the left side of Figure 4-3 lacked uniformity and clarity of explanations as there were no identifiable logic or hierarchy in directions provided. Information was accurate but had little user focus.

Since the survey carried out in 2008 has made clear that most tourists chose Rank A attractions for the first visiting place and some of them visited other types of attractions. Therefore, the design concept of the improved sign system should have a structure with an importance hierarchy illustrated in the right side in Figure 4-3 (Tsukaguchi *et al*. (2015)), which attempted to be aligned with user expectations.

In 2011, sign improvements were complete except within historic sites owned by Todaiji Temple, Kasuga-taisha Shrine, and Kofukuji Temple. Addition to these, signs constructed by Nara City remained unimproved. From the view point of planners, it has been expected to encourage visitor circulation among attractions and provide a sense of confidence to visitors that they are unlikely to get lost.

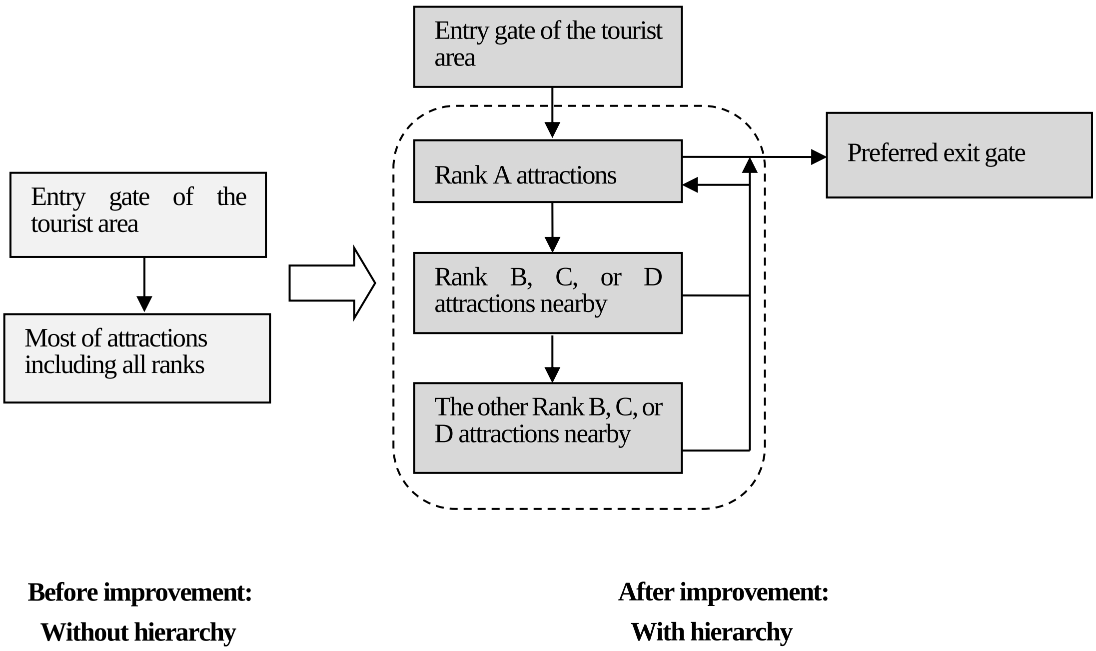


Figure 4-3 Concept diagram of the design objective of the modified sign system

(2) Signs constructed by Nara Prefecture

(a) Previous signboards

Even before improvement, there were several roadside signs constructed by Nara Prefecture. However, as mentioned above the sign system lacked uniformity and clarity of explanations as there were no identifiable logic or hierarchy in directions provided. The examples of previous signs are shown in Figure 4-4. Information offered by the system was accurate, but they were difficult for visitors to understand due to lack of uniformity and clarity of wording. For example, sample of the previous sign shown in the right side in Figure 2-4 indicates that too many information was given on one pole.

Figure 4-4 Former types of signs

(b) Improved signboards

The previous system has been improved from viewpoints of balancing simplicity and consistency. For balancing simplicity and consistency of the prefecture constructed signs, the number of styles of signs has been limited to three. Figure 4-5 shows examples from each of the style categories. The first category is referred to as ‘map boards’ which focused on providing an overview of the spatial distribution. The next type is called ‘arrow signs’ which focused on providing directions to destinations and landmarks by pointing arrows. A consistent icon system has been adopted to denote landmarks, destinations and services indicated on arrow signs. The third category is called ‘Map and Arrow signs’, indicating these locations contain a hybrid version of map boards and arrow signs.

The process to develop the improved sign system will be precisely described in Section **4.4**.

Figure 4-5 Examples of signs introduced during the modification

Arrow signs are mounted on posts and the destination boards are precisely aligned and spaced between each other to avoid the old style haphazard appearance. To further reduce the clutter, the maximum number of arrow boards mounted on a post was limited to 6. And the maximum number of destinations that can be indicated by one arrow was set to 2. Symmetry of signs is attempted where possible for aesthetic reasons. A consistent symbol system like computer icons is also included in the destination board to indicate the type of destinations.

Map boards and explanatory signs are vertical display panels, usually below the eye line of the visitors. An appropriate title is at the top frame of these displays. These information panels were mounted on two side posts and the posts are driven into a paved surface to complete the professional appearance of these signs. Map boards are helpful in providing orientation as well as the overall layout of sites whereas explanatory signs are helpful in providing a narrative and photographs to explain significant details related to this heritage site. The photo in Figure 2-7 indicates that all three type signs are combined.

(3) Signs constructed by other organizations

There are other signs constructed by temples, shrines, and Nara City Government. Some examples of such signs are shown in Figure 4-6. Most these signs remain as they were in the past.

Todaiji Temple　　Kasuga-taisha Shrine　　Nara City

Figure 4-6 Examples of sign boards constructed by other organizations

(4) All signs in Nara Park

Large temples and shrines including Todaiji Temple and Kasuga-taisha Shrine have construct signboards in their properties, also Nara City Government constructs signs in Nara-machi Area. The structure of these signs remains as they were in the last decade.

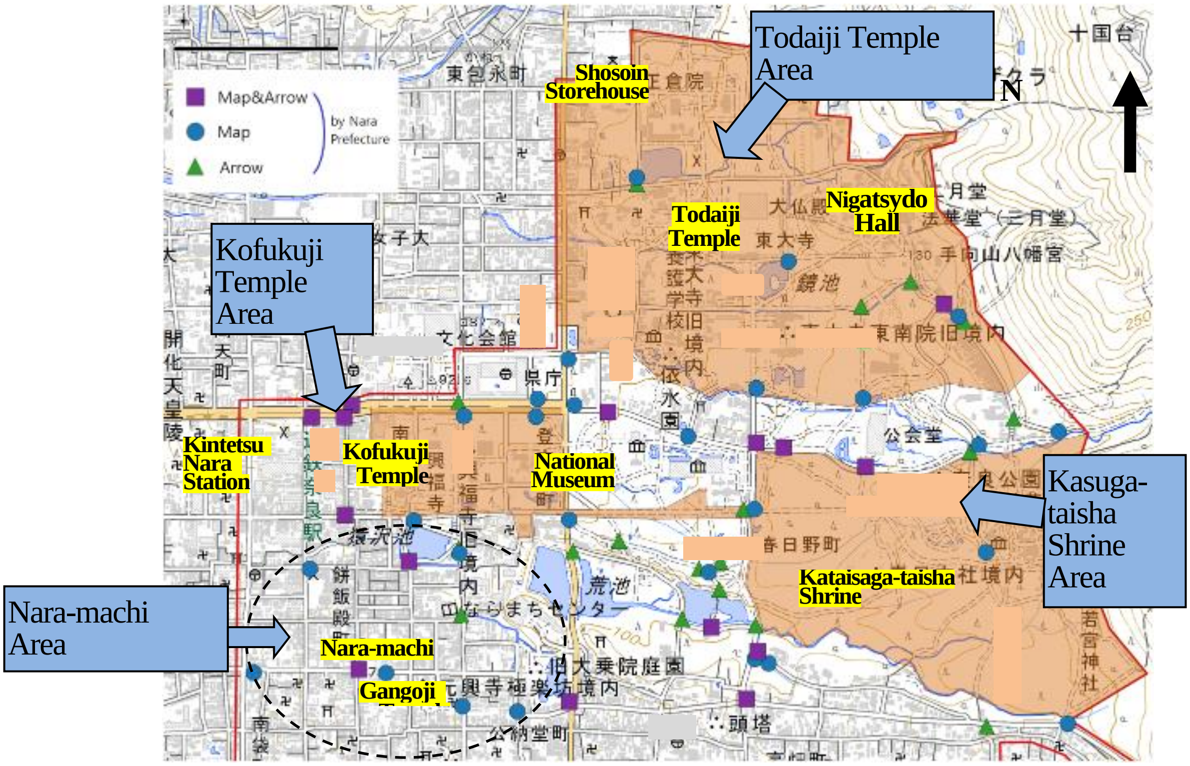
Table 2-2 shows number of signs cross-tabulated according to the sign owners and area where the signs are located. It can be seen there that Nara Prefecture accounts for about 35% of signs in the study area, but those signs are reasonably spread across complete park. Therefore, this project discusses mainly the signs constructed and managed by Nara Prefecture. Locations of signs constructed by temples and shrines are mostly within their properties, as it could be expected. More than 80% of signs owned by Nara city are found in Nara-machi Area. In Nara-machi Area located in the South West part of the study area. Many of these signs are the old square post type and considered difficult to understand as navigation aids especially to newcomers. About 50% of signs provided by the prefecture are map signs and 20% of signs provided by the prefecture belonged to this 'map and arrow' category.

Table 4-2 Cross-tabulation of current road signs in Nara Park area

Organization	Sign type	Location			Total	
		Prefectural Nara Park	Temples and Shrines	Nara-machi etc	Number	Percentage
Nara Prefecture	Map	22	3	12	37	17.5
	Arrow	18	1	2	21	9.9
	Map & arrow	10	0	7	17	8.0
	Sub total	50	4	21	75	35.4
Nara City	Map	1	4	0	5	2.4
	Arrow	0	2	33	35	16.5
	Sub total	1	6	33	40	18.9
Temples and Shrines	Map	0	25	13	38	17.9
	Arrow	1	58	0	59	27.8
	Sub total	1	83	13	97	45.7
Total		52	93	67	212	100.0

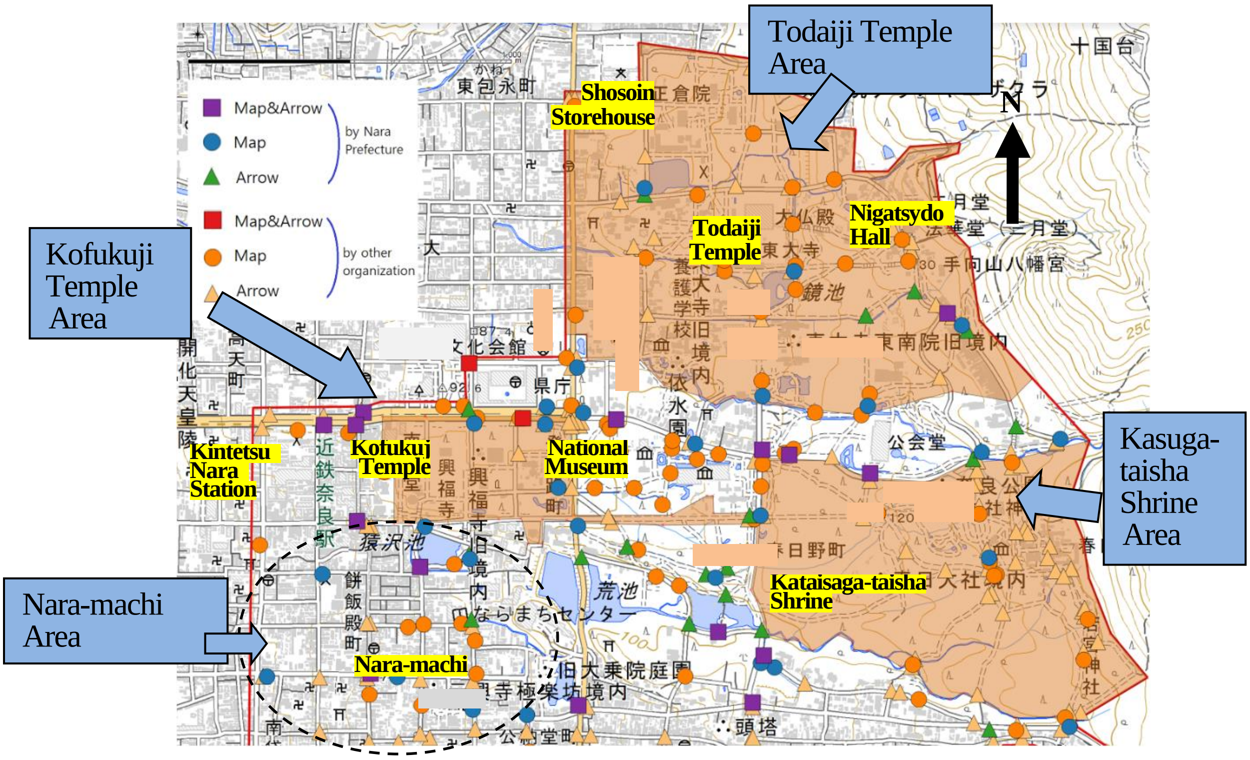
(5) Spatial distribution of signs

An inventory survey was carried out again in June and July 2016 to document the current situation of all signs installed in Nara Park. Figure 4-7 shows the spatial distribution of roadside signs constructed by Nara Prefecture. The spatial distribution of all signs including those constructed by Nara Prefecture and other organizations are illustrated later in Figure 4-8.



Note:(1) Orange-colored areas are historical grounds owned by religious properties.
(2) Since Todaiji temple is large temple, there are several famous attractions including Daibutsuden, Nigatsudo Hall, and Shosoin Storehouse. 'Todaiji Temple' in this map is shown in the location of Daibutsuden which is the most famous attraction in this temple.

Figure 4-7 Current sign boards improved by Nara Prefecture



Note:(1) Orange-colored areas are historical grounds owned by religious properties.
(2) Since Todaiji temple is large temple, there are several famous attractions including Daibutsuden, Nigatsudo Hall, and Shosoin Storehouse. 'Todaiji Temple' in this map is shown in the location of Daibutsuden which is the most famous attraction in this temple.

Figure 4-8 Current all sign boards located around Nara Park

4.3 Suitable Analytical Methods

In this chapter, suitable analytical methods for development of sign system and those for evaluation of the sign system are described.

(1) Development of sign system

Sign system in historical parks should constructs based on the following concept:

a) Important attractions should be guided in the sign system,
b) Sign system should satisfy continuity and consistency as illustrated in Figure 4-9,

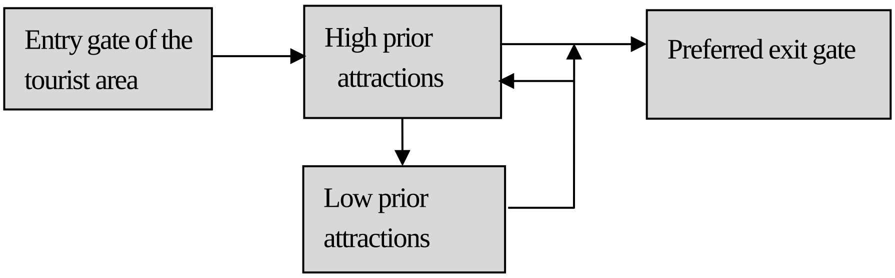


Figure 4-9 Concept of the design of sign system

c) Information indicated at one sign board should be restricted to be easily understood by visitors, and
d) Different type of sign board should be used corresponding to characteristics of the area.

In order to develop above-mentioned sign system, the current sign system, including types of sign boards, their locations are necessary to be investigated. Addition to this, major attractions in the study area and the visitor's behavioral characteristics in the area must be investigated. In this project, such surveys were carried out in 2008.

(2) Before and after comparison

It can be said that most tourist areas have their own sign systems. However, there is few studies discussed the efficiency of sign system introduction or improvement except for simple questionnaire surveys. Addition to this, even though behavioral changes on sign system improvement, precise investigation based on before and after surveys have been scarcely carried out.

The surveys were based on questionnaires seeking visitor's on-site travel behavior in terms of the number of sites visited and routes followed by visitors. The questionnaires also contained questions to measure the perceived level of satisfaction of visitors about the prevailing sign system.

The survey items include that those related to their visiting characteristics and those related to their assessment to the sign system. In the former category, stating and ending points during sightseeing, visiting attractions, order of visiting, selected routes, getting lost locations in Nara Park were included. For the latter category, visibility and ease of understanding of signs. Also, the survey asked visitors when and what kind of source they determined attractions visited.

Questionnaire surveys were performed at four different years in 2008, 2010, 2011, and 2013. Relationship between survey times and sign system construction are illustrated in Figure 4-10. The survey in 2008 was carried out to investigate the situation before the sign system improvement, and the surveys in 2010, 2011, and 2013 are belong to different stages after improvement. The first survey in 2008 achieved only about 10% response rate and it was hypothesized this low response rate could be due to a perception bias of the public against the research credentials of public servants who distributed the questionnaires. The second and third surveys employed university students with the questionnaires presented as part of a university research project. In 2010 the improvement was about 30% completed, and in 2011 most improvements were completed except within historic sites owned by Todaiji Temple, Kasuga-taisha Shrine, and Kofukuji Temple. As shown in Table 4-3, that change of questionnaire distribution method has been productive and the response rate has improved to above 30% following. The fourth survey carried out in 2013 provided a return envelope with a physical stamp individually pasted on it and achieved the highest response rate and the second highest response count.

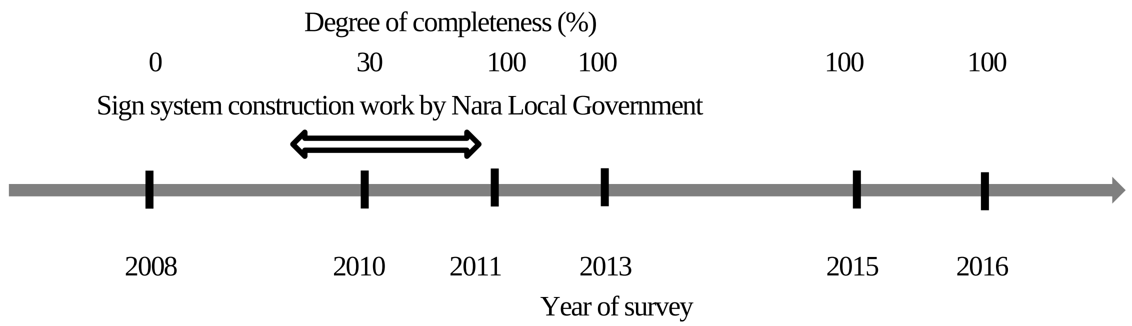


Figure 4-10 Relationship between survey times and sign system construction

Table 4-3 Summary of questionnaire distribution and response rates

	Year of survey			
	July 2008	Dec. 2010	Nov. 2011	Nov. 2013
Progress of sign improvement	0 %	30 %	100 %	100 %
Number of questionnaires distributed	10,020	932	2,000	997
Number of questionnaires returned	1,075	298	711	507
Response rate	10.7%	32.0%	35.5%	50.9%

Except for above-mentioned main surveys, the research team conducted supplementary surveys in 2015 and 2016. These were interview surveys of tourists who reported getting lost. Interviews were carried out to uncover the reasons for such events in November 2015, at areas where getting lost events frequently occurred, making clear by the previous surveys. There were two interview locations. First location was in Todaiji Temple area and second interview location was in Kasuga-taisha Shrine area enclosing by ovals in Figure 4-11.

The interviewer selected the passengers at random at the study area, and 86 tourists were interviewed. The subjects answered the questions including origin and destination of their trip, utilization of road signs, existence of getting lost, and reasons of getting lost.

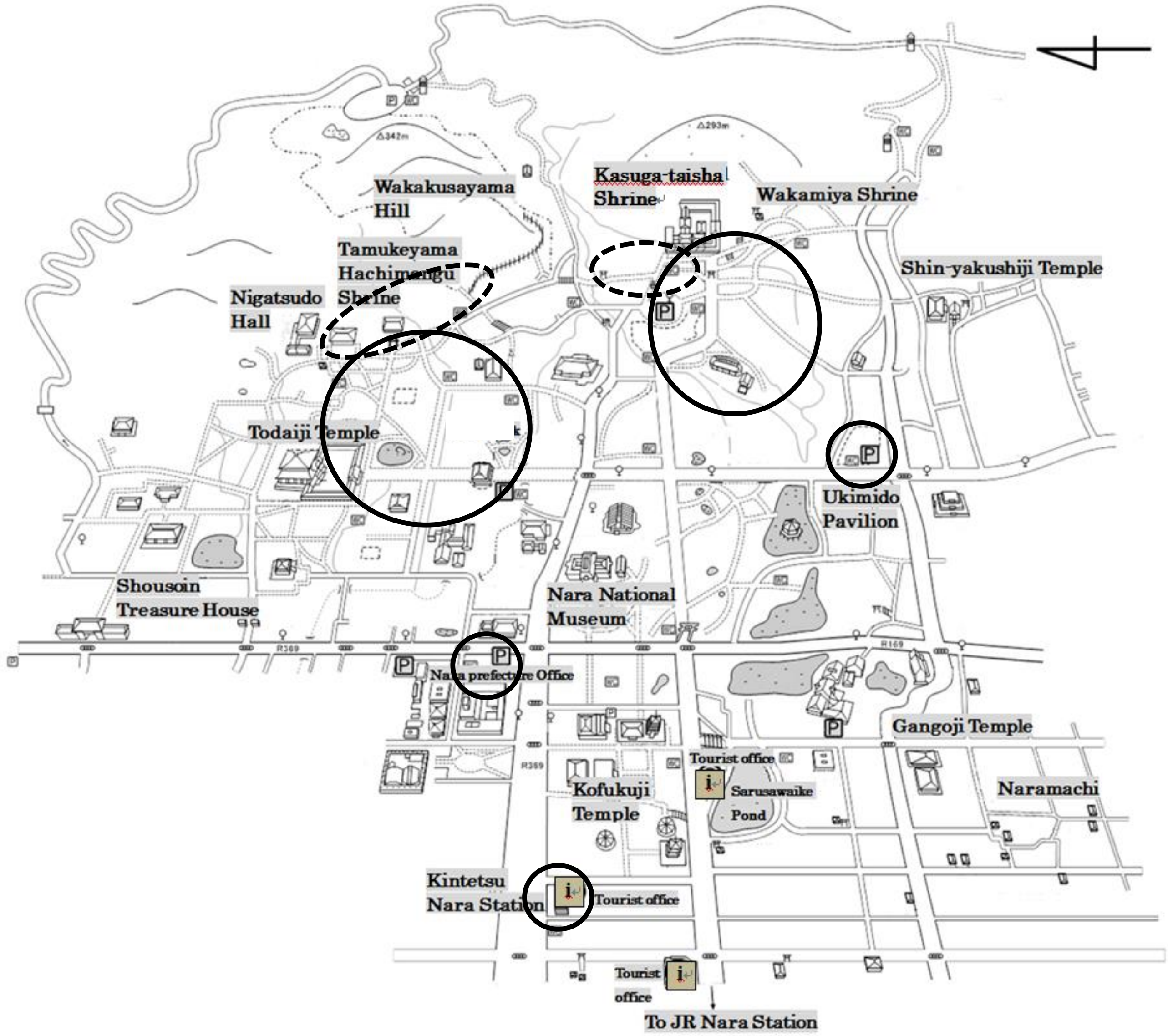


Figure 4-11 Locations of survey sites

(3) What items should be compared?

The purpose of this comparison is to verify the following phenomena exist when sign system installation or improvement in a tourist area as shown in Figure 4-12.

Assumption 1: Decrease of getting lost

Assumption 2: Circulation enhancement

Indices related to the above-mentioned phenomena are as follows:

for assumption 1: number of getting lost,

for assumption 2: number of visiting attractions in one travel and the probability to go to ending points from each visiting location.

In order to verify the assumptions, this project used the survey results on visitors to Nara Park. These surveys were performed to make clear the change of visitor's behavior based on the comparison between before and after sign system improvement.

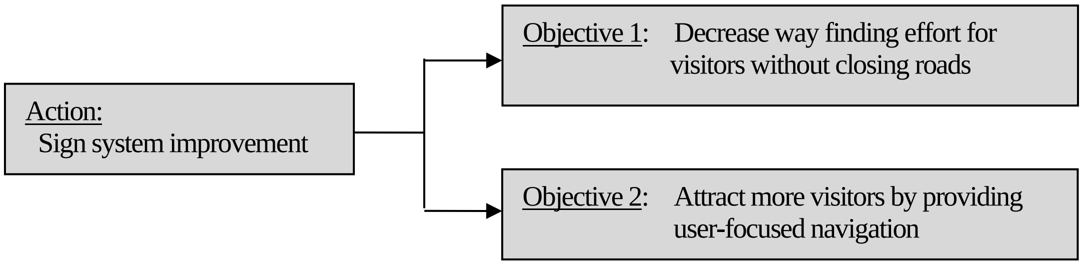


Figure 4-12 Planning objectives of the sign system improvement project

A statistical analysis of questionnaire survey responses was performed to identify differences and trends of on-site travel properties over the three time periods. The emphasis of this analysis component has been to identify the influence of information offered by the sign system on the sequence of sites visited and route choice behavior of visitors.

Basically, subjects were selected from visitors going to their attractions. Visitors in a group introduced by a guide were excluded, because they did not determine the attractions visited by themselves. Addition to this, since most visitors from overseas were seemed to be newcomers, they were not included, considering that this project intends to analyze the frequency of visiting Nara Park. Signboards are marked by four languages, including Japanese, English, Chinese and Korean.

4.4 New sign system

4.4.1 Improved sign system

(1) Ranking of attractions

An important step during the planning stage of the sign system modification is the selection of attractions to be considered for the visitor guidance. This was achieved through a ranking process that relied on two interrelated selection criteria.

Selection of attractions to be included in the guidance destination set was given much thought at the planning stage of the new sign system. This was achieved through a ranking process that relied on two interrelated selection criteria. One criterion considered for ranking of attractions is the heritage importance and the other is the popularity. The significance to heritage is determined through inspection of the status of the attraction in the register of 'important cultural properties'. This classification was adopted as the basis of ranking attractions within the park according to the cultural significance. Some cultural properties enjoy an elevated status within the nation and were referred to as 'national treasures' and they were placed top end of the ranking system. However, some of these attractions were open only at selected periods during the year and these were ranked below full-time attractions for this project. The top half of the Table 4-1 shows how heritage (criterion 1) was accounted for in determination of the ranking of attractions for signage design.

The other criterion adopted is the popularity, which was measured from responses to the first questionnaire survey. The lower half of Table 4-1 refers to the classification of attractions according to the level of popularity (criterion 2). Another obvious consideration is whether the site has been mentioned in guide books, tourist information websites and other documentation accessible to general visitors. Table 4-4 Ranking of attractions within the zone

Table 4-4 Ranking of attractions within the zone

Attribute		Rank A	Rank B	Rank C	Rank D
Heritage	National treasures - open for public all year around	✔	✔		
	National treasures - available only at selected periods			✔	
	Important cultural properties - open for public all year round			✔	
	Important cultural properties - available only at selected periods				✔
Popularity	Highest popularity in the first survey	✔			
	High popularity in the first survey		✔		
	Medium level popularity in the first survey			✔	
	Described in major guidebooks and tourist brochures	✔	✔	✔	✔
Number of attractions		4	25	19	24

The first survey carried out in 2008 revealed that most newcomers visited four major attractions as illustrated in Figure 4-12. Visitors make several trips within the historical park during the time they spend there. Figure 4-13 shows the pattern of first three trips visitors made according to a field survey reported in 2008. Figure 4-13 confirms that Todaiji Temple, Kofukuji Temple, Kasuga-taisha Shrine, and Nara National Museum are major attractions and they have become the destination in the first link of the trip chain of park visitors (Tanaka et al. (2009)). Todaiji Temple and Kasuga-taisha Shrine are large religious organizations, therefore number of historical and cultural sites spread out within their individual premises. For example, Daibutsuden, Nigatudo Hall, and Shosoin Storehouse belong to Todaiji Temple.

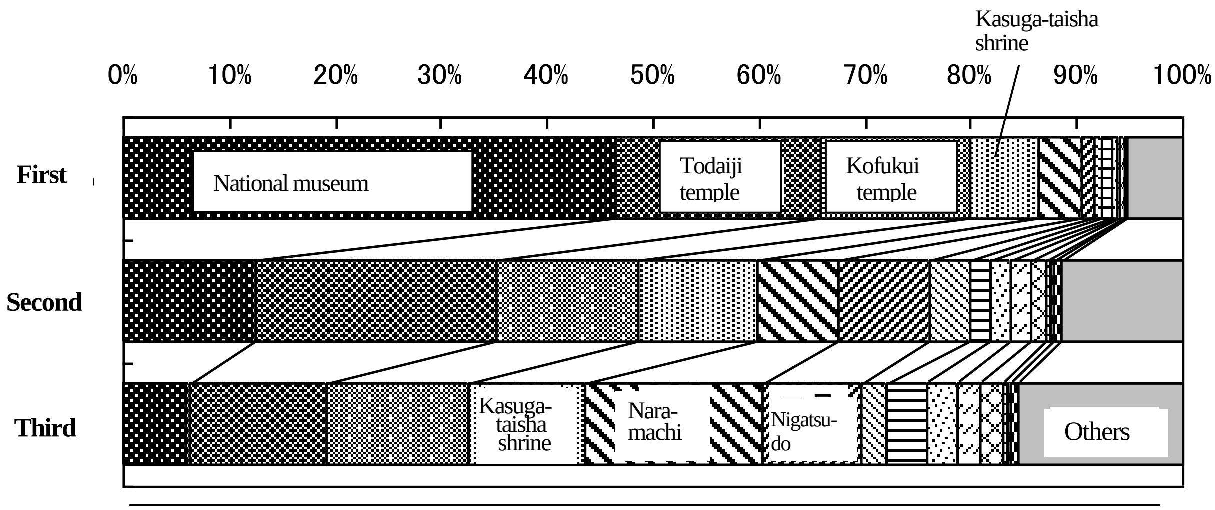


Figure 4-13 Order of attractions visited

The four sites such as Todaiji temple, Kofukuji temple, Kasuga-taisha Shrine and Nara National Museum all of which enjoy the highest status according the significance to heritage are placed as Rank A attractions of the park.

A similar association was observed between rankings according to heritage and popularity, in the lesser ranked attractions as well, as seen in Table 4-1. The number of attractions finally selected in each rank is shown in the last row of Table 4-1.

(2) Concept diagram of sign system improvement

Figure 4-14 provides a schematic comparison of the concept of previous signs and the improved sign system.

The previous sign system shown in the left side of the figure lacked uniformity and clarity of explanations as there were no identifiable logic or hierarchy in directions provided.   Information was accurate but had little

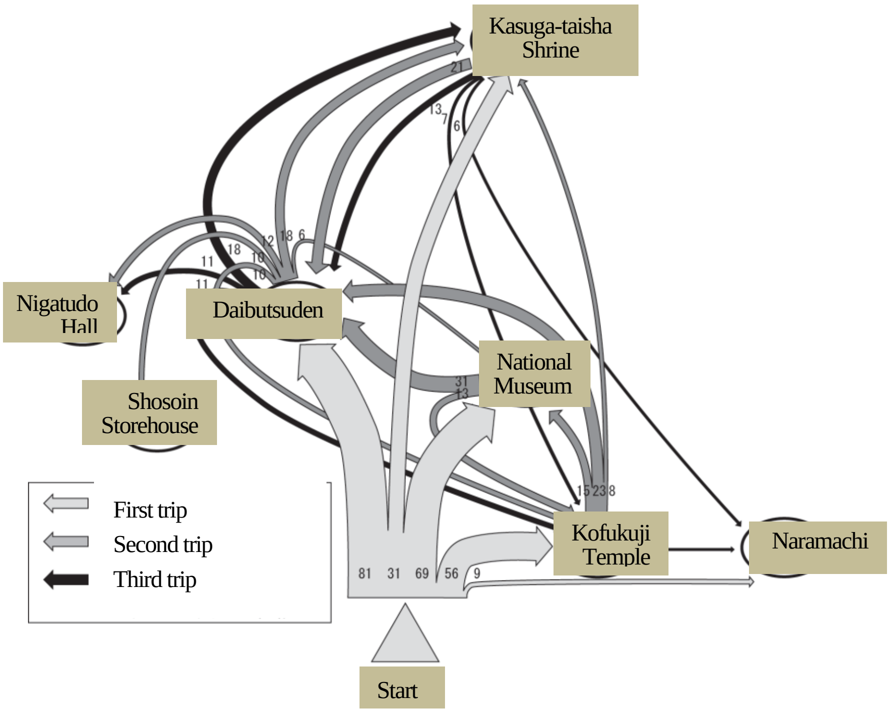


Figure 4-14 Typical circulation pattern in Nara Park

user focus.   The design concept of the improved sign system is shown in the right side which attempted to be aligned with user expectations.   From the view point of planners, it has been expected to encourage visitor circulation among attractions and provide a sense of confidence to visitors that they are unlikely to get lost. The proposed concept was passed on the site importance considered through the ranking system already mentioned and distance to attractions.

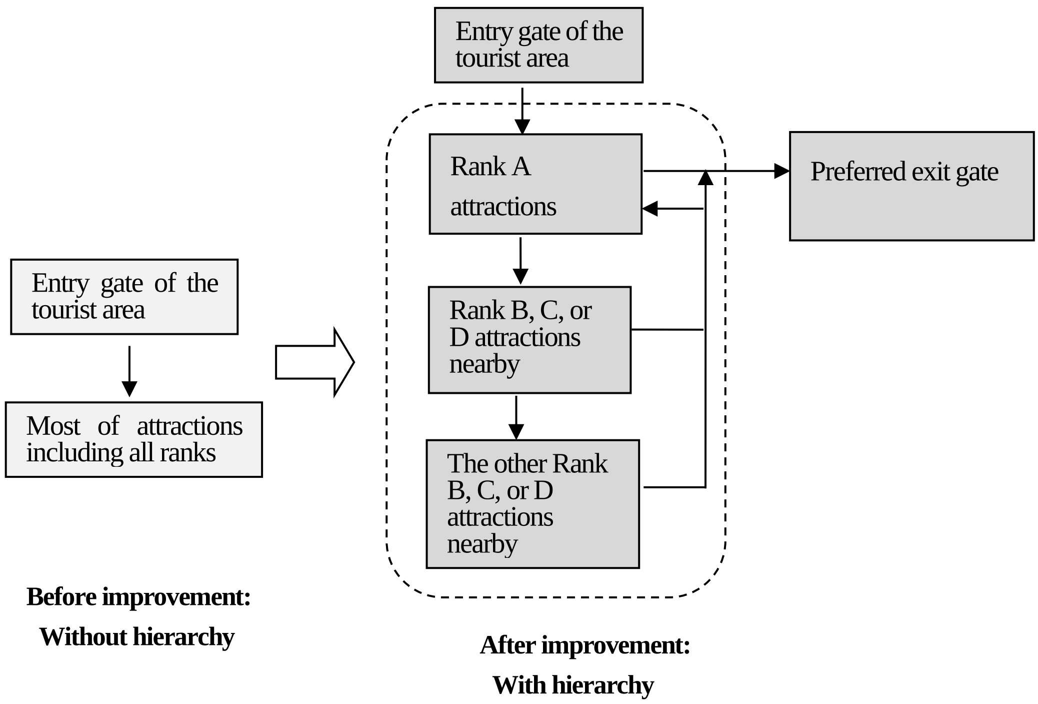


Figure 4-15 Concept diagram of the design objective of the modified sign system (rerecording Figure 4-3)

4.4.2 Use of the sign system

As mentioned earlier, some visitors are familiar with Nara Park and others are not familiar with it. It can be expected that user expectations of the sign system are different according to familiarity with Nara Park. Table 4-5 indicates that the relationship between familiarity with Nara Park and frequency of use of the sign system. The question related to the sign system usage was asked only in the third survey carried out in 2011, and it is acknowledged that comparable data for other years are not available.

From this table, newcomers often rely on the sign system as seen by values 15, 15, 32 and 31 in the four cells at the upper left corner. On the other hand, the percentage of those often-using signs reduces with the number of visits. Then, there is a corresponding increase of the percentage of visitors not using signs with the number of visits. Interestingly, this keeps the percentage of visitors using signs occasionally at a steady level in the range of 40 to 50% irrespective of the number of visits.

Table 4-5 Level of use of sign system by familiarity in Nara Park (2011 survey)

Number of visits \ Sign usage		Often	Sometimes	Never	Total
1	Newcomers	15 (46.9)	15 (46.9)	2 (6.2)	32 (100)
2		32 (47.0)	31 (45.6)	5 (7.4)	68 (100)
3	Repeat visitors	20 (37.7)	26 (49.1)	7 (13.2)	53 (100)
4		10 (30.3)	15 (45.5)	8 (24.2)	33 (100)
More than 4 times		59 (20.8)	124 (43.9)	100 (35.3)	283 (100)
Total		136 (29.0)	211 (50.0)	122 (26.0)	469 (100)

Note: Percentages are shown in parenthesis.

4.5 Way finding errors

4.5.1 Basic findings from surveys

(1) Attributes of respondence

This section describes the attributes of respondents of the major four surveys and then discusses way finding errors of visitors

(a) Gender and age

The percentage of female respondents was between 50% and 60% in the four surveys and always larger than that of male response rate (Table 4-6).

Table 4-6 Gender distribution of respondents in different surveys

Gender	Year of survey			
	2008	2010	2011	2013
Male	529 (49.2)	109 (36.6)	245 (34.9)	205 (44.1)
Female	546 (50.8)	188 (63.1)	404 (57.5)	260 (55.9)
Total	1,075 (100.0)	298 (100.0)	702 (100.0)	465 (100.0)

Note: Percentages are shown in parenthesis.

Figure 4-16 shows age distribution of respondents in each survey respectively. As illustrated in this figure, respondents between 30 and 40 years old accounts for 10~20 % of the sample, between 40 and 50 accounts for also 15~20%, between 50 and 60 accounts for 21~28%, between 60 and 70 accounts for 22~26%. It can be said that age distribution in these surveys do not have large bias.

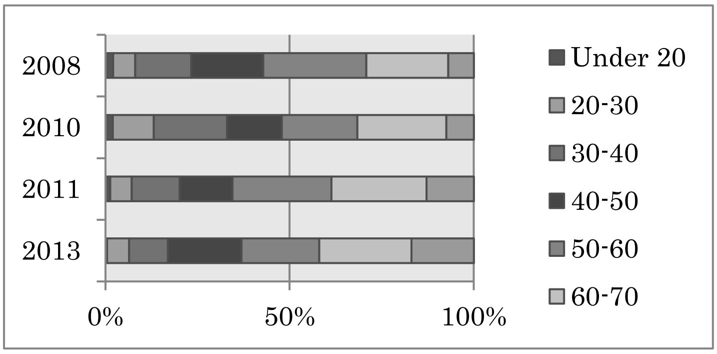


Figure 4-16 Age distribution of respondents in the four surveys

(b) Familiarity with the area

The design phase of the sign system considered the familiarity of visitors with the park. For this purpose, tourists were classified into two categories according to the number of times they have visited this tourist zone. The two categories were named “newcomers” and “repeat visitors”. Conceptually, a newcomer is a tourist who visits this area for the first time. However, that particular definition was disregarded in this project because majority of Japanese schools have excursions to this important historical area. The project team decided to discount that first trip made during a person’s school days which may have been insufficient to provide sufficient familiarity to the visitor to consider the next trip as a true repeat visit. Thus, for the purpose of this project, a newcomer is a person visiting for the first or second time to this park. These visitors are considered unfamiliar with the orientation and layout of the park whereas repeat visitors are considered to have some familiarity. A repeat visitor is a person who has made at least two previous visits to Nara Park.

The proportion of visitors in these two categories changed from survey to survey. Figure 4-17 shows that the proportion of repeat visitors in the 2008 survey was 81.6%, in the 2010 survey it was somewhat low at 67.4% and in the 2011 survey it was back to the previous range and was 82.5%. The simple conclusion is that repeat visitors form about three quarters of all the visitors to the site. This observation highlights the popularity of Nara Park as a leading tourist destination in Japan.

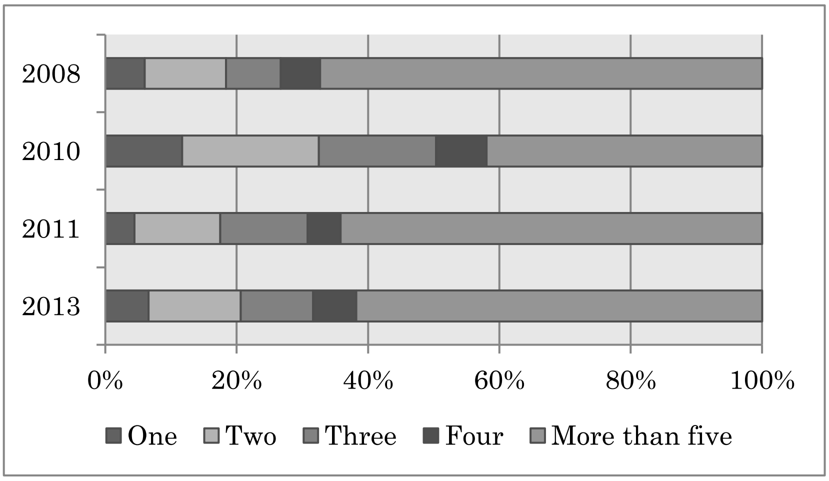


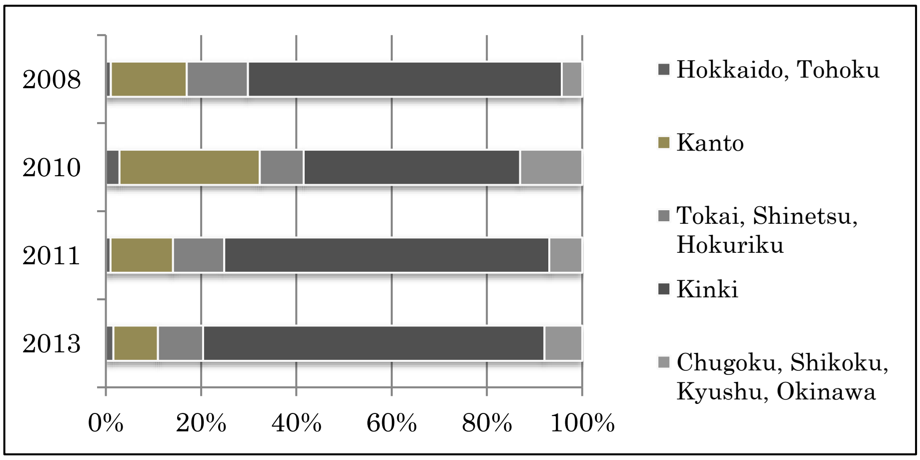
Figure 4-17 Count of visits (including the current day) to Nara Park

As mentioned before, there are three type of sign boards in improved sign system in Nara Park. The design of the system focused on providing plain and simple direction signs for the newcomers and concentrated on leading these visitors to the primary attractions. In other words, newcomers are directed toward must-see sites.

Providing an enhanced experienced for repeat visitors was achieved through providing descriptive signs with directions provided to experience additional elements of the park. Conceptually, this is akin to guiding the visitors who have some previous experience to other hidden treasures of the park. Invariably, somewhat verbose and schematic signs are required to satisfy the repeat visitors.

(c) Regions visitors coming from

For the purpose of identification of origins of visitors, Japan has been divided into eight regions as shown in Figure 4-18. Most visitors of Nara Park had come from Kinki Region immediately surrounding Nara Park, except in 2010 when the 1300 anniverary events were held in the acient capital site close to Nara Park when there was a surge from all other parts of Japan as well. To put it concretely, in 2010 about 30 % of visitors came from Kanto Region where the capital Tokyo is located and has the largest population among the eight regions.



Note: Hokaido and Tohoku : **Area 1**, kanto : **Area 2**, Tokai,Shinetsu, Hokuriku : **Area3**, Kinki : **Area 4**, Chugoku, Kyushu, Okinawa : **Area 5** in Figure 4-1

Figure 4-18 Visitor's origin regions considered (Major part of Japan)

(d) Information sources

Information sources used by visitors are shown in Figures 4-19 and 4-20. Figure 4-19 shows that internet, guidebooks, and pamphlet were the major sources of information prior to coming to the site. On the other hand, after arriving at Nara Park, street sign is the most influential source that amounts to about 40% of sample. Then, guidebooks and maps obtained from the information center amounted to about 40% of responses.

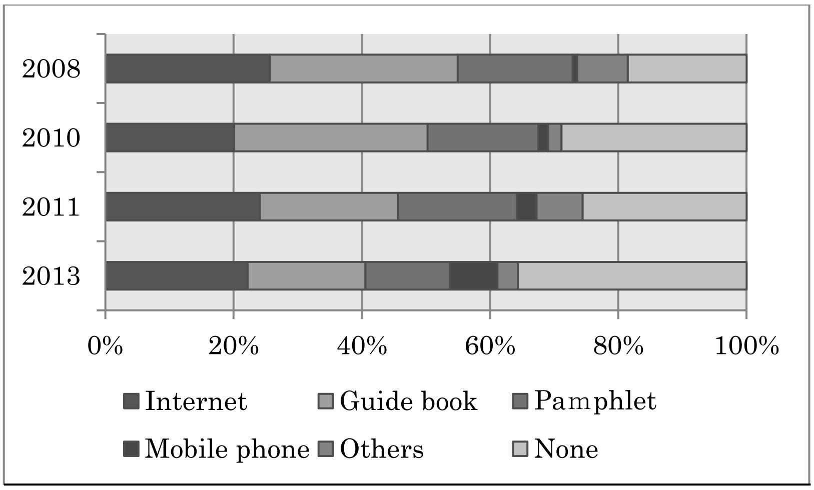


Figure 4-19 Information sources prior to arrival at Nara Park

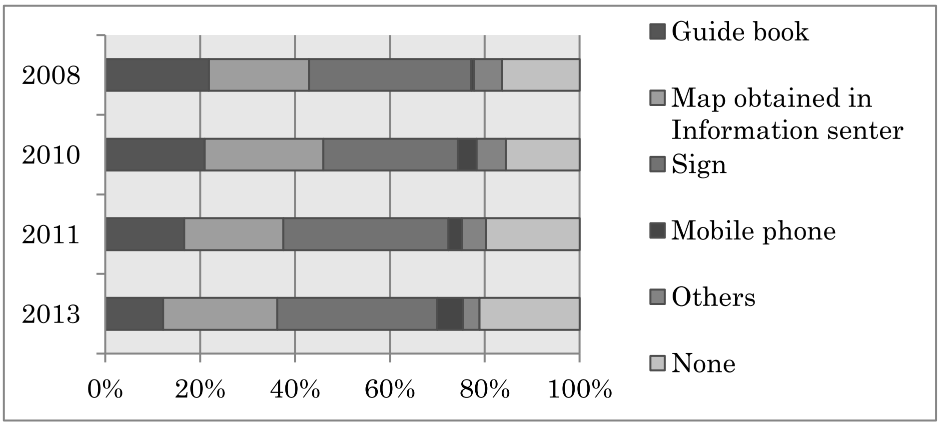


Figure 4-20 Information sources after arriving at Nara Park

(2) Suitability of comparison among survey results carried out in a different season

Among four surveys conducted in this project, survey in 2008 was carried out in summer season, on the other hand, surveys in 2010, 2011, and 2013 were conducted in late autumn. Since these surveys are not panel surveys, the respondents in each survey were different. Therefore, it is necessary to compare the basic attribute of the respondents.

In order to make the before and after comparison meaningful, it was decided to estimate the difference of circulation time available for tourists in summer and late autumn. Figure 4-21 shows the distribution of start and end times of sightseeing of respondents in 2008 and 2011 surveys. Frequency of start times is plotted towards the top of the diagram and frequency of end times is plotted towards the bottom of the diagram. Majority of the entries to the park happens in the morning over a four-hour period and most of the exits occur in the afternoon over a six-hour period. The graphs are reasonably close to each other and do not indicate a reason to consider there are seasonal effects that need to be considered for analysis of the travel behavior of visitors to this park although the seasonal variation may have influenced other aspects of their day. The average duration of stay in Nara Park was identical at 5 hours in both survey periods. Based on these findings, it can be said that there is not large difference among the four surveys.

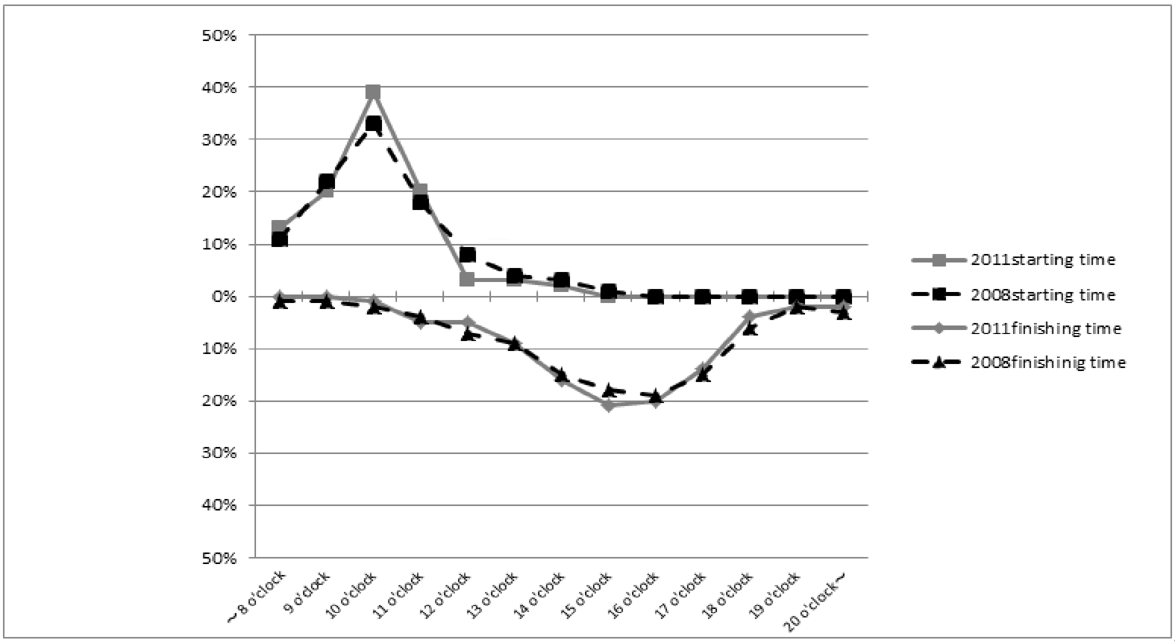


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Figure 4-21 Start and end times of respondents in 2008 and 2011

4.5.2 Locations where visitors lose their way

It is not easy to define getting lost behavior, because it is difficult for investigators to observe the behavior. Therefore, we cannot help to entrust self-assessment by persons. This study adopts data obtained by questionnaire surveys in which respondents answered existence of getting lost, when, where, and why their getting lost occurred.

To guide visitors to their destination surely is vital importance of sign system improvement. Accordingly, when we discuss visitor's behavioral change by improvement of sign system, getting lost behavior should be analyzed.

In the survey, the respondents were asked to when they got lost by naming the origin and destination landmarks at the time of the problem in addition to the approximate location of the event. At the next step of the analysis, origins and destinations of trips where visitors encountered way finding difficulties were transformed to zone numbers specified above.

Then it was possible to compute a numerical magnitude for the intensity of way finding errors. An index referred to as the proportion of way finding difficulties is introduced for this purpose. This value is available by dividing the number of respondents who lost their way between a given zone pair by the total number of visitors who have reported to have travelled between that zone pair in the same direction. Therefore;

$$\text{Proportion of way finding difficulties for travelers between an origin and destination pair} = \frac{\text{Number of respondents who lost their way between the given origin and destination pair}}{\text{Total number of respondents who traveled between the given origin and destination pair}}$$

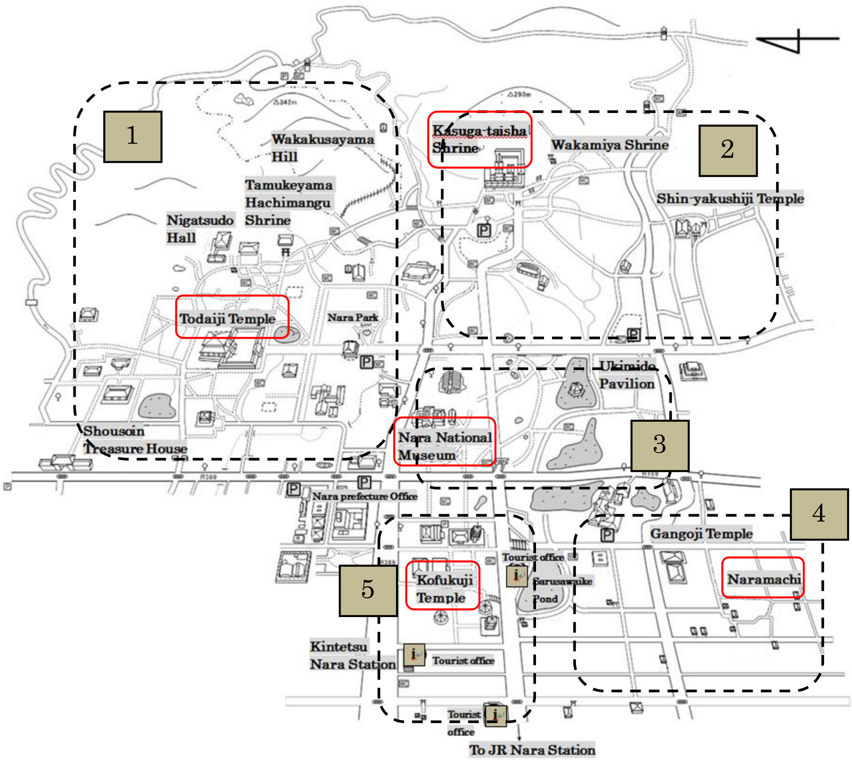
An attempt was made to record the distribution of locations where visitors lose their way. Here, attractions were divided into 6 zones as shown in Figure 4-22 and identified in the tabulation provided at the bottom of the figure. The study area was divided into 5 zones, and the remaining space was considered as the 6th zone for this arrangement.

To analysis visitors who reported completely lost or slightly lost experience were counted in the denominator of the above formulation.

Table 4-7 shows the values of above proportion values computed for zone pairings in the second row of each cell. The first row in each cell contains two numbers, the first value is the number of respondents reported to have lost their way (i.e. the numerator of the above computation) and the second value within brackets is the total number of respondents who have reported to have travelled between the origin destination pair (i.e. the denominator of the above computation). First five zones were considered as the relevant origins and destinations.

Table 4-7 allows us to identify areas where way finding problems were more frequent. In Table 4-7 cells that exceed 10% are indicated in bold letters. Bold value cells in the generation column and attraction rows provide an initial indication for zones and pairings of concern. More than 10% visitors who went to Nara-machi zone lost their way in each survey. Visitors leaving Kasuga-taisha zone have provided unacceptable level of this value in the last two surveys performed. Therefore, comparison of data from the four surveys, does not show a reduction in way finding errors to users even after the sign improvement.

As mentioned before, Kasuga-taisha Shrine and Nara-machi zones being private property, the sign modernizing project could not be fully implemented in those zones. Many old signs remain according property owner wishes. Therefore, some incompatibilities exist with modern signs introduced during the improvement project. Further coordination of signs is necessary in these zones.



Zone	Major facilities
1 Todaiji Temple area	Todaiji Temple, Shosoin, Nigatsudo, Temukaiyama-hachiman Shrine, Yakakusayama Hill
2 Kasugataisha Shrine area	Kasuga Shrine, Wakamiya Shrine, Shin-Yakushiji Temple
3 National Museum area	Nara National Museum, Ukimido
4 Naramachi area	Gankoji Temple, Naramachi
5 Kofukuji Temple area	Kofukuji Temple, including Kintetsu Nara Station
6 Other space	Other attractions

Figure 4-22 Zoning for analysis of way finding difficulties

Table 4-7 Proportion of way finding difficulty values in four surveys

2008 survey

Destination / Origin	1 Todaiji Temple	2 Kasugataisha Shrine	3 National Museum	4 Naramachi	5 Kofukuji Temple	Generation
1 Todaiji	11 (134) 8.2	4 (76) 5.3	0 (38) 0	**4 (24) 16.7**	2 (135) 1.5	21 (407) 5.2
2 Kasugataisha	4 (50) 8.0	**5 (29) 17.2**	**2 (17 11.8**	**3 (17) 17.6**	1 (62) 1.6	15 (175) 8.6
3 Museum	3(125) 2.4	1 (42) 2.4	**5 (16) 31.3**	2 (52) 3.8	1 (170) 0.6	12 (405) 3.0
4 Naramachi	0 (11) 0	**3 (8) 37.5**	1 (13) 7.7	**4 (14) 28.6**	2 (107) 1.9	10 (153) 6.6
5 Kofukuji	2 (109) 1.8	0 (37) 0	4 (298) 1.3	5 (66) 7.6	0 (161) 0	11 (671) 1.6
Attraction	20 (429) 4.7	13 (192) 5.0	12 (382) 3.1	**18 (173) 10.4**	6 (635) 0.9	69 (1811) 3.8

2010 survey

Destination / Origin	1 Todaiji Temple	2 Kasugataisha Shrine	3 National Museum	4 Naramachi	5 Kofukuji Temple	Generation
1 Todaiji	8 (124) 6.5	4 (42) 9.5	0 (9) 0	**4 (19) 21.1**	2 (107) 1.9	18 (301) 6.0
2 Kasugataisha	2 (55) 3.6	**5 (16) 31.3**	1 (11) 9.1	**1 (4) 25.0**	1 (32) 3.1	10 (118) 9.3
3 Museum	1 (11) 9.1	0 (5) 0	0 (0)	**1 (6) 16.7**	1 (16) 6.3	3 (38) 7.8
4 Naramachi	1 (11) 9.1	0 (5) 0	0 (1) 0	**3 (9) 33.3**	1 (43) 2.3	5 (69) 7.2
5 Kofukuji	4 (106) 3.8	**6 (48) 12.5**	0 (19) 0	**6 (29) 20.7**	6 (111) 5.4	22 (313) 7.0
Attraction	16 (307) 5.2	**15 (116) 12.9**	1 (40) 2.5	**15 (67) 22.4**	11 (309) 3.6	58 (991) 5.9

2011 survey

Destination / Origin	1 Todaiji Temple	2 Kasugataisha Shrine	3 National Museum	4 Naramachi	5 Kofukuji Temple	Generation
1 Todaiji	15 (238) 6.3	6 (79) 7.6	2 (49) 4.1	**5 (46) 10.9**	5 (190) 2.6	33 (602) 5.5
2 Kasugataisha	**9 (47) 19.1**	**5 (21) 23.8**	**5 (18) 27.8**	**4 (14) 28.6**	1 (44) 2.3	**24 (144) 16.6**

3 Museum	8 (168) 4.8	1 (20) 5.0	**1 (4)** **25.0**	**4 (34)** **11.8**	5 (132) 3.8	19 (358) 5.3
4 Naramachi	1 (11) 9.1	**1 (6)** **16.7**	1 (13) 7.7	**7 (24)** **29.2**	3 (121) 2.5	13 (175) 7.4
5 Kofukuji	10 (169) 5.9	1 (28) 3.6	5 (256) 2.0	**10 (66)** **15.2**	2 (147) 1.4	28 (666) 4.3
Attraction	43 (633) 6.8	14 (154) 9.1	14 (340) 4.1	**30 (184)** **16.3**	16 (634) 2.5	117 (1945) 6.0

2013 survey

Destination / Origin	1 Todaiji Temple	2 Kasugataisha Shrine	3 National Museum	4 Naramachi	5 Kofukuji Temple	Generation
1 Todaiji	19 (207) 9.2	**11 (90)** **12.2**	2 (25) 8.0	3 (25) 8.0	7 (136) 5.1	42 (483) 8.7
2 Kasugataisha	19 (87) 8.0	**4 (16)** **25.0**	1 (20) 5.0	1 (25) 4.0	5 (59) 8.5	**30 (207)** **14.5**
3 Museum	2 (18) 11.1	1 (31) 3.2	0 (0)	**3 (8)** **37.5**	2 (36) 5.6	8 (93) 8.6
4 Naramachi	0 (9) 0	0 (3) 0	**1 (8)** **12.5**	**3 (9)** **33.3**	3 (74) 4.1	7 (103) 7.8
5 Kofukuji	6 (165) 3.6	5 (68) 7.4	**4 (36)** **11.1**	**8 (40)** **20.0**	3 (111) 2.7	26 (420) 6.7
Attraction	46 (486) 9.5	**21 (208)** **10.1**	8 (89) 9.0	**18 (107)** **16.8**	20 (416) 4.8	113 (1306) 8.7

Note: Percentages are shown in parenthesis.

Locations where visitors got lost have been plotted in Figure 4-23. As expected from observation of Table 4-7, the distribution of these locations appears denser in the upper left quadrant of Figure 4-23, mainly between Todaiji Temple and Kasuga-taisha Shrine. Similarly, there is a patch of high density area of black spots on the lower right corner of the map, in the Nara-machi zone.

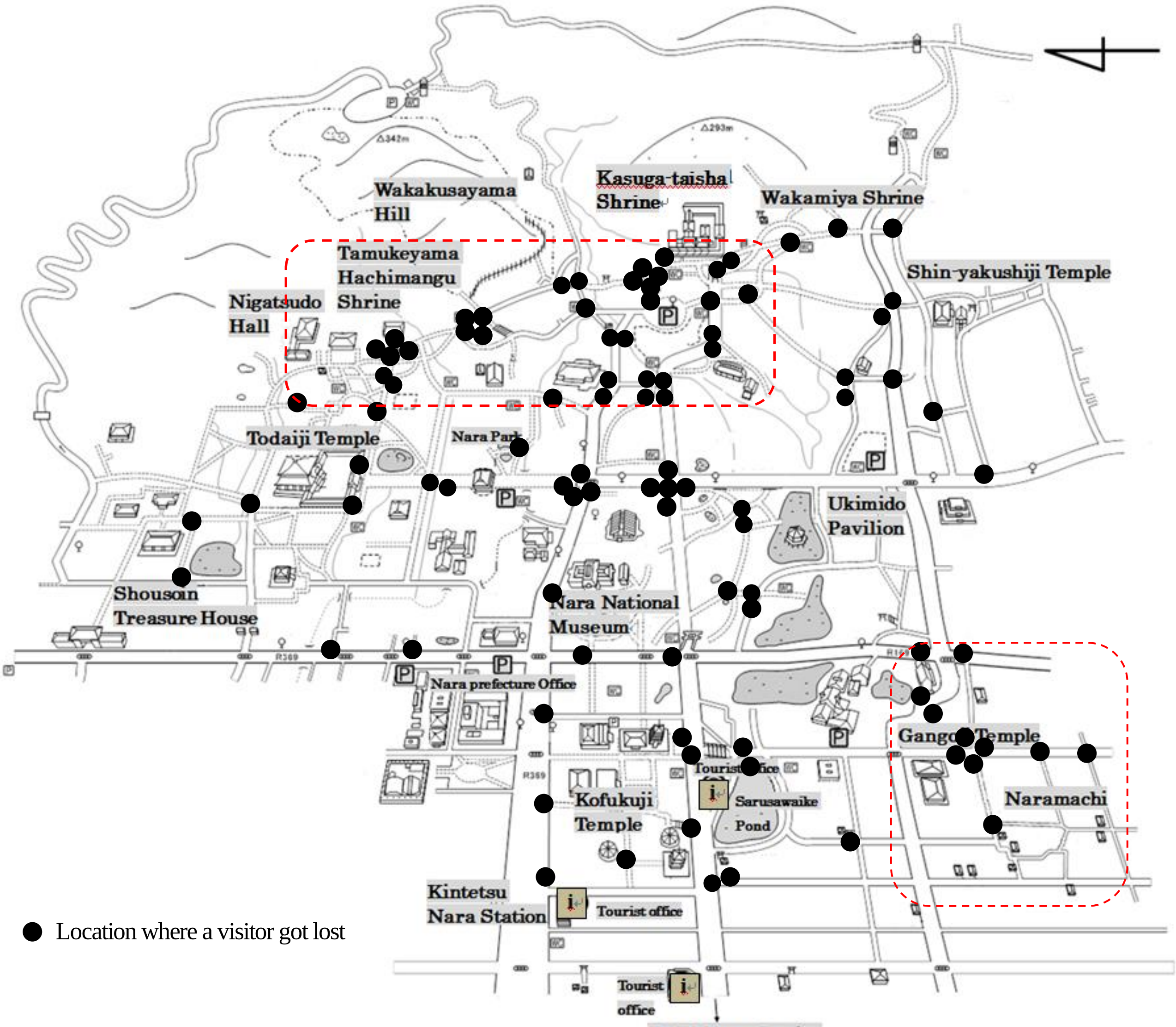


Figure 4-23 Locations where visitors lost their way

4.5.3 Changes in way finding movement

This study classified user experience of way finding errors into three types. These were "completely lost", "slightly lost", and "never lost". Percentages of visitors in each category are illustrated in Figure 4-24. Completely lost experience was 4.2% in 2008 and decreased a little in following surveys, though the percentage increased a little in 2010 when visitors from far away origins increased because of the1300 anniversary events. Anyhow, the percentage value was around 5% over the five-year period of the surveys. On the other hand, the percentage with slightly lost experience increased from about 15% in 2008 to about 20% after 2010. This agrees with observations in Table 4-7

This may appear counterintuitive, but it will be shown later that the average number of attractions visited per person also increased during this period. Therefore, it is difficult to confirm validity of the following assumption 1 (see Section 4.3) immediately:

Assumption 1: Decrease of getting lost by the sign system modification.

We discuss the relationship between way finding behavior and circulation behavior in Section 4.6.

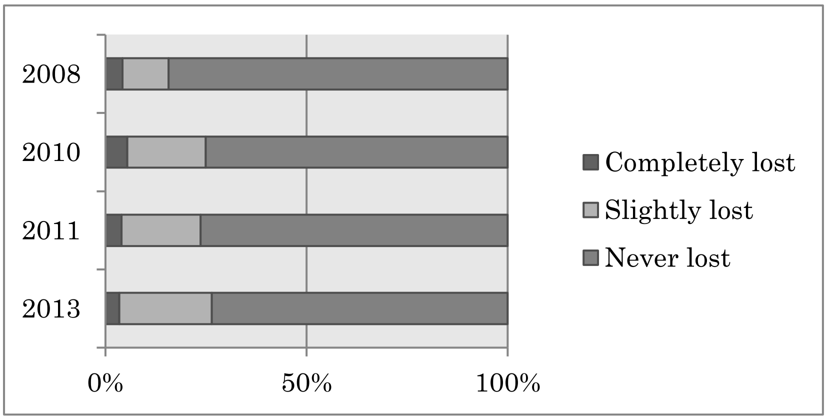


Figure 4-24 Percentage of visitors according to the level of way finding difficulty

Table 4-8 shows the percentages of visitors getting lost in each survey. This table indicates that getting lost percentages were not greatly changed. But if we compare the new comers and repeat visitors, there is clear difference in new come's behavior, that is, the percentage decreased in order 2008 (before improvement), 2010 (30% improved), and 2011 (100% improved). On the other hand, there was no change for repeat visitors and slightly getting lost conversely increased.

Table 4-8 Percentages of getting lost in each survey

	Survey year	Completely lost	Slightly lost	Did not lost	Whole
New comers	2008	20 (10.1)	44 (22.2)	134 (66.7)	198 (100.0)
	2010	8 (8.2)	25 (25.8)	64 (66.0)	97 (100.0)
	2011	6 (5.3)	33 (29.2)	74 (65.5)	113 (100.0)
Repeat visitors	2008	25 (2.9)	80 (9.1)	772 (88.0)	877 (100.0)
	2010	8 (4.0)	34 (17.0)	158 (79.0)	200 (100.0)
	2011	22 (4.2)	104 (19.7)	403 (76.2)	529 (100.0)
All tourists	2008	45 (4.2)	124 (11.5)	906 (84.3)	1075 (100.0)
	2010	16 (5.4)	59 (19.9)	222 (74.7)	297 (100.0)
	2011	28 (4.4)	137(21.3)	477(74.3)	642 (100.0)

Note: Percentages are shown in parenthesis.

4.5.4 Way finding methods used by those getting lost

The way finding methods visitors were using when they got lost were classified into the following three categories, including;

(a) Signs
(b) A paper map
(c) Other; not a map or signs.

Figure 4-25 shows that the percentage of visitors who were using signs was about 40 percent and that of visitors in using maps was also about 40 percent, about 80 percent in total. In other words, most visitors relied on traditional guidance sources although they were not perfect in assisting users.

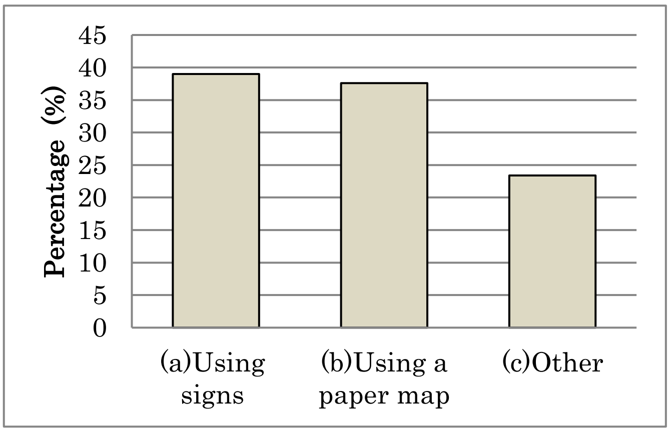


Figure 4-25 Guidance used before visitors got lost

The distribution of way finding method used, however, has a somewhat different pattern when the analysis was done with respect to the location where the way finding error occurred. It is acknowledged that the sample size is low when the overall sample was divided to perform the analysis specific to different zones. Figure 4-26 indicates that lost visitors following signs account for about 50 percent around Todaiji and Kasuga-taisha Shrine zones. On the other hand, approximately 60 percent of lost visitors were using paper maps around Nara-machi and Kofukuji Temple zones.

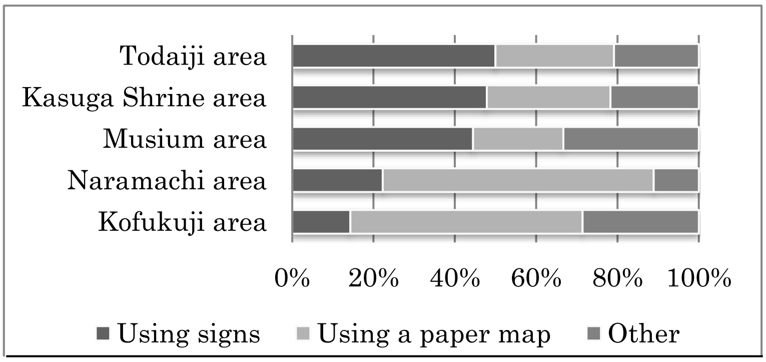


Figure 4-26 Situation when visitor lost ways by a respective area

4.5.5 Way finding recovery behavior

Invariably, visitors who lost their way tried to recover from the incident to resume the journey. Survey allowed five answers to the relevant questions. What did the respondent do to find the way to the planned destination when they got lost? Answers were separated into following five categories:

(1) Searched for direction information where they got lost,
(2) Returned to a known location and resumed the journey,
(3) Asked another person who was able to provide directions,
(4) Used another method not mentioned above to find the way, and
(5) Failed to find the way to the destination.

Figure 4-27shows that the most frequent behavior in a lost situation was looking for direction information in the neighborhood of the incident. The percentage of this response was 47 %. The next frequent behavior was to ask someone (24% of the sample). A small percentage of those who got lost had failed and given up searching for the planned destination.

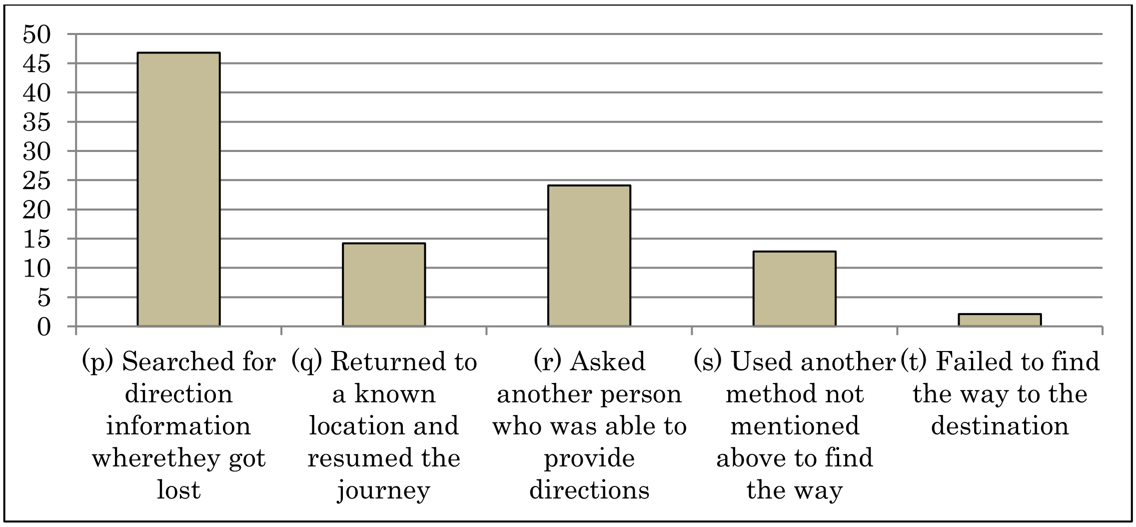


Figure 4-27 Analysis of the recovery behavior

The breakdown of this behavior with signs and no signs available at location of the lost incident is shown in Figure 4-28. It indicates that if signboards were available at the location then 60% of lost visitors could manage to find the way by searching for information nearby. As expected, when signs were not installed at such a location, the percentage who can recover directly from the lost location is reduced according to Figure 4-28. Interestingly, returning to a known location and other strategies researchers have not mentioned have become more useful on a percentage basis, when sign posts were not available, according to this analysis.

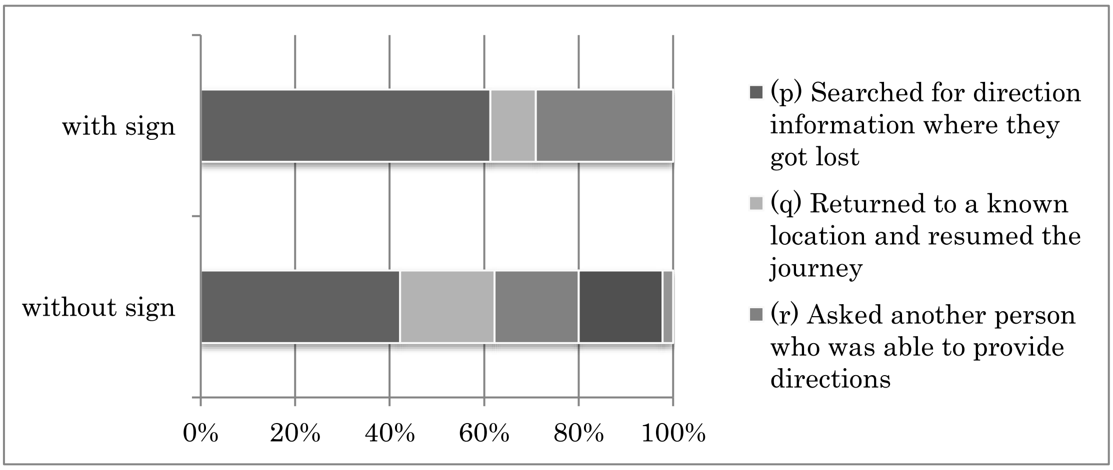


Figure 4-28 Comparison of recovery behavior with and without signs

4.5.6 Relationship between way finding efforts and sign installment

(1) Location of getting lost

Where visitors get lost was surveyed using a self-administered questionnaire survey performed in 2013 are used here. Responses were collated on to the map of Nara Park to identify problem areas from the point of view of way finding. There were 90 respondents whose getting lost place was identified on the map. Figure 4-29 identifies the reported locations where respondents lost their way with star symbols. The size of the star symbol is proportional to the number of reported lost-events. This method was applied to prepare a shortlist of six priority locations to investigate. These are labeled from (A) to (F) in Table 4-9.

Figures 4-7, 4-8 and 4-28, and Table 2-1 were inspected to identify the type of signs available near the locations where visitors getting lost reports were high. Table 4-9 summarizes preliminary observations.

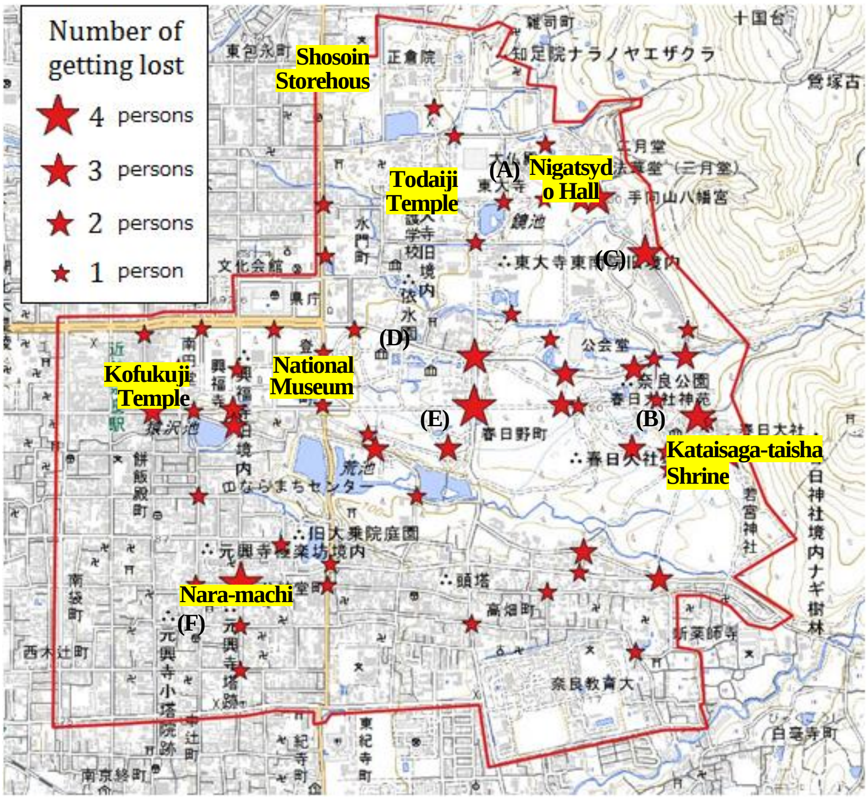


Figure 4-29　　Locations where getting lost behavior occurred

Table 4-9 Relationship between getting lost behavior and signs installation

Spots	Characteristics of roadside signs	Owner
(A) and (B)	Most Sigs in these areas are constructed by Todaiji Temple and Kasuga-taisha Shrine.	landlords
(C)	New signs installed by Nara Prefecture and older type signs constructed by Temples or Shrines are mingled in this area.	Mixed suppliers of roadside signs
(D) and (E)	These are two signal-controlled intersections near to each other connected by a short road link.　Similarity of orientation of roads and other identifying features may have caused confusion to visitors. New signs installed by Nara Prefecture are available at both locations.	Nara Prefecture
(F)	This area contains of dense network of narrow lanes with only few road signs. Pedestrians can obscure the short square post type signs.	Nara City

(2) Pedestrian routes associated with getting lost events

This section investigates examples of pedestrian routes associated with getting lost events. Figures 4-30-1 through 4-30-6 are examples of routes that could have been involved with getting lost events for each of the priority locations mentioned earlier.

There are number of potential routes that could have caused confusion at location (A).　These routes are shown in Figure 5-10-1 and the location (A) is marked as X there.　Route from Kasuga-taisha Shrine to Nigatsudo Hall is one possibility.　Route from Daibutsuden (Todaiji main hall) to Nigatsudo Hall is another possibility. There is also a possibility that visitors on route from Daibutsuden to Kasuga-taisha Shrine also experienced way finding problems at this location. Daibutsuden and Nigatsudo Hall belong to Todaiji Temple.

Signs installed near that location are shown in Figure 4-30-1. Photograph of the map sign constructed by Todaiji Temple is also shown in Figure 4-30-1. All of the signs installed there were not arrow type but map type which was not useful for direct guidance to the destination. Addition to this, the signs has little information to other organizations. Therefore, it is not easy to determine the correct direction using this schematic map.

Tourists coming from Kasuga-taisha Shrine to Daibutsuden or Nigatsudo Hall got lost at location (B) marked as X in Figure 4-30-2. Map boards are installed near this location by Kasuga-taisha Shrine. However, they limit information to their own shrine and have not considered the information need of visitors walking to Todaiji Temple and other popular destinations.

At location of (C) mentioned before, there are two different types of signs, one provided by Nara Prefecture and the other constructed by Kasuga-taisha Shrine. Figure 4-30-3 shows school students studying these signs during an excursion to the park, because different maps with its own concept show different information in almost the same area.

Locations (D) and (E) are located at major intersections in Nara Park. Sign boards are available at these locations. However, since the intersection is large and sign boards exist only at a particular corner, some tourists seemed to be confused here to find their ways (Figures 4-30-4 and 4-30-5).

Location (F) is different from other locations mentioned above. Four photos presented with Figure 4-30-6 were taken at that particular location, toward north, south, east and west directions. Those photos show that there are no visible signs in any direction, at this intersection.

Figure 4-30-1 Spot (A)

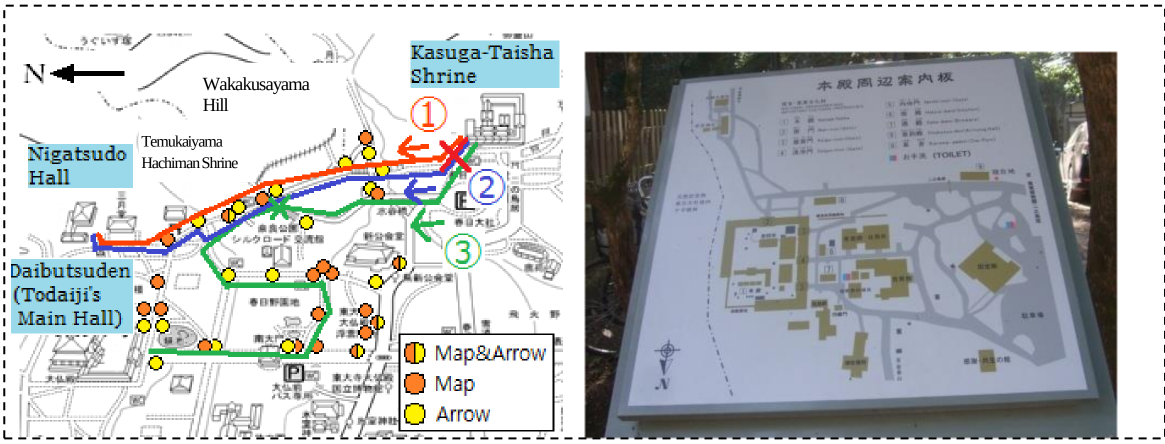


Figure 4-30-2 Spot (B)

Figure 4-30-3 Spot (C)

Figure 4-30-4 Spot (D)

Figure 4-30-5 Spot (E)

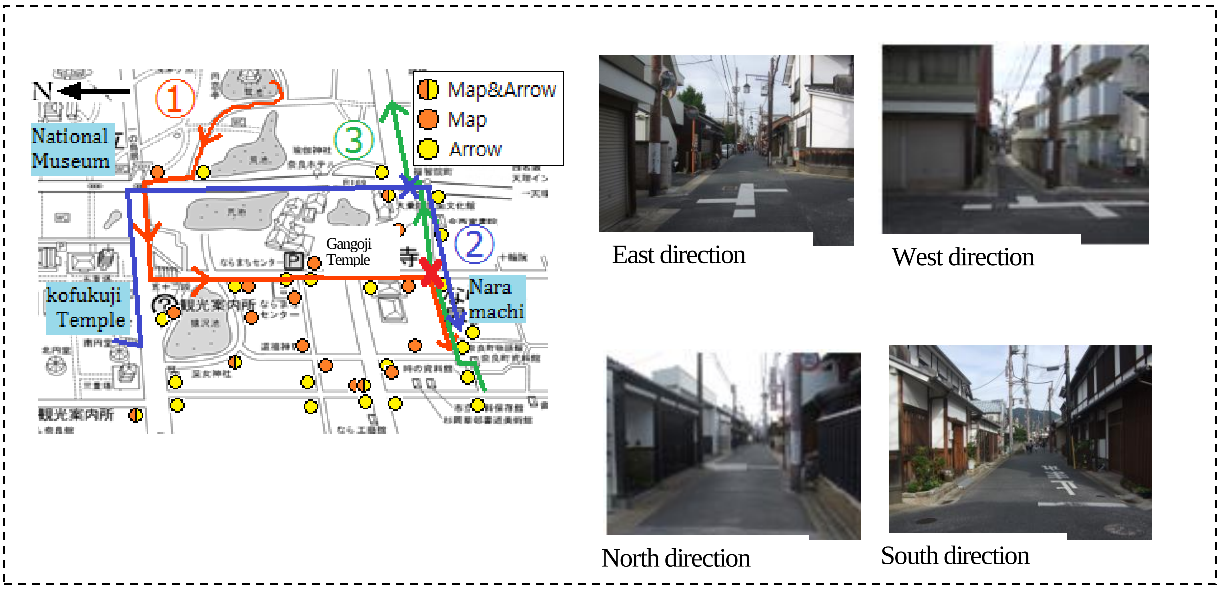


Figure 4-30-6 Spot (F)

As described in Section **4.3**, the interviewer selected the passengers at random at the study area, and 86 tourists were interviewed. The subjects answered the questions including origin and destination of their trip, utilization of road signs, existence of getting lost, and reasons of getting lost. Their situations of way finding activities were shown in Table 4-10. The percentages of getting lost were 32.6 %. Comparing average percentage of getting lost of 26.4 % in 2013 (Tsuakguchi, et al. 2015), it can be said that the above-mentioned sites were more confused areas for visitors.

Table 4-10 Percentage of getting lost

	Number of respondents
Completely getting lost	20 (23.3)
Slightly getting lost	8 (9.3)
Never getting lost	58 (67.4)
Total	86 (100.0)

Note: Percentages are shown in parenthesis.

As for reasons of getting lost, Table 4-11 is obtained. It suggests that the main cause for getting lost events has been the lack of understandable signs for respondents both of Todaiji Temple area and Kasuga-taisha Shrine area, though there were several signs. Also, respondents near Kasuga-taisha Shrine identified lack of signs.

Table 4-11 Reasons for getting lost

Cause of getting lost event	Number of getting lost		
	Todaiji Temple area	Kasuga-taisha Shrine area	Total
I could not find sign board	0	3	3
Not enough sign boards	1	4	5
My destination was not shown in sign board	4	1	5
Sign boards were not easy to understand	5	4	9
Sign board were not consistent with the site	2	1	3
Others	1	1	2
Total	13	14	27

(3) Distribution of path finding errors

Figure 4-31 illustrates the distribution of count of getting lost events in percentage terms with respect to the length of the trip chain. Figure 5-11 was drawn using the 140 data which were clear the relationship between getting lost events and the trip chain in the survey carried out in 2013. It is apparent that there is an upward trend in the latter half of trip chain. For example, in the case of tourist visiting six attractions and more, most got lost events occurred after the third trip.

The average number of attractions in the trip chain of visitors is 3.13 (Tsukaguchi, et.al. (2015)). The details are mentioned in Section **4.6**. Therefore, it is better to focus on length of trip chains such as three or four. When they visited three or four attractions, most getting lost events occurred after the first link. It is likely that visitors experienced only little problem in finding way to their selection of the most important attraction in the park, that may have been the destination of the first link.

Visitors who performed a trip chain of two links, reported a tendency to get lost in the second trip more than in the first trip of the trip chain, according to Figure 4-31. Visitors with three links had more difficulties encountered in the second and third than in the first link of the trip chain. Anyhow, implications of the distribution shown in Figure 4-31need further investigation.

Importance of the second and third links of trip chains shown earlier in Figure 4-29is consistent with more getting lost events being reported in locations such as (D) and (E) which are between two level A attractions. In these areas, where sign boards are owned by temples and shrines, there is a need to persuade the owners to cooperate in assisting visitor outflow also with their signs while not compromising their main objective of attracting visitors. A mutually agreeable systemized approach may need to be developed to improve smooth flow among competing attractions. In this context, some form of formalization of best practice in use of map boards as roadside signs may be of long term benefits as improved visitor experience to this park, particularly for newcomers and unfamiliar visitors.

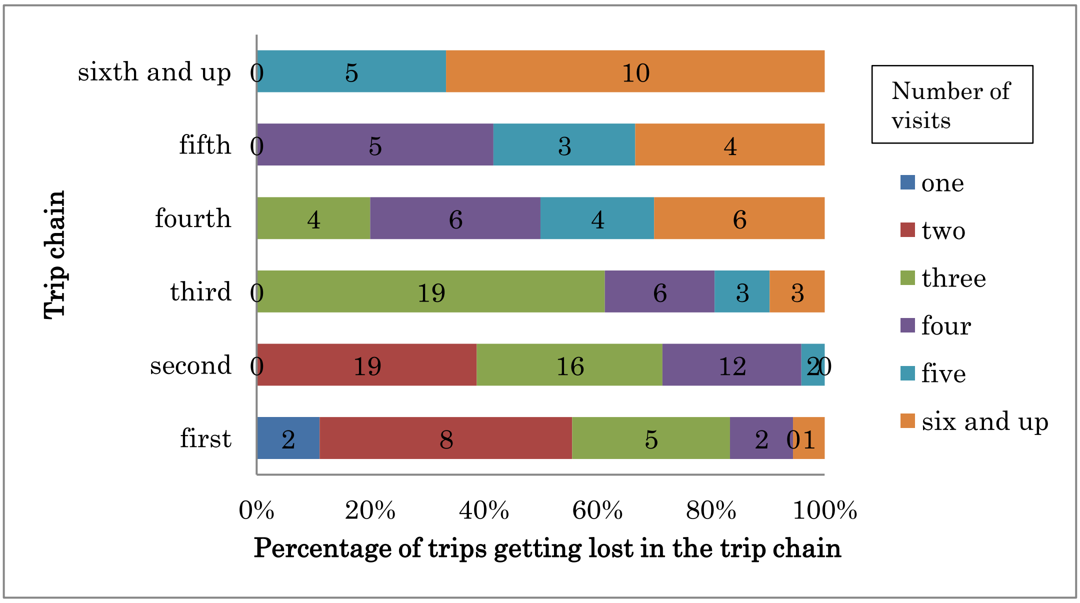


Figure 4-31 Getting lost behavior considering tourist's trip chain

4.6 Impact of the signs on the trip circulation

4.6.1 Relationship between trip circulation and getting lost

An obvious objective of the sign system improvement is reliable guidance so that tourists can reach their destinations. The survey included questions for respondents to reveal whether they got lost during the day. The initial survey was an eye opener for the study team as it showed about 10% of newcomers felt they have lost their way somewhere in the park. The following surveys were slightly modified to obtain more information about where respondents get lost to enable the study team to home in on the locality of the problem.

Figure 4-24 and Table 4-8 in Section **4.5** showed percentages of tourists who lost their way according to the three surveys. The results are presented for newcomers and repeat visitors separately as there is a numerical difference in the experience for these two groups. In general, newcomers have tendency to get lost more than repeat visitors according to the data. Interestingly, for newcomers, rate of losing their way steadily decreased from 2008 to 2011. Recall that the three surveys correspond to 0%, 30%, and 100% completion of the sign improvement. Therefore newcomers position has improved quite well as the improvement project progressed. However, there is not much difference observed for repeat visitors, if any there was a slight increase in the rate of getting lost.

However, if we combine percentages of “Somewhat lost the way” with “Lost the way”, the percentages are almost the same between 2008 and 2011 for the newcomers, and these percentages increase slightly for the repeat visitors. These results seem to challenge the gains reported in previous sections and attributed to the sign improvement project.

This study classified user experience of way finding errors into three types including "completely lost", "slightly lost", and “never lost”. Completely lost experience was 4.2% in 2008 and the percentage was around 5% over the five-year period of the surveys. On the other hand, the percentage with slightly getting lost increased from about 15% in 2008 to about 20% after 2010. This may appear counterintuitive. But it is necessary to investigate the circulation change after sign system improvement. The authors make the following ratiocination.

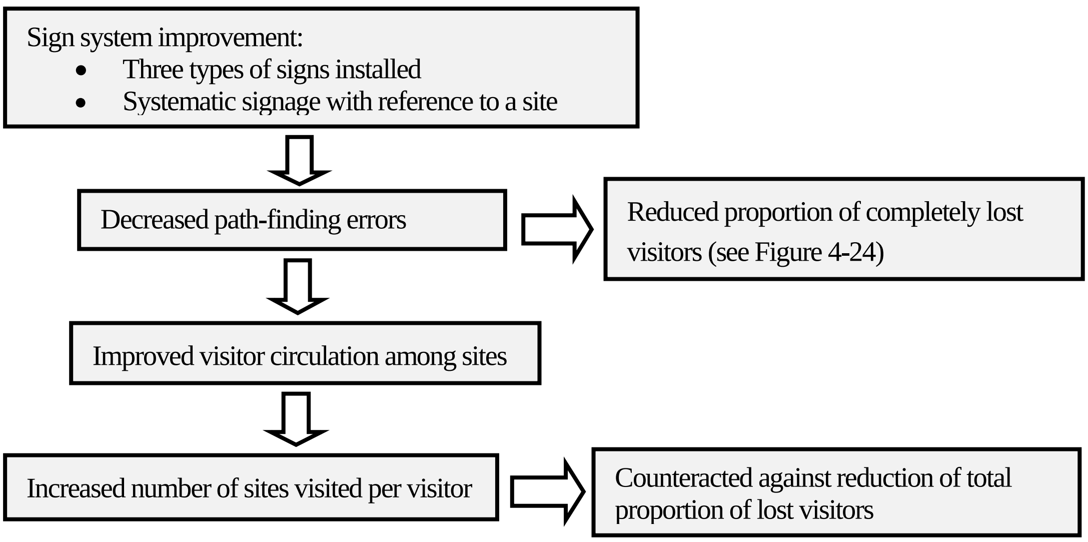


Figure 4-32 Ratiocination of getting lost and circulation level

4.6.2 Circulation during sign system improvement

(1) Average number of attractions visited

Here, we investigate way finding behavior and level of circulation among attractions using Figure 4-33 which provides the average number of attractions visited per visitor. The average values for overall samples show a jump going from 2.89 in 2008 to 3.06 in 2010 and then a smaller jump going to 2011 surveys. The values appear to have stabilized after that showing only a small increase from 2011 to 2013. As explained in an earlier section, the 2008 survey represents the before sign improvement project. By 2010, the project was partially complete and 2011 represents the first fully complete sign systems installed by Nara Prefecture. It has been verified that the difference is significant between the average number of visits in 2008 and 2011, and 2008 and 2013 based on t-test at 1% significant level. T-test has also shown that there is a statistically significant difference between 2008 and 2011, and 2008 and 2013 for repeat visitors. On the other hand, the apparent deference between 2008 and 2011, and 2008 and 2013 values is not significant for newcomers at 1% significant level.

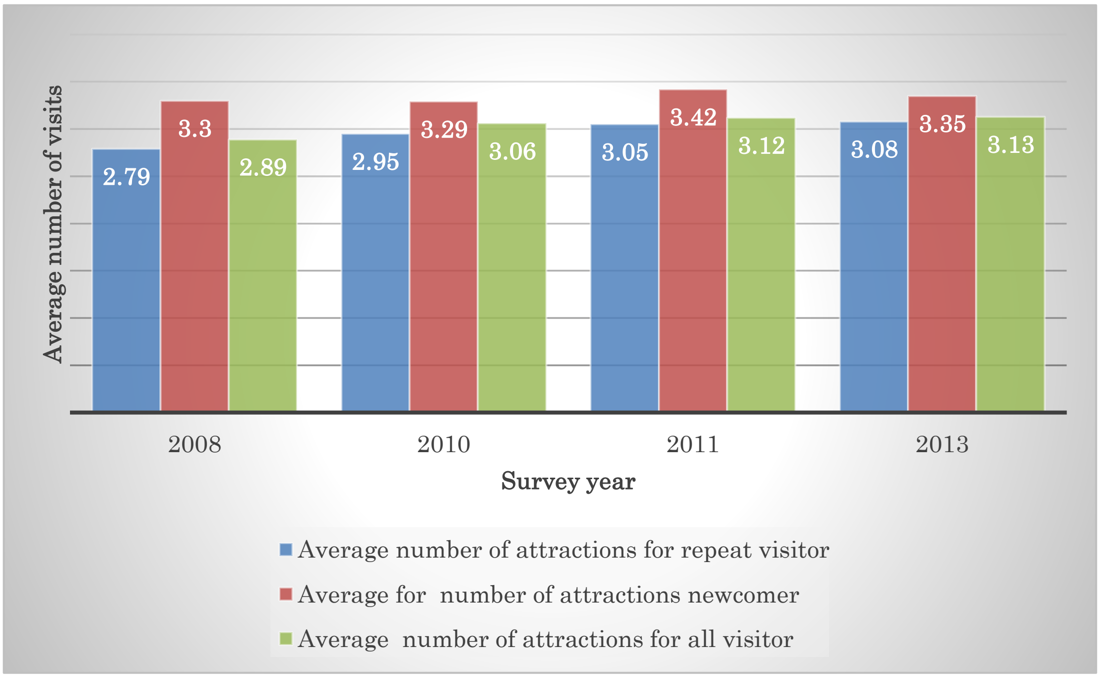


Figure 4-33 Average number of attractions visited

Comparing the repeat visitors and newcomers, average number of attractions visited by newcomers was larger than those visited by repeat visitors in each survey. That is partly because that the new comers tend to visit many popular attractions as possible, on the other hand the repeat visitors are likely to focus on their favorite attractions.

The results bewildered the survey team as it was expected that the repeat visitors would go to more attractions than newcomers who are not even familiar with the area. What the surveys revealed was the opposite, in all three surveys. The newcomers claimed to have visited more number of attractions than the average repeat visitors. This makes sense however, when we look at their travel paths. Repeat visitors get side tracked and meander to soak up the experience and invariably have to sacrifice the quantity of sites they can experience.

Monitoring what happens to circulation patterns with the introduction of new signs is important to the park administrators. Table 4-3 shows the frequency count of tourists visiting a given number of attractions. These allow computation of average count of attractions visited. Table 4-12 provides these average values separately for newcomers and repeat visitors.

Table 4-12 indicates the percentages of number of attractions visited in four surveys addition to average number of visits. This table shows that percentages of tourists visited more than four attractions increased from 23.7% in 2008 survey to 28.9% in 2011 survey.

Table 4-12 Percentages of number of attractions visited by each survey

Number of attractions visited	Survey in 2008	Survey in 2010	Survey in 2011	Survey in 2013
1	142 (13.2)	37 (12.5)	88 (12.5)	51 (10.2)
2	249 (23.2)	64 (21.5)	179 (25.5)	102 (20.4)
3	430 (40.0)	119 (40.1)	233 (33.2)	203 (40.7)
4	167 (15.5)	36 (12.1)	95 (13.5)	68 (13.6)
5	48 (4.5)	20 (6.7)	39 (5.6)	43 (8.6)
6	22 (2.0)	12 (4.0)	32 (4.6)	18 (3.6)
7	7 (0.7)	7 (2.4)	23 (3.3)	9 (1.8)
8	6 (0.6)	0 (0.0)	5 (0.7)	4 (0.8)
9	4 (0.4)	1 (0.3)	2 (0.3)	0 (0.0)
10	0 (0.0)	1 (0.3)	6 (0.9)	1 (0.2)
Total	1075 (100.0)	297 (100.0)	702 (100.0)	499 (100.0)
Average	2.89	3.05	3.12	3.13

Note: Percentages are shown in parenthesis.

(2) Transition matrix for circulation behavior

In order to analyze changes of circulation behavior, major attractions were divided into eight groups as shown in Table 4-13. Indeed, there are various facilities tourists often visit such as restaurants and souvenir stores, but these facilities are located near the major attractions. To reduce the complexity of this analysis, the study area has been divided into five zones as shown in Table 4-13. Addition to the five zones, the other three zones such as “other area”, “starting point”, and “finishing point” are indicated.

The first column named ‘zone’ briefly describes the general area covered by each zone. Examples for key attractions in those zones are named in the last column. The origin and exit transportation terminals are listed as the first and last zones respectively. Zone 7 refers to areas not covered by any of the previous zones in the list.

Based on the zoning, the following transaction matrix is developed as shown in Table 4-14.

Table 4-13 Zones and included tourist attractions

Zone	Major facilities
1 Starting point	Kintetsu Nara Station, several parking places
2 Todaiji Temple area	Todaiji Temple, Shosoin
3 Wakakusayama hill area	Nigatsudo, Temukaiyama-hachiman Shrine, Wakakusayama hill
4 Kasugataisha Shrine area	Kasuga Shrine, Wakamiya Shrine, Shin-Yakushiji Temple
5 Central area	Nara National Museum, Ukimido
6 Naramachi area	Gankoji Temple, Naramachi
7 Other area	Other attractions
8 Finishing point	Kintetsu Nara Station, several parking places

Table 4-14 Transition probability values (upper matrix for 2008 and lower matrix for 2011)

	1	2	3	4	5	6	7	8
1	0.0	0.184	0.015	0.076	0.485	0.181	0.059	0.0
2	0.0	0.063	0.201	0.149	0.089	0.173	0.093	0.233
3	0.0	0.169	0.093	0.123	0.073	0.105	0.093	0.294
4	0.0	0.169	0.082	0.100	0.116	0.174	0.084	0.274
5	0.0	0.205	0.033	0.087	0.027	0.271	0.110	0.266
6	0.0	0.076	0.025	0.055	0.127	0.151	0.076	0.490
7	0.0	0.040	0.048	0.059	0.078	0.104	0.163	0.508
Survey in 2011								
	1	2	3	4	5	6	7	8
1	0.0	0.228	0.020	0.054	0.439	0.185	0.074	0.0
2	0.0	0.110	0.196	0.075	0.069	0.159	0.104	0.287
3	0.0	0.122	0.211	0.178	0.052	0.103	0.146	0.188
4	0.0	0.176	0.075	0.112	0.096	0.139	0.139	0.262
5	0.0	0.364	0.018	0.046	0.009	0.198	0.109	0.255
6	0.0	0.133	0.008	0.032	0.088	0.179	0.094	0.466
7	0.0	0.129	0.065	0.039	0.068	0.197	0.146	0.356

Makov chain process is a useful mathematical tool to document the transition probabilities. In the context of this tourist zone, the circulation behavior of individuals relates to walking from the origin transport terminal to a series of attractions in some sequence and terminating at the exit transport terminal. The transition matrix captures the movement probabilities from one attraction to any other attraction (or transport terminal).

Suppose S is a discrete set of a probability variable Xi. If the current condition is determined, the following equation is held in the case of Markov chain.

$$P(X_n = x_n | X_{n-1} = x_{n-1}, X_{n-2} = x_{n-2}, \ldots, X_0 = x_0) = P(X_n = x_n | X_{n-1} = x_{n-1})$$

Visitors visit their attractions in a tourist area, who depart a station or parking place and always leave the places from the station or car park. It seems that their activities likely follow an absorbed Markov chain.

A transition matrix of absorbed Markov chain may be one of the effective indicators of their circulation behavior. Table 4-14 is the transition matrix developed in this project.

As mentioned in earlier chapter, the survey in 2008 was carried out to investigate the situation before the sign system improvement, and the surveys in 2010, 2011, and 2013 belong to different stages after improvement. In 2010 the improvement was about 30% completed, and in 2011 most improvements were completed except within historic sites owned by Todaiji Temple, Kasuga-taisha Shrine, and Kofukuji Temple.

As shown in Table 4-14, the probabilities from zone 2 through 7 in which attractions are located, to the exit zone 8 is low in 2011 compared to those in 2008 except for the case of zone 2. This indicates that circulation level in 2011 is higher than that in 2008, which is consistent with the increase in average number of locations visited by respondents as described in Figure 4-33 and Table 4-12. These findings are evidence to confirm the following assumption 2 described in Section **4. 3**:

Assumption 2: circulation enhancement by the sign system modification.

4.7 Concluding Remarks

Large scale urban parks with historical and cultural background, and comfortable environment are attractive tourist areas and have potential to fascinate lots of visitors. To make these areas more vital by accepting more visitors, it is very important to install deliberate information system. In some cases, such urban parks include UNESCO World Heritages inside. Now variety of Information and Communication Technology can play an important role to tourists in large parks, however, traditional roadside signs must be still the basis of information provision from now on.

Based on the belief, this study team has discussed sign system in a historical park from improving and its evaluation point of view.

Considering the sign system problems in Nara Park before 2008, Nara Prefecture decided to improve the sign systems managed by the prefecture completely. The concept of the new sign system is as follows:

a) Important attractions should be guided in the sign system,
b) Sign system should satisfy continuity and consistency,
c) Information indicated at one sign board should be restricted to be easily understood by visitors, and
d) Different type of sign board should be used corresponding to characteristics of the area.

The sign system in Nara Park has been improved based on the above-mentioned concept. The process is as follows:

1) Popular attractions are investigated and classified into four categories.
2) Concept diagram of the sign system are developed.
3) Three types of signs are considered, including arrow signs, map boards, and explanatory signs.
4) To reduce the clutter, the number of arrow is limited.
5) These signs are aligned to satisfy continuity and consistency.

In order to assess the improved sign system, the study team made the following assumptions (Section **4.3**):

Assumption 1: Decrease of getting lost
Assumption 2: Circulation enhancement

According to several investigations, one before and three after the improvement, these assumptions were verified. The followings are the outline and major findings of this research work.

As a typical large historical park, this study adopts Nara Park in Japan which attracts many tourists from inside Japan and overseas. Nara was developed as the capital of ancient Japan in the year 710. As year 2010 was the 1300 anniversary since the establishment of the former capital, series of spectacular events were planned to commemorate the centenary. As a result, lot more visitors were expected during that period to come from all parts of Japan and beyond. This prompted Nara Prefecture to embark on a project to upgrade the sign system to a simplified and readily understandable system for both first timers as well as repeat visitors. A development project for modification of the sign system managed by Nara Prefecture was carried out leading up to 2010 as part of preparation for the 13th Centenary celebrations, considered one of the most significant historical milestones for the nation and an opportunity to showcase this heritage area.

It can be said that most tourist areas have their own sign systems. However, there is few studies discussed the efficiency of sign system introduction or improvement except for simple questionnaire surveys. Addition to this, even though behavioral changes on sign system improvement, precise investigation based on before and after surveys have been scarcely carried out.

This study evaluated outcomes to tourists visiting a popular national heritage site following the sign improvement project that was mostly completed in 2011. The analysis was based on a before and after study that relied on a self-completed questionnaire. Data are available from surveys conducted in four different years. Addition to these, two supplementary surveys were carried out.

Tourists were classified into newcomers and repeat visitors. The study team associated different objectives for newcomers and repeat visitors. Newcomers were deemed to be interested in seeing the major attractions. Repeat visitors were considered to be willing to wonder off to lesser known attractions in the area. A hierarchical ranking system of attractions was devised to aid the design of the guidance system plan. Signs introduced were classified into four categories (see Table 4-2).

After sign system improvement, several changes have appeared in tourist's behavior. As for tourists getting lost, the percentage of visitors getting lost did not reduce after sign system improvement, although the percentage who claimed to have been completely lost has reduced (see Figure 4-24). This may appear counterintuitive. But we should pay attention to tourist's circulation activities at the same time. The average number of attractions visited per person also increased during this period. This is an interesting situation created because the average number of attractions visited per visitor increased during the sign system improvement (see Figure 4-33).

It is shown that the sign system modification has delivered benefits in terms of increased coverage of attractions. The sign system improvement has increased the number of attractions visited although the amount of time spent at the site has not changed between the before and after study. This points toward a positive outcome to visitors from the improvement to signs.

Since the average number of attractions visited increased after the sign system improvement, it can be said that the improved sign system in Nara Park contributes to rise tourist's circulation behavior but getting lost rates did not decrease after the sign system improvement. Therefore, some problems must exist related to getting lost behavior.

This analysis presented has shown that visitors getting lost are more frequent in Nara-machi and Kasuga-taisha zones. These areas correspond to areas where owners of properties could not be convinced to fully cooperate with the new signs project, which have provided an insight to the nature of the navigation errors that occur in problem areas. The difficulty to visitors at some locations is how to find the location.

There were sensitive property ownership issues that prevented a uniform sign system being introduced everywhere at the site. This may explain why the proportion of repeat visitors getting lost has not decreased with the implementation of the modified sign system. Anyhow, the proportion of newcomers getting lost has been halved with the introduction of the modified signs.

Considering these analyses, as for above-mentioned two assumptions, the assumption 1 (see Sections4.3 and 4.5) may need further investigation. On the other hand, assumption 2 has been verified (see Sections 4.3 and 4.6). Anyhow, it can be said that making these assumptions and developing the method to verify them are appropriate to inspect effectiveness of sign system planning and management.

The study area in this project is limited in Nara Park. However, Nara Park and its neighborhood have four UNESCO World Heritages, and similar tourist areas are not rare in the world. Therefore, the experience and findings of this project have a possibility to offer useful information for sign system planning and management in similar tourist areas

After identifying the locations where getting lost behavior often occurred, detailed sign boards including locations, establisher, and board types were investigated again. Then the following findings were confirmed:

(a) Two particular areas (Todaiji Temple and Kasuga-taisha Shrine) where visitors reported losing their way were identified. Probable cause is signs constructed and managed by relevant landlords inconsistent with the modernized signs elsewhere in the park (see Figures 4-30-1 and 4-30-2).
(b) There are locations where improved sign boards and older style constructed by other owners exist close to each other. An attempt must be made to minimize the occurrence of such redundancies and confusions (see Figure 4-30-3).
(c) Frequency of getting lost events peaks at the second or third links of trip chains of park visitors (see Figure 4-31).
(d) Count of getting lost events was high at several large intersections, although at least one sign has been available in the area. These locations may need further evaluation. Additional signs maybe required to assist visitors (see Figures 4-30-4 and 4-30-5).
(e) Nara-machi area has been identified as an area with insufficient supply of signs. Few signs are available there and they could be easily obscured and not readily understandable to visitors (see Figure 4-30-6).

The sign system of Nara Park which was supported by different providers has allowed the study team to make the following recommendations.

(i) This study has revealed that there is still some confusion of the sign system after the major improvements completed in 2011. The main cause of confusion to tourists is the difference in sign system concepts in Nara Park and its adjacent area public perceive as part of the that historical grounds. Other proprietors should be persuaded to catch-up with the style and concept of sign system introduced by Nara Prefecture,
(ii) Sign system is vital to smooth circulation performance and visitor experience. Therefore, signs must consistently display attractions with conformity of their importance ranking in Nara Park. Signs of competing proprietors distract visitors from the required consistency. Way finding difficulties encountered in second and third links of trip chains of visitors appear to be concentrated in areas where temples and shrines have ownership of signs,

(iii) Several areas where there is a lack of effective signs have been identified in this study. Additional signs consistent with the new sign system provided by Nara Prefecture should be introduced to such areas, and

(iv) Frequency of tourists getting confused their way is relatively high at large intersections. These locations have been identified. Map boards near those locations should be reviewed and revised if necessary. Precise locations of sign boards should be considered carefully. Not only map signs, it is better for tourists to install arrow signs at crucial locations. Installation of supplementary arrow signs should be also considered such critical intersections.

Chapter 5. Pedestrian Route Choice Behavior under the Influence of Sign System

This chapter describes pedestrian route choice behavior under the influence of sign systems in Nara Park and Osaka Transport Hub. Two dimensional route choice is discussed in Nara Park, and three dimensional route behavior is discussed in Osaka Transport Hub.

5.1 Pedestrian Route Choice Behavior in Nara Park

5.1.1 Route choice characteristics of visitors in Nara Park

Most visitors to Nara Park have at least one attraction when they start sightseeing. Therefore, it is reasonable to think that they know approximate direction of their most interested attraction. Therefore, the route choice model can be expressed as the binary choice model. In this section, pedestrian route choice models developed following the modelling concept mentioned in Section **2.3**.

The study area of this section is almost the same area described in Chapter **4**, and the data used here are also the same as the former chapter.

Here, we would like to set up one more assumption addition to two assumptions in Section **4.3**:
Assumption 3: realization of reasonable route choice by the sign system modification.

Table 5-1 shows the route choice models developed in Nara Park based on the concept explained in Section **2.3**. The three models developed based on survey in 2008, 2010, and 2011 are acceptable because plus and minus signs are rational, and each parameter is significant at 1% level.

When the parameter ration, expressed in equation 2-3, is smaller than 1.0, tendency keeping a straight movement is superior to minimizing the angle of orientation. On the other hand, when the parameter ration is larger than 1.0, minimizing the angle of orientation is superior. Section **2.2** shows that going straight movement is preferred when no information about the destination is offered. Therefore it can be expected that the parameter ratio will increase with sign system improvement.

Table 5-1 shows that parameter ratio in 2008 was smaller than 1.0, on the other hand, that in 2010 and 2011 was larger than 1.0. The sign system in Nara Park was improved between 2008 survey and 2010 survey. After sign system improvement, the parameter ratio became larger than 1.0 and the value in 2011 is larger than that in 2010. This fact means that visitors changed their behavior to attach more importance to minimizing the angle of orientation. Figure 5-1 illustrates the changes of parameter ratio by new comers, repeat visitors, and all tourists respectively.

The earlier section described that pedestrians prefer going straight movement if there is no information. Table 5-1 and Figure 5-1 indicate that pedestrians are likely to choose going straight when there is no guidance to their destination. Considering this nature, it can be understood that going straight behavior gained an advantage over minimizing the angle of orientation in 2008, because the sign system was not improved. On the other hand, the opposite characteristics appeared in 2011 when the sign system had improved. Considering this characteristic, the above-mentioned change of parameter ratio is likely to be a result of sign system improvement. Also, comparing new comers and repeat visitors, the parameter of new comers was larger than that of repeaters. Therefore, sign system improvement may greatly affect new comers.

Table 5-1 Route choice models developed based on surveys at Nara Park

	Survey in 2008	Survey in 2010	Survey in 2011
All data			
Tendency keeping a straight movement	-0.0134 (-10.4**)	-0.0149 (-8.95**)	-0.0213 (-18.6**)
Minimizing the angle of orientation	-0.0155 (-19.89**)	-0.0145 (-15.6**)	-0.0154 (-23.8**)
Parameter ratio	**0.866**	**1.03**	**1.38**
Likelihood ratio	0.306	0.250	0.387
Reproducibility	0.791	0.753	0.819
New comers			
Tendency keeping a straight movement	-0.0127 (-4.23)	-0.0114 (-4.65)	-0.0171 (-7.32)
Minimizing the angle of orientation	-0.0169 (-9.13)	-0.0137 (-9.63)	-0.0144 (-11.0)
Parameter ratio	**0.747**	**0.835**	**1.19**
Likelihood ratio	0.329	0.214	0.303
Reproducibility	0.803	0.748	0.791
Repeat visitors			
Tendency keeping a straight movement	-0.0136 (-9.44)	-0.0175 (-7.71)	-0.0226 (-17.0)
Minimizing the angle of orientation	-0.0151 (-17.7)	-0.0151 (-12.3)	-0.0157 (-21.0)
Parameter ratio	**0.897**	**1.16**	**1.44**
Likelihood ratio	0.300	0.300	0.413
Reproducibility	0.787	0.787	0.824

(** : 1%significant)

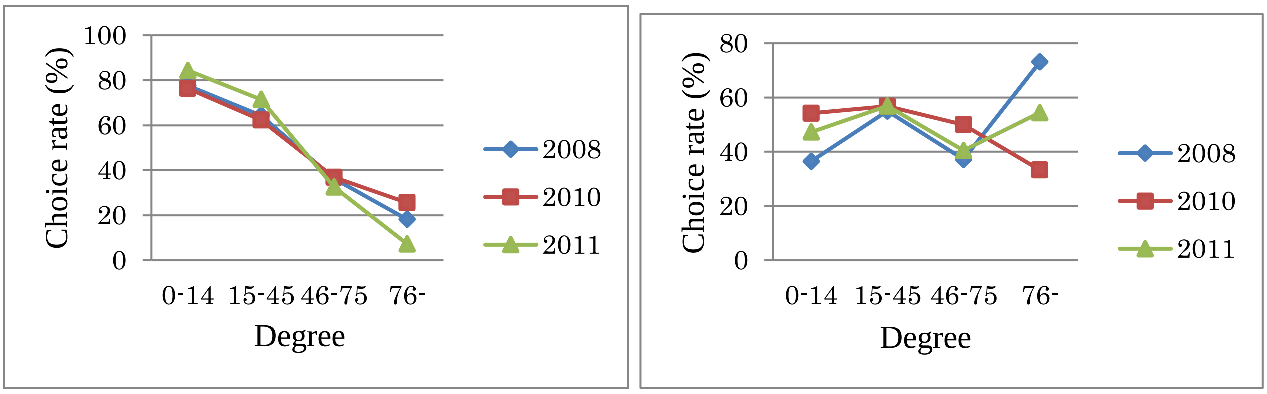
Figure 5-1 Change of parameter ratio

The findings in this section are evidence to confirm the assumption 3.

5.1.2 Parameter ratio in route choice model when getting lost

It is needless to say that "getting lost" means missing the direction and route to destination. This can be understood by comparing the relationship between the index of minimizing the angle of orientation and route choice provability.

Figure 5-2 shows relationship between the angle of orientation and route choice provability by visitors getting lost and not getting lost respectively. There is clear difference between them. The left figure of Figure 5-2 shows the relationship for the visitors without getting lost behavior, where route choice provability decreases in accordance with increase of the angle of orientation. On the other hand, in the case of visitors getting lost, there is no relationship between the angle of orientation and route choice provability. These angles were illustrated in Figure 2-3 before.



All tourists

Tourists getting lost

Figure 5-2 Relationship between the angle of orientation and route choice rate

In the face of the increased circulation in terms of number of attractions visited per person, the proportion of the worst category of way finding errors have reduced and remained low. This indicates a general decline in way finding errors experienced by users. This maybe also interpreted as an improvement of the 'quality' of the guidance system. Nevertheless, the total amount of visitors getting lost to some extent (though not to the serious level), has increased in keeping with the increased amount of travel performed within the study area by each visitor. This indicates that there are still challenges ahead to be solved by the project team.

5.2 Pedestrian Route Choice Behavior in Osaka Transport Hub

5.2.1 Three-dimensional route choice analysis

In order to assess the effectiveness of sign system, analysis on characteristics of pedestrian route choice behavior is one of the important factors. The route choice model described here is based on surveys in which pedestrians seemed to be scarcely influenced by sign system. Therefore, pedestrians who usually took a look at signs were excluded as data for the modeling.

Three-dimensional route choice model is necessary to discuss pedestrian behavior in large transport hubs. Roughly speaking, there are two ways to develop three-dimensional route choice models. One is a model which estimates selected route from an origin to a destination at once which is called as 'lump model' in this project. The other is a model which consists of two parts including two sub-models such as (a) estimating locations of the points for up-and-down movements, and (b) estimating routes selected in each floor which is called as 'stepwise model' in this project. A lump model is developed in Section **2-4**. A stepwise model is developed in Section **2-3**.

As for the lump model, total walking distance, walking distance on ground and underground, environment along a route including types of up-and-down facilities may play an important role in route choice behavior.

As for the stepwise model, some explanation is necessary. Sub-model (a) of the stepwise model estimates the spot where up-and-down movements takes place, on the other hand sub-model (b) estimates route choice behavior at the same floor. The principal concept of the sub-model (b) is as follows;

1) A shortest path that has the least number of turns requires less direction instructions to be given. Therefore, they need less signs to direct pedestrians. The emphasis in such systems is to maximize straight through movements. Pedestrian flows with such guidance information have low probabilities associated with left and right turns and behave as if the individual pedestrians behave under the influence of momentum concept (or inertia) in physics, and
2) The other shortest path of significance stays close to the straight line connector between origin and destination. From behavioral viewpoint, in studies done on horizontal networks, it has been observed that humans tend to minimize the angle of orientation with destination when they are regular users of a network. These pedestrians attempt to minimize the geometric angle between the current movement vector and the imaginary vector that connects the present location to the destination.

The details on the pedestrian route choice model were already described in Chapter **2**.

5.2.2 Assessment of indoor sign system as a whole

There seems to be few researches of sign system from a viewpoint of reliability. Since there is no missing link or impassable link in most large transport hubs, reliability may be satisfied in the general meaning of network reliability. However, if suitable sign system is not installed, the network in the hub may be less reliable for unfamiliar passengers. Therefore, this project proposes a new approach for sign system evaluation, based on sign system reliability concept on network. The flow of this research is illustrated in Figure 5-3.

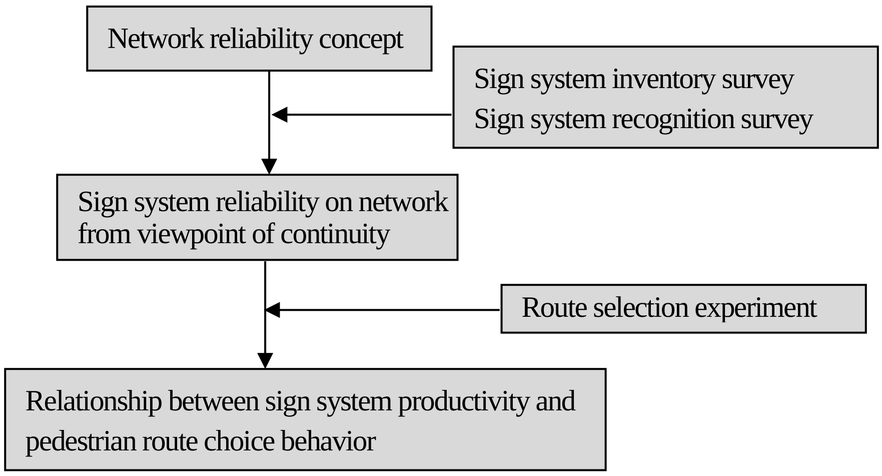


Figure 5-3 Flow diagram for assessment of indoor sign system

In a network, let a node and the connecting link ahead be a unit as illustrated in Figure 5-4. If a unit has at least one sign, the sign system between the current and ahead units are regarded as continuous. However, if a pedestrian does not recognize the sign, the sign cannot be working. Therefore, unit recognition rate at the unit m on the route n, $R_{nm,}$, can be formulated as equation (5-1).

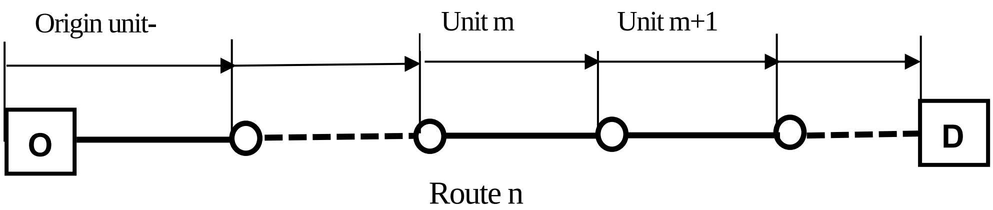


Figure 5-4 Unit on a route in this study

$$R_{nm} = 1 - \{(1-x)^a(1-y)^b(1-z)^c\} \quad (5\text{-}1)$$

where,

n: route,
m: unit on the route n,
a: number of arrow signs,
b: number of name boards,
c: number of map boards on from origin unit to current unit m of route n,
x: recognition rate of arrow signs,
y: recognition rate of name boards, and
z: recognition rate of map boards.

Values of x, y and z are calculated by equation (5-2) respectively. If no information is provided on the unit m on route n, R_{nm}= 0.

$$\text{Recognition rate by sign type} = \frac{\sum(\text{total number of recognized passing signs by type})}{\sum(\text{total number of passing signs by type})} \quad (5\text{-}2)$$

Addition to these, if passengers do not obey the sign system, sign system never work well. Obedient rates for each type of signs are obtained by equation (5-3).

$$\text{Obedient rate of sign} = \frac{\sum(\text{number of obeyed signs})}{\sum(\text{total number of passing signs})} \tag{5-3}$$

Strictly speaking, Equation (5-3) should be considered in Equation (5-1). However, since it is difficult to grasp the obedient rate by observation survey, besides obedient rate can be obtained for arrow signs only in this study. Accordingly, Equation (5-3) is not referred in the following calculation.

There are multiple forks where passengers have to choose the correct direction of their destination. The locations of such forks are important for sign system planning. There are two kinds of units in which the node belonging to the unit is a fork, and that is not a folk.

Here, let express the probability of correct route selection at a fork k as P_{nk}. If correct guidance is offered at node k, then the probability of correct route selection is R_{nk}. On the other hand, no guidance is offered, then the probability is $(1-R_{nk})$ / $(fk-1)$. Accordingly, the probability that a passenger can choose the correct direction to the destination at the fork k, P_{nk}, can be shown in Equation (5-4).

$$P_{nk} = R_{nk} + \{(1 - R_{nk})/(fk - 1)\} \tag{5-4}$$

where,

fk: number of branches at fork k

Finally the probability of correct selection of the route n (P_n), is expressed as the following equation.

$$Pn = \prod_{i=1}^{M_n} ((1-\theta)\, P_{nm} + \theta\, P_{nk}) \tag{5-5}$$

where,

M_n: number of units on route n

θ : If unit i includes a fork, θ =1, otherwise θ =0.

This study defines the sign system reliability of signs along the route n by Equation (5-5).

5.2.3 Assessment of indoor signs in a shopping and business complex

The methodology of this study is illustrated in Figure 5-5. First, based on on-site inspection of the sign system in a large shopping and business complex, the current situation including its continuity and consistency of the system is investigated. Second, an experiment in order to investigate passenger's route choice behavior in the shopping and business complex is carried out. This study employs several university students as subjects of the experiment. Although the subjects in this experiment are asked to visit pre-designated destinations following the sign system, they were not given complete information along the route to the destination. Therefore, the routes selected by the subjects are acceptable choice at each turning point, however, the route are not always the most suitable one. Thirdly, the most suitable route when passengers know complete information along the route offered by sign system is estimated. The last is the analysis on the relationship between the two different types of routes to make clear the effect of the current sign system and the way of improvements. In other words, these results are compared with each other in order to evaluate the effects of the current system and find something desirable to be improved.

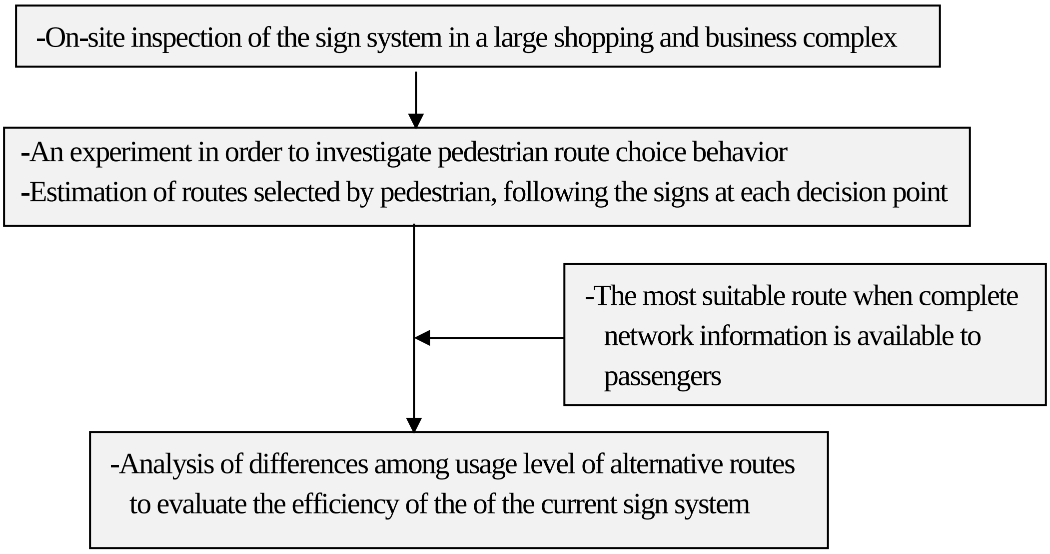


Figure 5-5 Flow chart of this section

5.3 Study Area and Data Collection

5.3.1 Study Area

To achieve the purposes, this study adopts Osaka Transport Hub including a large shopping complex to be discussed. Osaka, the third largest city in Japan, next to Tokyo and Yokohama, had 2.7 million population in 2018. In the CBD of Osaka City, there is a large multiple transport hub which consists of seven railway stations including JR Osaka Station, JR Kita-shinchi Station, Hankyu Railway Umeda Station, Hanshin Railway Umeda Station, and three stations of Osaka Municipal Subway (Subway Umeda Station, Higashi-Umeda Station, and Nishi-meda Station). The total number of passengers is about 2.4 million per day (2015). The ground level and underground area of the hub is illustrated in Figures 5-6 and 5-7. In the underground level of the transport hub there is a large underground shopping arcade with several independent shopping centers.

There is an association for coordination of discussions of sign system construction and management in the transport hub. However, uniform signage concept has not been yet realized, because there are many views from different operators and vendors occupying the transport hub.

Most passengers in this space visit both of ground level and underground level. Their route choice problem is in a complicated three-dimensional network. The sign system is essential element in the transport hub for its users to successfully navigate the available pedestrian routes.

The study area for Sections **5.4** and **5.5** are shown in Figures 5-6 and 5-7.

In almost same area discussed in this study, Consultative meeting of sign system at Osaka/Umeda Stations has published ‘Common rule of sign system at Osaka/Umeda Stations’ in 2018. This meeting consists of railway companies, road administrator, Osaka underground shopping center company, except for Osaka Prefecture and Osaka City. In this area, it is very important to make common rule of sign system.

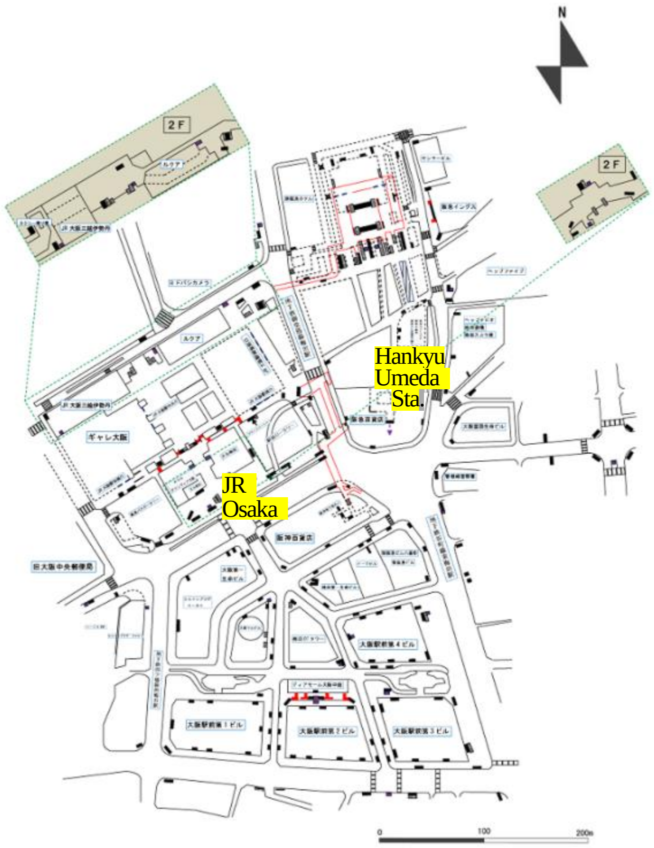


Figure 5-6 Pedestrian network of Osaka Transport Hub (ground level)

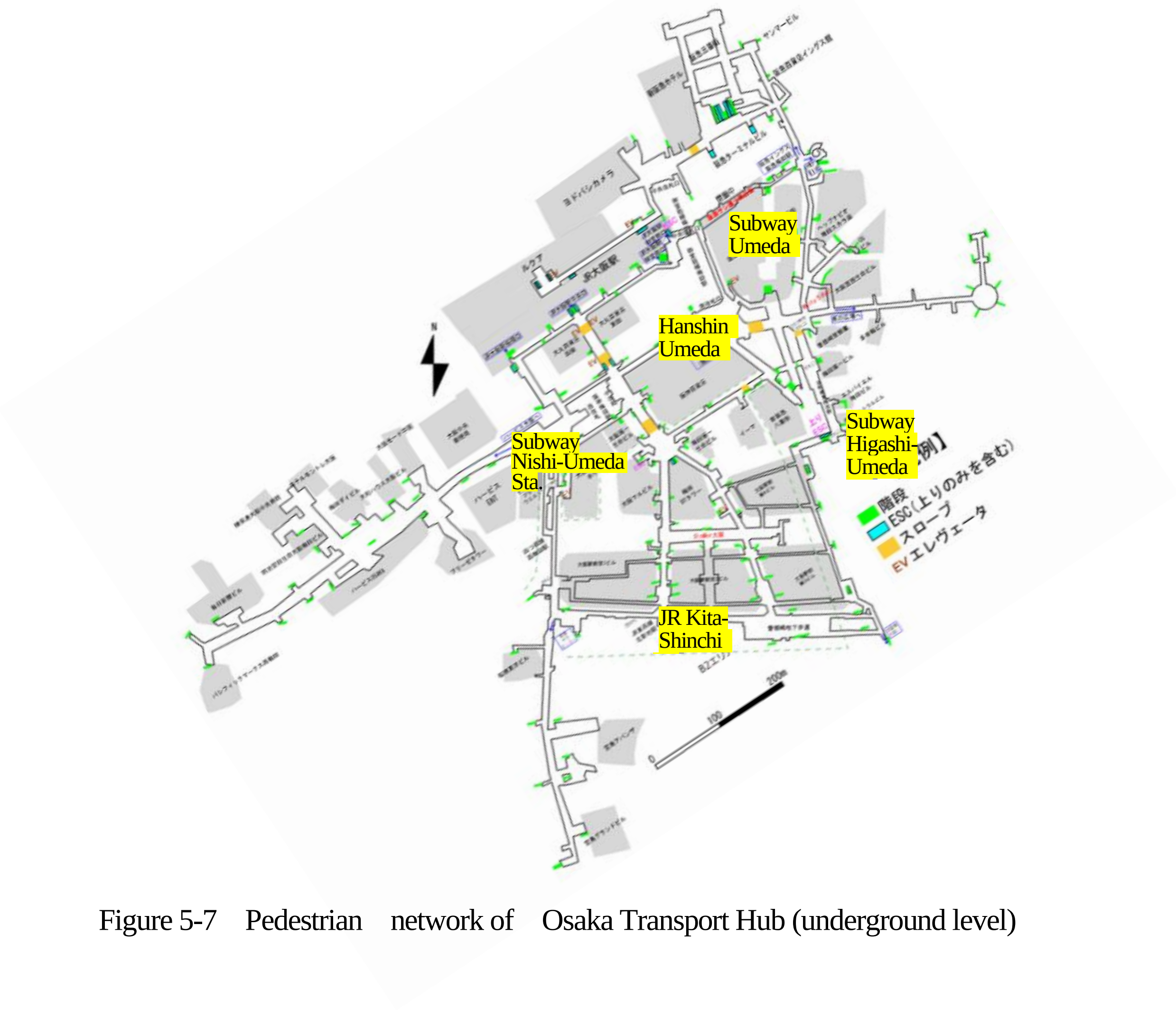
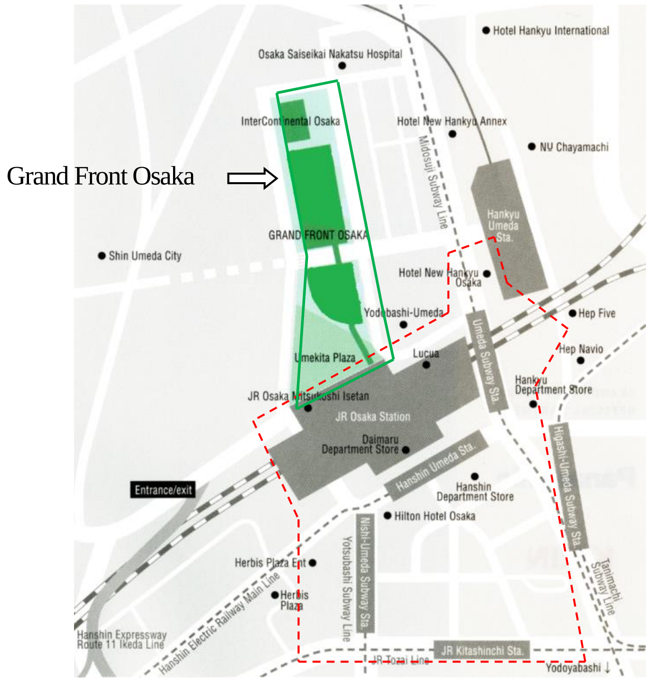


Figure 5-7 Pedestrian network of Osaka Transport Hub (underground level)

North of JR Osaka Station, there was a large freight terminal. After moving this freight terminal to other areas, this place attracts many people's attention. As the first stage of redevelopment project in this area, 'Grand Front Osaka' has been developed in April 2013.

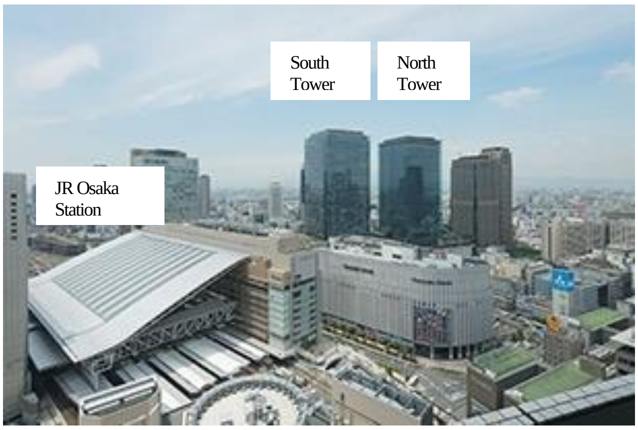
The Grand Front Osaka is planned to consist of a string of four large buildings, about 40 stories tall (Figures 5-8 and 5-9). This research project covers parts of the North Tower and South Tower near the transport hub (See Figure 5-9 for a pictorial view of four towers on the skyline). 6th floor and below were selected in the North Tower whereas 9th floor and below were selected in the South Tower for the study areas. The detailed layout of Grand Front Osaka is illustrated in Figure 5-10. Upper floors of both these buildings are classified as office space and not covered in this research work. The two Towers are connected by a skyway at the second floor level as shown in Figure 5-10. The area illustrated in Figures 5-8 through 5-10 are used in Section **5.5**.



Note:
The area surrounding by red dashed line is the part of Osaka transport terminal district previously surveyed by the authors. See section 3.2.

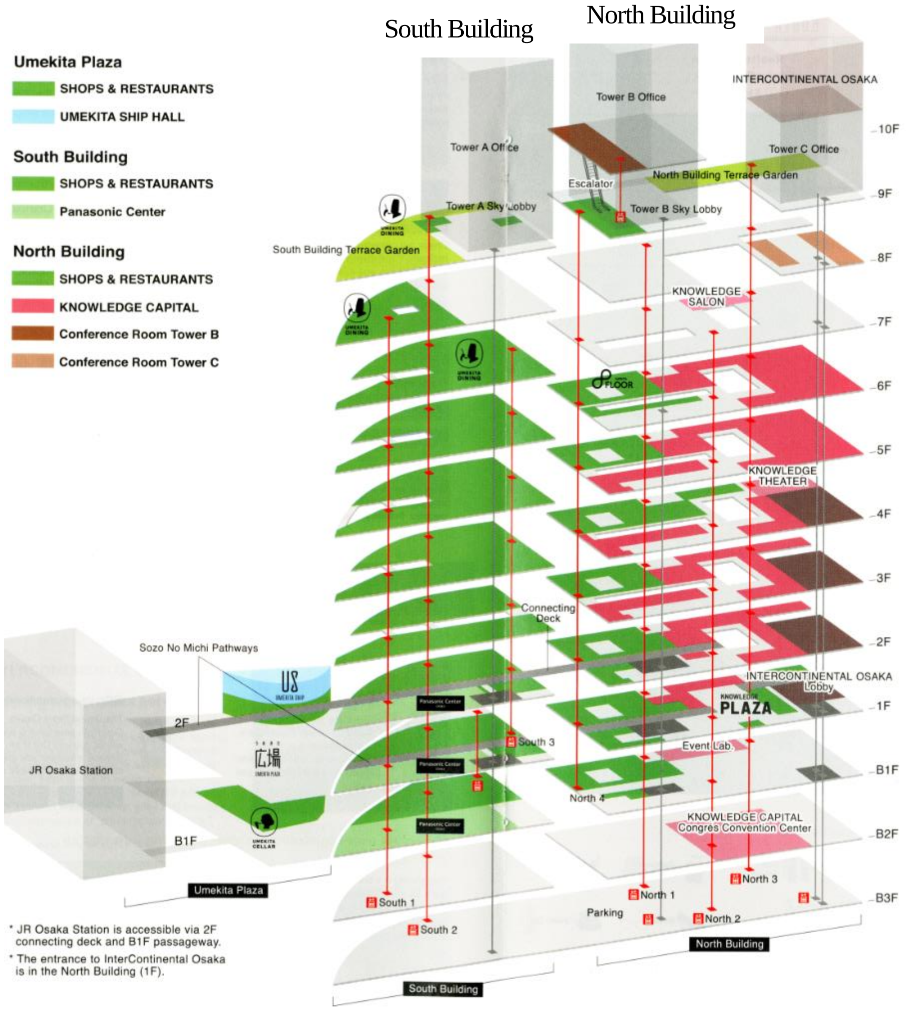
Source: http://www.grandfront-osaka.jp/

Figure 5-8 Location of Grand Front Osaka in Osaka Transport Hub



Source: http://www.grandfront-osaka.jp/

Figure 5-9 Grand Front Osaka towers in the background of JR Osaka Station



Source: http://www.grandfront-osaka.jp

Figure 5-10 Layout diagram of the multistorey shopping and business complex, Grand Front Osaka

5.3.2 Outline of the surveys

(1) Inventory surveys of signs in Osaka Transport Hub

(a) Signs in the main part of Osaka Transport Hub (Except for Grand Front Osaka)

As mentioned earlier, the transport hub consists of seven independent railway stations. The transport hub also has number of underground shopping malls. Authors have previously conducted surveys in parts of this transport hub and the coverage area of the survey has been identified in Figure 3-3. The frequency of signs by content types and location types are shown in Figure 5-11. The surveys were conducted in 2009, 2011, and 2012.

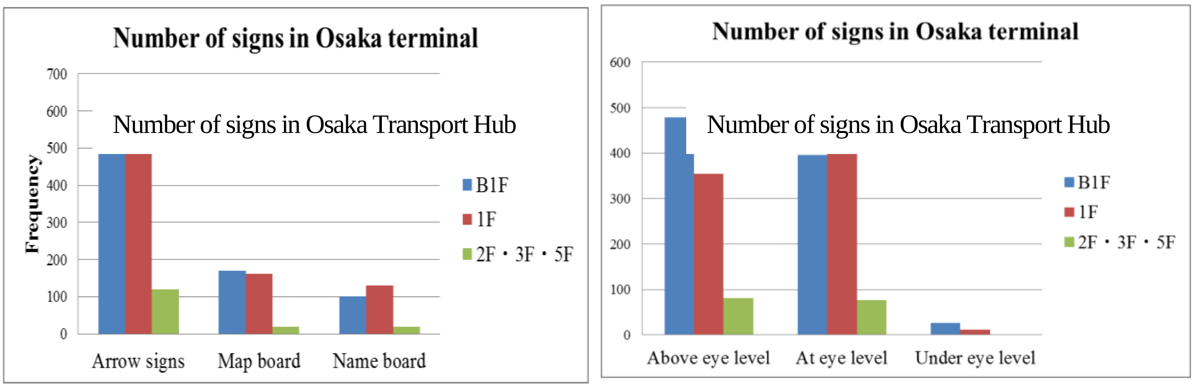


Figure 5-11 Types and location of sign boards in Osaka Transport Hub

(b) Sign system in Grand Front Osaka

For the purpose of this study, signs have been classified into three types according to the way content is presented as arrow signs, map boards and name boards. Examples of the tree types of signs are shown in Figure 5-12. Arrow signs have prominent arrows to guide users and may use icons and facility names in few words to describe destinations to a moving stream of pedestrians. Map boards show the layout of most facilities in the particular floor and may require the user to stop to read. Name boards indicate several facilities together in a given floor as shown on the photograph on right in Figure 5-12. Individual name boards of a facility managed by its owner are ignored here. They are generally installed by the building consultant to direct users to generic facilities and may also be used to confirm to the user that he or she has arrived at the destination. The survey was carried out in 2013.

Arrow type　　Map type　　Name board type

Figure 5-12 Three types of signs introduced

Also, these signs are classified into following three categories from point of view of the installed location as; above eye level, at eye level, and below eye level as illustrated in Figure 5-13. Most above eye level signs are hung from the ceiling. At eye level signs are placed on walls and pillars. Below eye level signs are painted on the walking surface to read without slowing down.

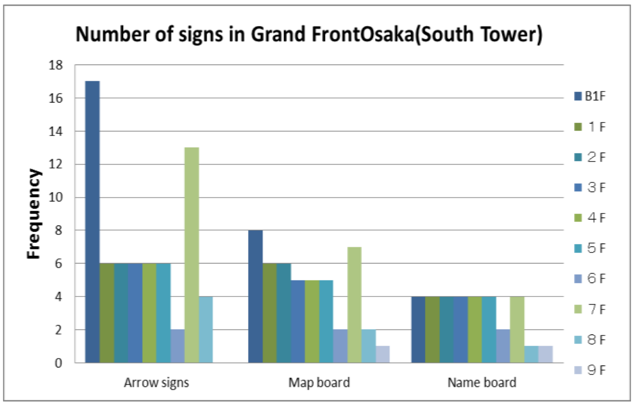
Above eye level At eye level Below eye level

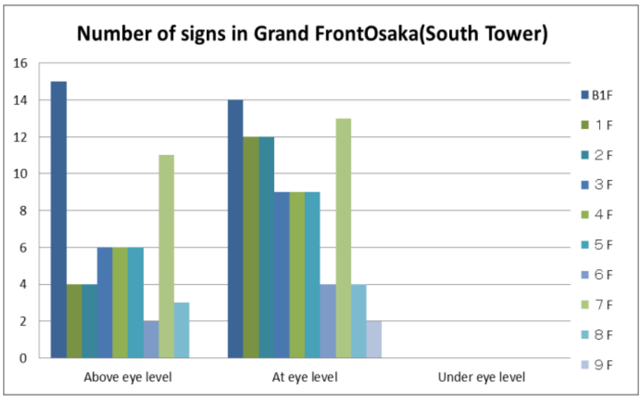
Figure 5-13 Placement of signs installed

An inventory survey was carried out using the above classifications in the two towers, and the results are presented in Figure 5-14.　In the South Tower, arrow signs were more prevalent at 45.5% of the total sign boards. Map boards and name boards were 32.4 % and 22.1 % respectively. Percentages of these three type signs in the North Tower were found to be almost identical. Distribution according to the location type shows that in both towers 'at eye level' had the highest percentage of signs, i.e. 71.6 % in the North Tower and 60.7% in the South Tower.

There were many arrow signs between JR Osaka Station and Grand Front Osaka at the underground level, and at 7th floor of the South Tower which contained various types of restaurants. As the two towers are connected at the second floor, there are more than ten arrow sign locations at the second floor in the North Tower pointing to the partner building. There is a lack of signs to the transport hub from most parts of the complex indicating that tenants and Grand Front Osaka have little interest in directing pedestrians away from them to the railway stations. Signs to the transport hub are only available from the underground and second floors of the South Tower and at the first and second floors of the North Tower.

Signs installed in Grand Front Osaka were seen to be in logical sequences using consistent words and icons. One third of signs were map boards which had the possibility to provide an overview of the complex. These map boards were available near all escalators. In general, the complex has provided a professional quality sign system helpful to most shoppers.





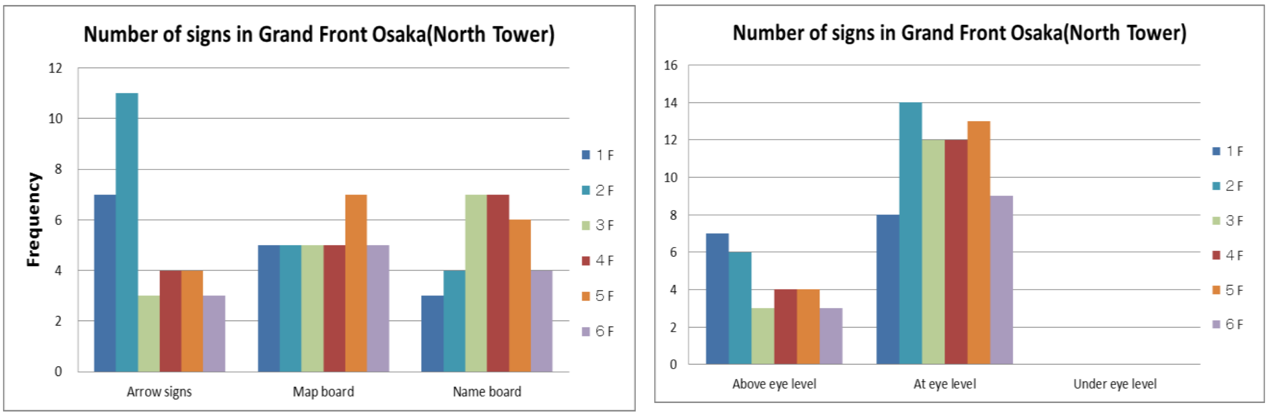


Figure 5-14 Types and location of sign displays at Ground Front Osaka

(c) Comparison between main part of Osaka Transport Hub and Grand Front Osaka

Figure 5-15 shows comparison of the two areas according to the content type classification. The percentage of arrow signs in the transport terminal is larger than that in the tower complex. Therefore, the percentages of map boards and name boards are larger in the tower complex. Since passenger volumes are large among the stations, arrow signs are adequate and convenient to pedestrians in that area. In comparison, in Grand Front Osaka, there is a diverse variety of destinations such as shops, restaurants, and educational service providers sought after by different types of visitors. Such situations justify application of a high proportion of map-based signs.

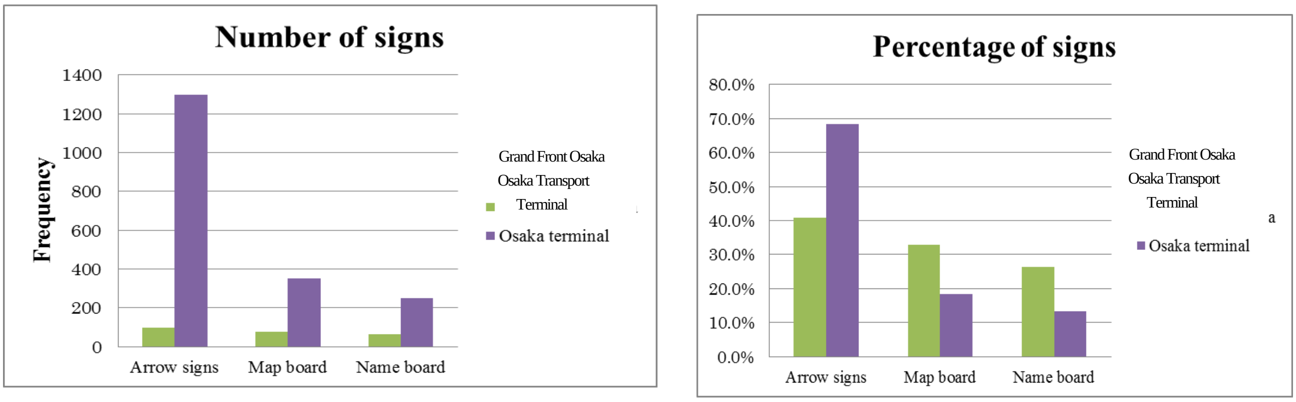


Figure 5-15 Comparison between the transport hub and Grand Front Osaka

(2) Surveys to investigate visitor's movement in main part of Osaka Transport Hub
To analyze pedestrian movements in the studied area, pedestrian route choice behavior was investigated. This study performed an observational survey by several observers who discretely followed pedestrians from their origins, including temporary origins, to the destinations in the networks. That is, a shadowing technique was adopted to perform the observational survey.

The surveys were carried out in August and September 2009, and November 2010 in Osaka Transport Hub. Each survey was done between 10:00 am and 5:00 pm. Pedestrian behavioral data obtained in Osaka Transport Hub are 416 samples. Observers selected passengers at random at ticket wickets or major entrances of the shopping complexes in the area. These data are limited to the movements with up-and-down behavior, excluding the movements only carried out in the same floor.

Based on the surveys, this study has obtained the pedestrian behavioral data, including the locations of up-and-down movements and routes selected by pedestrians. Using these field observation data, this study has analyzed the characteristics of pedestrian movements and has developed route choice model in a three-dimensional structure. The above-mentioned data will be used in Section **5.4**.
Addition to these, the project team developed route choice models on pedestrian movements on ground network and underground network, based on surveys carried out in 2009. The data obtained at ground streets were 973, and 462 data were obtained at underground streets to develop route choice models.

(3) Surveys to investigate sign system recognition and route choice using signs
This project team conducted three surveys for Section **5.5**, including assessment of sign system inventory, sign system recognition by users, and route selection of pedestrians using signs.

(a) Sign System Inventory Survey
There were two classifications adopted during the inventory survey in 2009, at the phase of the research project in 2009. Signs installed in this area were classified into 'above eye level', 'at eye level', and 'below eyelevel 'according to height of the sign installation. Also, signs are classified into 'arrow type', 'map board', and 'name board' according to the contents presented in the signs. All signs for pedestrians on the ground and underground levels were recorded by digital photography. The results of the survey are indicated in Table 5-2.

Table 5-2 Results of sign system inventory survey

Classification viewpoint	Type of signboard	Number of signboards
Height of sign installation	Above eye level	915 (48.2)
	At eye level	948 (49.9)
	Below eye level	37 (1.9)
	Total	1900 (100.0)
Form of the signs	Arrow type	1297 (68.2)
	Map board	351 (18.5)
	Name	252 (13.3)
	Total	1900 (100.0)

Note1: Percentages are shown in parenthesis.
Note2: 'Name board' means a public sign only name of the facility is indicated, excluding private shop sign. Inside the parenthesis are percentages.

In 2013, a large new development called 'Grand Front Osaka' for retail shopping and commercial activities opened in the north part of the transport hub. It is acknowledged that the transport hub responded with some minor changes to sign system covered in the inventory survey conducted in 2009.

(b) Sign System Recognition Survey

In order to understand the sign system recognition and obedience, the following experiment was conducted. Here we select three stations JR Osaka Station, Umeda Station of Hankyu Railway, and Higashi-Umeda Station of Osaka Municipal Subway, considering construction of the transport hub. Subjects were requested to make five trips as shown in Figure 5-16 among the three stations. The sequence begins at JR Osaka Station and visits Hankyu Railway Umeda Station and Subway Higashi-Umeda Station, and ends at Hankyu Railway Umeda Station, as illustrated in Figure 5-16.

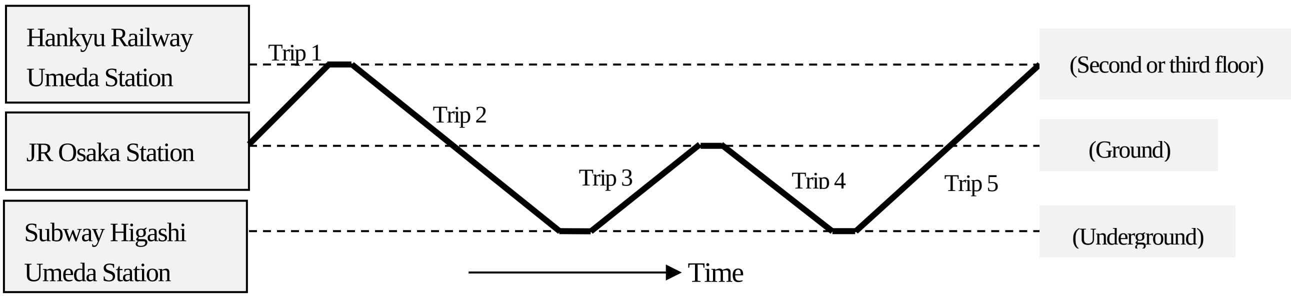


Figure 5-16 Sequence of trips on sign recognition survey

Subjects were asked to wear the head mounted digital camera to take a video of their route and perform the specified sequence of five trips. The subjects were free to choose the route. They were also required to take photographs of all signs related to their route they see along the path. Taking photographs of signs related to their route ensured those signs that can be 'recognized' by subjects. The signs not related to navigation to their next destination are ignored.

Subjects were given no navigation information at the starting point. They were requested to visit the destination with the help of on-site signs. Any entrance to be the destination station is considered the valid destination point for the trip. Also, an examiner followed the subject to inspect his or her navigation behavior and recorded the position of signs the subject taken pictures, with the path on a map.

The survey was carried out in December 2011. Twenty four students (19 male and 5 female) of Ritsumeikan University were recruited. Their ages were the first half of twenties. The level of their familiarity as stated by them is shown in Table 5-3. The study area located at the center of Osaka City is well known to public, and therefore only few persons had no information of the area as shown in Table 5-3. However, the authors have verified that the subjects are not daily users of the study area.

Table 5-3 Level of familiarity of subjects with the study area

OD / Familiarity with the route	origin	JR Osaka	Hankyu Umeda	Subway Higashi-Umeda	JR Osaka	Subway Higashi-Umeda
	destination	Hankyu Umeda	Subway Higashi-Umeda	JR Osaka	Subway Higashi-Umeda	Hankyu Umeda
1 Complete		15	10	16	12	10
2 Partial		6	8	5	5	6
3 None		3	6	3	7	8

(c) Route Selection Experiment

The influence of sign system at the site on pedestrian route selection behavior was investigated using an experiment conducted in October 2013. The study area for this experiment is illustrated in Figure 5-17. Three origins and one destination zone were specified. The origins were located underground level and the destination was on the second or third floor of Hankyu Railway Station. Origins are indicated as red square with numbered as 1, 2, and 3 in Figure 5-17. Also, the destination is indicated as the blue square at North-East corner of Figure 3-7. The three origin-destination parings had multiple pedestrian paths available for the trip.

For the subjects of the experiment, twenty two students of Ritsumeikan University, their ages were the first half of twenties, were recruited, and they were asked to visit the destination only using on-site signs. An investigator walked subjects to the starting point, in a route selected to disorient the subjects about their current location.

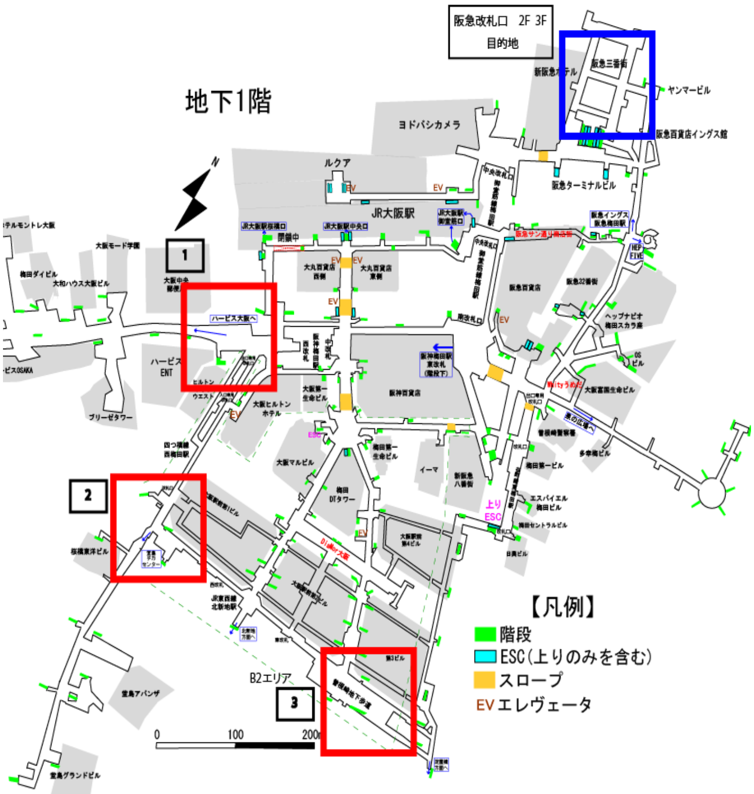


Figure 5-17 Study area and origin and destination for the experiment

(4) Experiment for evaluation of pedestrian sign system in a shopping and business tower complex

To obtain behavioral data, an experiment was carried out at the two towers during three days in December 2013. Detailed path layout of the study area spread over the South and North towers are shown in Figure 5-10. Subjects for the experiment were 24 male students recruited from Ritsumeikan University. Their ages were the first half of twenties. As people who are familiar with the study area were not suitable for the experiment, the subjects were screened beforehand to eliminate those who were familiar with the tower complex. Figure 5-18 shows the selected subjects prior level of familiarity with the tower complex. 70% of subjects (17 out of 24) knew the location of Grand Front Osaka. 9 subjects had partial knowledge of the interior layout, and 15 persons did not have any information about the interior layout. Also, 10 subjects had not been to the tower complex before the experiment. Though number of subjects had some idea about the interior of the building, the study team was satisfied that no one had a good level of knowledge about the interior layout as the tower complex was rather new at time of the experiment.

The subjects were asked to visit pre-selected sites within the towers as shown by the six numbers marked on Figure 5-19. Subjects were asked to start from location 1 and travel to other locations in sequence according to the ascending order of location numbers. Once the subject is at location 6, he then has to return to location 1 to complete the circuit. This yielded data related to six trips between the marked locations as listed below.

Trip 1: from location 1 to location 2,
Trip 2: from location 2 to location 3,
Trip 3: from location 3 to location 4,
T rip 4: from location 4 to location 5,
Trip 5: from location 5 to location 6, and
Trip 6: from location 6 to location 1 (the final destination, the tour ends here).

These destinations were selected based on an approximate proportionality with the number of different types of traders in the complex and spread of their locations. The sequence of the tour allowed for routes that require multiple floor level changes and lateral movements to the next tower.

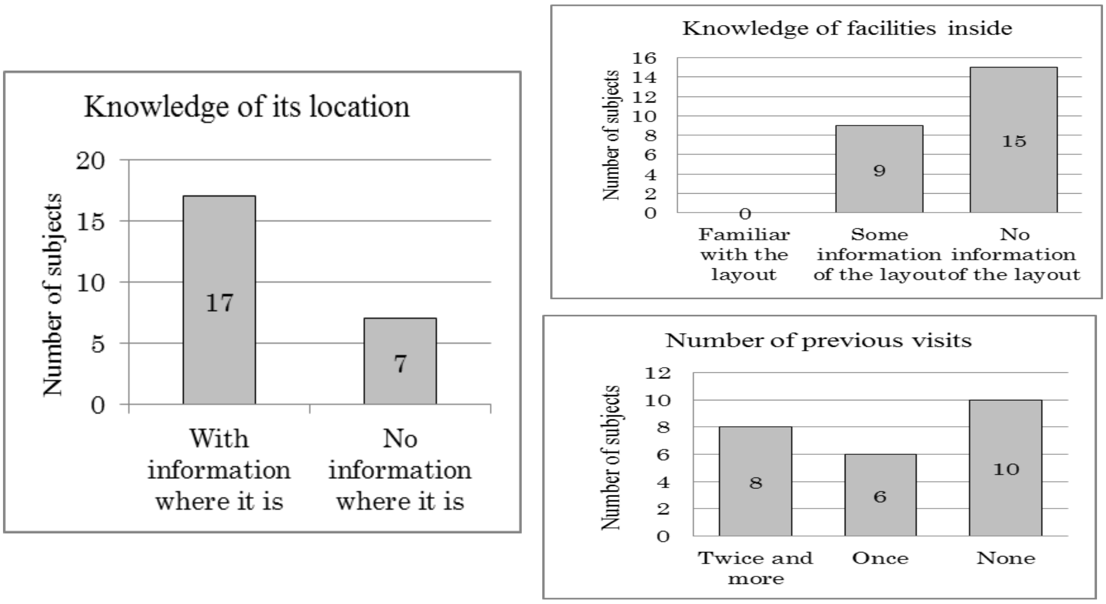


Figure 5-18 Attributes of subjects for the experiment

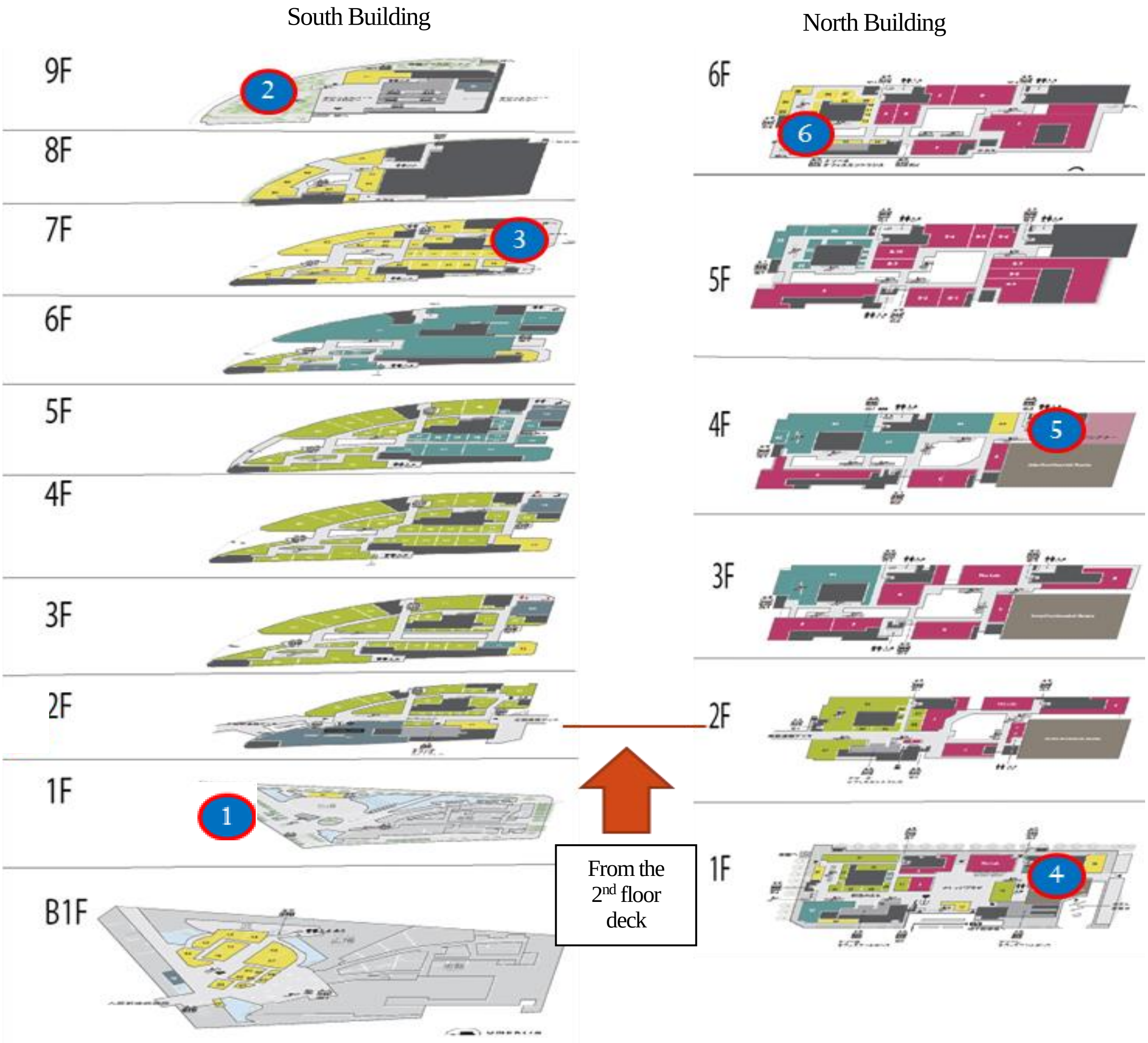


Figure 5-19 Six origins and destinations selected for the experiment

There were three other noteworthy aspects of the experiment:

a) Every subject had to wear a head mounted small video camera to capture signs he saw along the path he selected,

b) At the beginning subjects were told to find the destinations in sequence only using help from the signs they see along their trips (i.e. not allowed to ask someone or use a smart phone), and

c) An investigator with a clipboard and map followed each subject to record the exact route choice behavior.

5.4 Assessment of Productivity of Signs in an Indoor Pedestrian Network

Most large transport hubs in large cities serve commercial functions in addition to the transport function. Modern transport hubs are complex structures. Variety of passengers including unfamiliar visitors using transport hubs depends on sign system for successful navigation. This section investigates sign system of a transport hub containing seven independent railway stations in Osaka City, Japan. Three major surveys were carried out as described in Section **5.3** excluding an inventory survey. That is: surveys to investigate visitor's movement, surveys to investigate sign system recognition and route choice behavior, and experiment for evaluation of pedestrian sign system, in a shopping and business tower complex.

5.4.1 Sign recognition rate and rate of obedience

Results of the sign system recognition survey described in Section **5.3** are presented in this section. Among the three stations such as JR Osaka Station, Hankyu Railway Umeda Station and Subway Higashi-Umeda Station, recognition of signs was investigated. Networks used in this section were selected from the network described in Section **5.3**. The findings are shown in Table 5-4.

The influence of sign type and installed location upon recognition rate is displayed in the upper part of Table 5-5. Among three types of signs, highest recognition rate (35.3%) appears for arrow type, and the next is name board type (15.2%), and the lowest recognition type is map type (2.4%). As for locations of signs, signs installed in the second floor and underground level keep high recognition rates, whereas signs in the ground level have relatively low rates, in the case of arrow type signs. As for position of signs installed, 'above eye level' is more recognized, and especially recognition rates of arrow type sign boards at above eye level in the second floor and underground level are very high.

The middle part of Table 5-4 indicates that the influence of pedestrian's familiarity upon recognition rate. As for pedestrian's familiarity, recognition rate of passengers without familiarity is higher than that of passengers with familiarity in the case of arrow type signs for all locations installed. On the other hand, there is no large difference on map type and name board type signs, excluding the name board type installed at eye level.

The lower part of Table 5-4 indicates the influence of sign type, installed location, and familiarity of passengers upon recognition rate. It is distinctive that recognition rates are more almost 60% in the case of arrow type signs installed above eye level in the second floor for the passengers with partially or no familiarity with the area.

Table 5-4 Sign recognition rate

Sign type / Location	Arrow type				Map type	Name board type		
	Above eye level	At eye level	Below eye level	Total	At eye level	Above eye level	At eye level	Total
1F	27.2%	30.0%	8.7%	27.3%	3.6%	11.3%	---	11.3%
2F	49.6	16.7	---	46.4	4.2	28.6	0%	9.8
Underground	44.6	28.9	6.6	39.4	1.9	43.6	31.4	38.9
Total	38.8	28.8	7.3	35.3	2.4	18.3	7.1	15.2

Sign type / Location / Familiarity with the area studied	Arrow type				Map type	Name board type		
	Above eye level	At eye level	Below eye level	Total	At eye level	Above eye level	At eye level	Total
Completely	35.2%	25.2%	7.4%	31.9%	1.2%	18.8%	4.4%	14.7%
Partially	42.0	28.8	5.6	37.8	4.6	17.6	8.0	14.5
None	43.4	35.9	9.1	40.1	2.4	17.5	16.7	17.4
Total	38.8	28.8	7.3	35.3	2.4	18.3	7.1	15.2

Familiarity with the area studied	Location / Sign type	Arrow type				Map type	Name board type		
		Above eye level	At eye level	Below eye level	Total	At eye level	Above eye level	At eye level	Total
Completely	1F	24.5%	29.8%	11.1%	25.5%	2.9%	10.5%	---	10.5%
	2F	43.2	13.6	---	40.2	4.1	36.8	0.0%	12.4
	UG	41.5	21.5	6.0	35.2	0.2	47.8	25.0	38.5
Partially	1F	29.4	24.1	6.7	27.0	4.6	11.7	---	11.7
	2F	58.0	25.0	---	55.1	3.9	21.4	0.0	6.8
	UG	46.7	34.9	4.8	42.5	4.6	35.3	30.0	33.3
None	1F	31.3	35.6	7.7	31.5	4.4	12.7	---	12.7
	2F	59.0	16.7	---	55.2	4.8	9.1	0.0	3.9
	UG	48.4	37.8	10.0	44.2	1.8	46.7	44.4	45.8
Total		38.8	28.8	7.3	35.3	2.4	18.3	7.1	15.2

5.4.2 Reliability of sign system between some of major stations

(1) Case study of reliability of sign system

This section calculates reliability index of sign system for some OD pairs. OD pairs selected here are (i) from JR Osaka Station to Hankyu Umeda Station, (ii) from JR Osaka Station to Subway Higashi-Umeda Station, (iii) from Hankyu Umeda Station to JR Osaka Station, (iv) from Hankyu Umeda Station to Subway Higashi-Umeda Station, (v) from Subway Higashi-Umeda Station to JR Osaka Station, and (vi) from Subway Higashi-Umeda Station to Hankyu Umeda Station.

Equations (5-1) through (5-5) in Section **5.2** and Table 5-4 make the calculation possible. The results are indicated below.

(i) Reliability from JR Osaka Station to Hankyu Umeda Station

Selected routes by experiment subjects from JR Osaka Station to Hankyu Railway Umeda Station are illustrated in Figure 5-20. Table 5-5 shows that the reliability from the Central Entrance, Midosuji Entrance, and 3rd Floor Entrance at JR Osaka Station to Hankyu Umeda Station is high. On the other hand, those from South Entrance and Sakurabashi Entrance to Hankyu Umeda Station is relatively low, partly because most of the routes pass ground level.

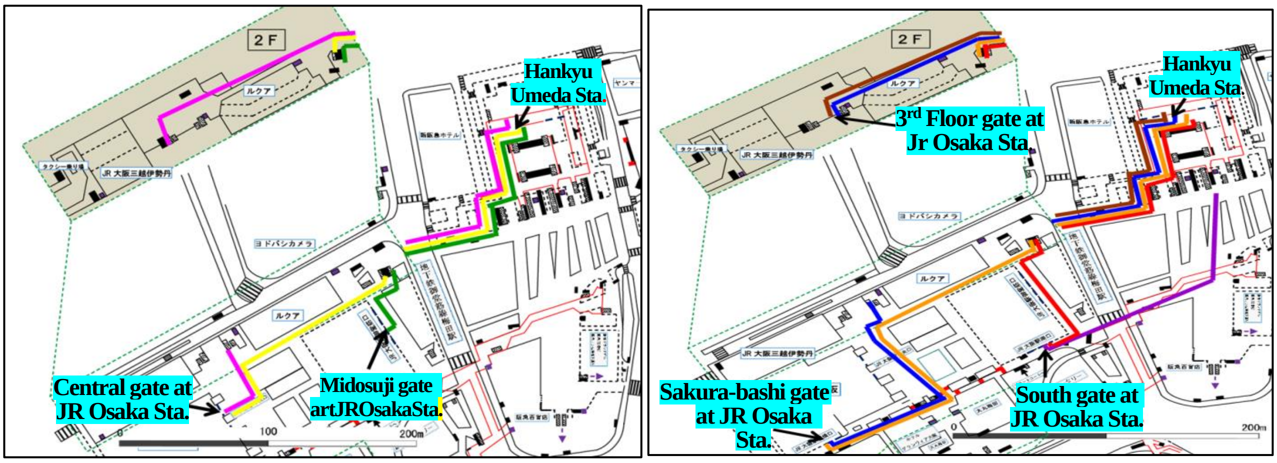


Figure 5-20 Selected routes from JR Osaka Station to Hankyu Umeda Station

Table 5-5 Reliability of paths from JR Osaka Station to Hankyu Umeda Station

Origin (JR Osaka Station)		Destination	Length(m)	Number of signs	Sign system Reliability
	Central Entrance (a)	Hannkyu Umeda	422	26	0.860
	Central Entrance (b)	Hannkyu Umeda	447	26	0.694
	Midosuji Entrance	Hannkyu Umeda	278	21	0.807
	South Entrance (a)	Hannkyu Umeda	358	24	0.494
	South Entrance (b)	Hannkyu Umeda	260	14	0.374
	Sakurabashi Entrance (a)	Hannkyu Umeda	572	39	0.503
	Sakurabashi Entrance (b)	Hannkyu Umeda	597	39	0.406
	3rd Floor Entrance	Hannkyu Umeda	402	25	0.894

Note: Colored lines of Figure 5-20 are corresponding to colors in the left side column of Table 5-5.

(ii) Reliability from JR Osaka Station to Subway Higashi-Umeda Station

Selected routes by experiment subjects from JR Osaka Station to Subway Higashi-Umeda Station are illustrated in Figure 5-21. Table 5-6 shows that routes from Central and 3rd Floor Entrance of JR Osaka Station to Subway Higashi-Umeda Station show high recognition rates, partly because the routes are located on the second floor and underground level where the recognition rates are high in general explained in Table 5-4. Reliability of routes from Sakurabashi Entrance to Subway Higashi-Umeda Station are low, partly because there are several branches at the fork indicated as A in Figure 5-21.

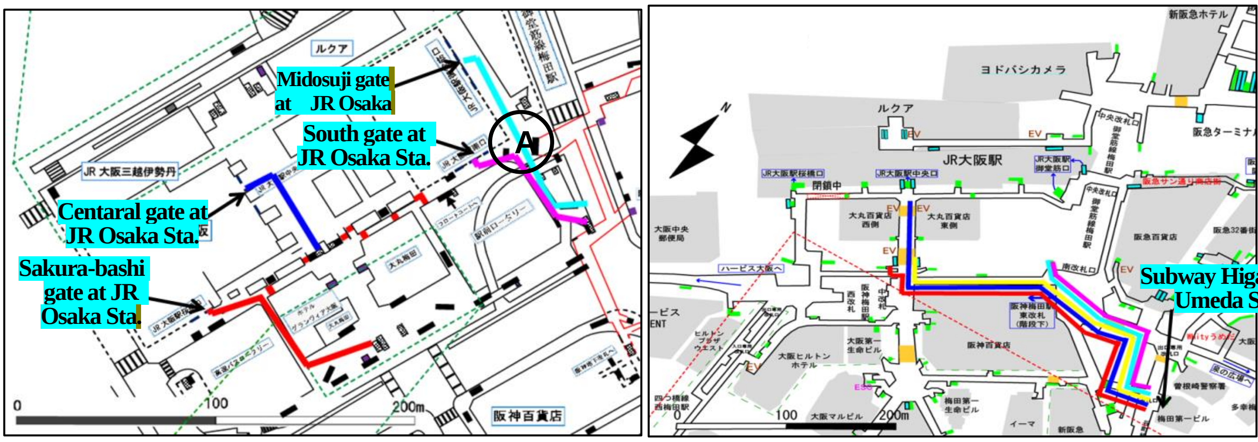


Figure 5-21 Selected routes from JR Osaka Station to Subway Higashi-Umeda Station

Table 5-6 Reliability of paths from JR Osaka Station to Subway Higashi-Umeda Station

Origin (JR Osaka Station)		Destination	Length (m)	Number of signs	Sign system Reliability
	Central Entrance	Subway Higashi-Umeda	510	50	0.728
	Midosuji Entrance	Subway Higashi-Umeda	374	33	0.584
	South Entrance	Subway Higashi- Umeda	333	34	0.584
	Sakurabashi Entrance	Subway Higashi-Umeda	510	44	0.309
	3rd Floor Entrance	Subway Higashi- Umeda	470	45	0.733

Note: Colored lines of Figure 5-21 are corresponding to colors in the left side column of Table 5-6.

(iii) Reliability from Hankyu Umeda Station to JR Osaka Station

Selected routes by experiment subjects from Hankyu Umeda Station to JR Osaka Station are illustrated in Figure 5-22. Routes from the second floor entrance at Hankyu Umeda Station to JR Osaka Station keep high effective rates, however reliability of route from third level entrance to JR Osaka Station is relatively low.

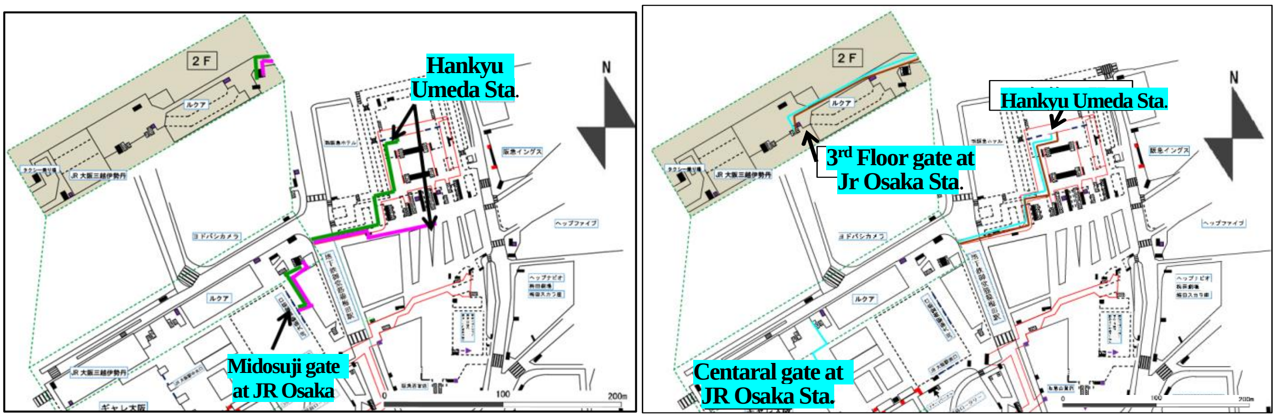


Figure 5-22 Selected routes from Hankyu Umeda Station to JR Osaka Station

Table 5-7 Reliability of paths from Hankyu Umeda Station to JR Osaka Station

Origin		Destination (JR Osaka Station)	Length (m)	Number of signs	Sign system Reliability
	HankyuUmeda2F	Midosuji Entrance	18	278	0.734
	HankyuUmeda2F	Central Entrance	23	422	0.719
	HankyuUmeda2F	3rd Floor Entrance	26	402	0.719
	HankyuUmeda3F	Midosuji Entrance	17	227	0.526

Note: Colored lines of Figure 5-22 are corresponding to colors in the left side column of Table 5-7.

(iv) Reliability from Hankyu Umeda Station to Subway Higashi-Umeda Station

Selected routes by experiment subjects from Hankyu Umeda Station to Subway Higashi-Umeda Station are illustrated in Figure 5-23. Each route from Hankyu Umeda Station to Subway Higashi-Umeda Station keeps high rate of reliability, because most parts of the routes are located underground level where recognition rates are high.

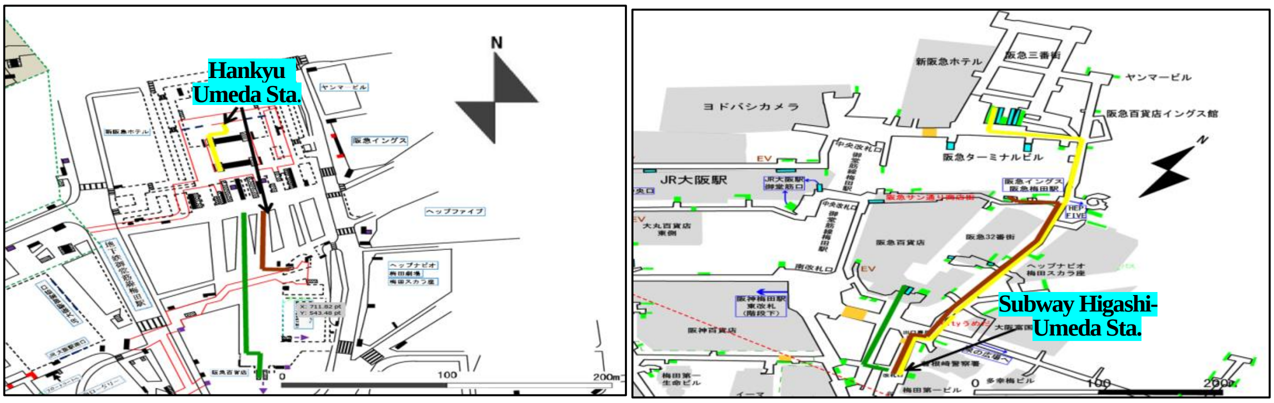


Figure 5-23 Selected routes from Hankyu Umeda Station to Subway Higashi-Umeda Station

Table 5-8 Reliability of paths from Hankyu Umeda Station to Subway Higashi-Umeda Station

Origin		Destination	Length (m)	Number of signs	Sign system Reliability
(green)	Hankyu Umeda3F	Subway Higashi-Umeda (a)	381	26	0.692
(brown)	Hankyu Umeda3F	Subway Higashi-Umeda (b)	453	33	0.722
(yellow)	Hankyu Umeda2F	Subway Higashi-Umeda	478	32	0.749

Note: Colored lines of Figure 5-23 are corresponding to colors in the left side column of Table 5-8.

(v) Reliability from Subway Higashi-Umeda Station to JR Osaka Station

Selected routes by experiment subjects from Subway Higashi-Umeda Sta.to JR Osaka Station are illustrated in Figure 5-55. Route from Subway Higashi-Umeda Station to Osaka Station has high recognition rate, because most of the route is located underground level. Also, there are multiple forks at the point B in Figure 5-55, but as the point is inside Osaka Station, it seems to be easy to understand the direction for passengers.

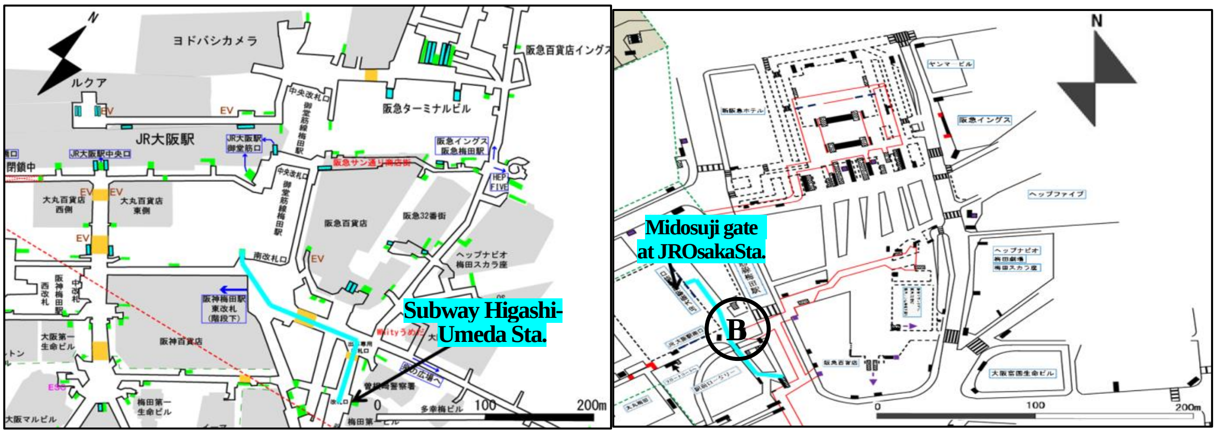


Figure 5-24 Selected routes from Subway Higashi-Umeda Station to JR Osaka Station

Table 5-9 Reliability of paths from Subway Higashi-Umeda Station to JR Osaka Station

Origin		Destination (JR Osaka Station)	Length (m)	Number of signs	Sign system Reliability
(light blue)	Subway Higashi-Umeda	Midosuji Entrance	374	43	0.801

Note: Colored lines of Figure 5-24 are corresponding to colors in the left side column of Table 5-9.

(vi) Reliability from Subway Higashi-Umeda Station to Hankyu Railway Umeda Station

Selected routes by subjects from Subway Higashi-Umeda Station to JR Osaka Station are illustrated in Figure 5-25. Routes from Subway Higashi-Umeda Station to Hankyu Umeda Station keeps high reliability rate, partly because signs are densely installed at the point C in Figure 5-25.

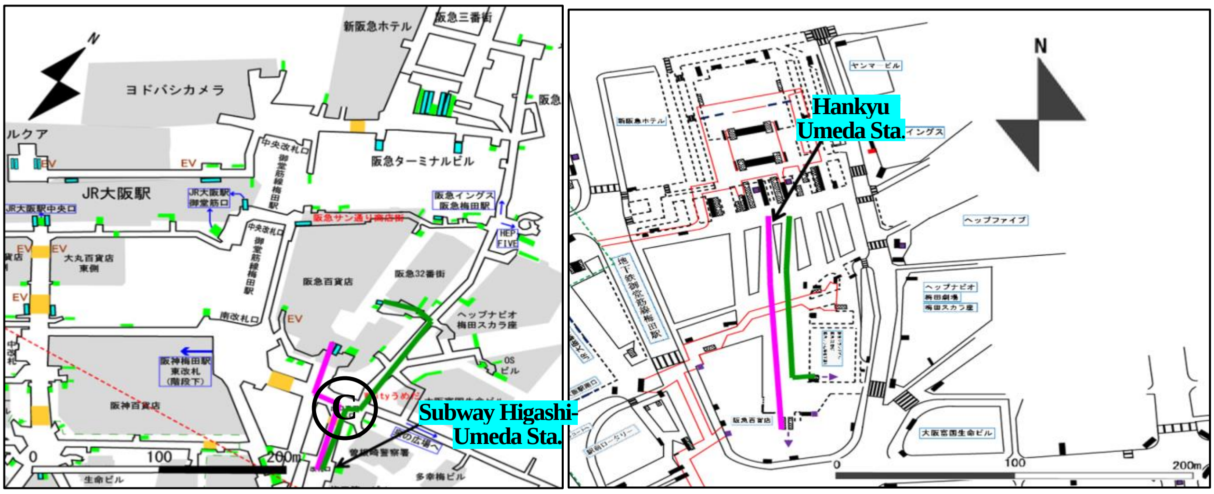


Figure 5-25Selected routes from Subway Higashi-Umeda Station to Hankyu Umeda Station

Table 5-10 Reliability of paths from Subway Higashi-Umeda Station to Hankyu Umeda Station

Origin		Destination	Length (m)	Number of signs	Sign system Reliability
(magenta)	Subway Higashi-Umeda	Hankyu Umeda3F (a)	381	41	0.882
(green)	Subway Higashi-Umeda	Hankyu Umeda3F (b)	327	39	0.603

Note: Colored lines of Figure 5-25 are corresponding to colors in the left side column of Table 5-10.

(2) Considerations

Results of above-mentioned case studies of sign system reliability of paths for several OD pairs are illustrated. Reliability values of sign system for 23 sample paths examined in this section spread from 0.3 to 0.9 as shown in Figure 5-26. Though Osaka Transport Hub has installed a sign system to some extent, sign system reliability of several paths remains in low condition. As it can be understood, sign system reliability on each route depends on recognition rates of signs installed along the route.

As indicated in Table 5-5, recognition rates appear to be relatively low in several cases reflecting locations and types of signs. Signs installed in ground level or the first floor level in buildings (ground level) is less recognized than others. It is valuable to pay attention to improvement of such signs.

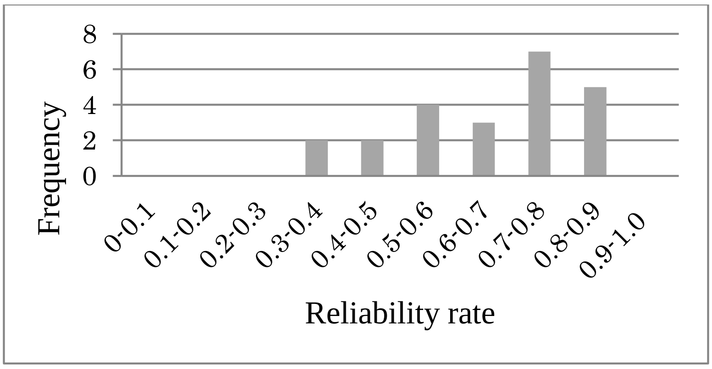


Figure 5-26 Sign system reliability of sampled paths

5.4.3 Route choice behavior based on sign system reliability

This section aims to make clear influence of sign system reliability on pedestrian's route choice behavior. To achieve this aim, logit models are developed. Data used here are obtained from the survey mentioned in Section **5.3**. OD characteristics obtained to develop route choice models are shown in Table 5-11.

Previous studies including our studies have indicated that most major paths selected by pedestrians are shorter than 1.4 times of the shortest path (Tsukaguchi and Ohashi (2007)). Considering this feature, we can limit paths which are likely used by pedestrians to about three paths in this study area. Therefore, the logit models in this section have three options. The explanatory variables are sign reliability of a path, walking distance along the path, and average width of the paths. The route choice model in this section is 'lump model' to analyze three-dimensional movement described in Section **5.2**.

Table 5-11 OD characteristics of data used for

Origin	Destination	Sample size	Number of selected routes
Nishi-Umeda	Hankyu Umeda Station	19	3
Dojima		19	3
Daisan building		18	3
Hankyu UmedaSta.2F	Subway Higashi-Umeda Station	26	3
Subway Higashi-Umeda Station	Hankyu Umeda Station 3F	20	3
Total		102	

Developed models are shown in Table 5-12 One model has been explained by sign reliability of a path and walking distance, and another has been explained by sign reliability of a path and width of the path. Though the likelihood ratio and reproducibility are not satisfied, but it can be said that sign system reliability plays an important role to select suitable path to the destination.

Table 5-12 Developed models

Explanatory variable	Parameter value	t value
Walking distance	-0.000817	-0.218
Reliability of sign system	9.35	5.59**
ρ^2	0.186	
Reproducibility	57.8	

Explanatory variable	Parameter value	t value
Reliability of sign system	5.65	2.10*
Width of path	0.194	1.69*
ρ^2	0.198	
Reproducibility	57.8	

** 1% significant, * 5% significant

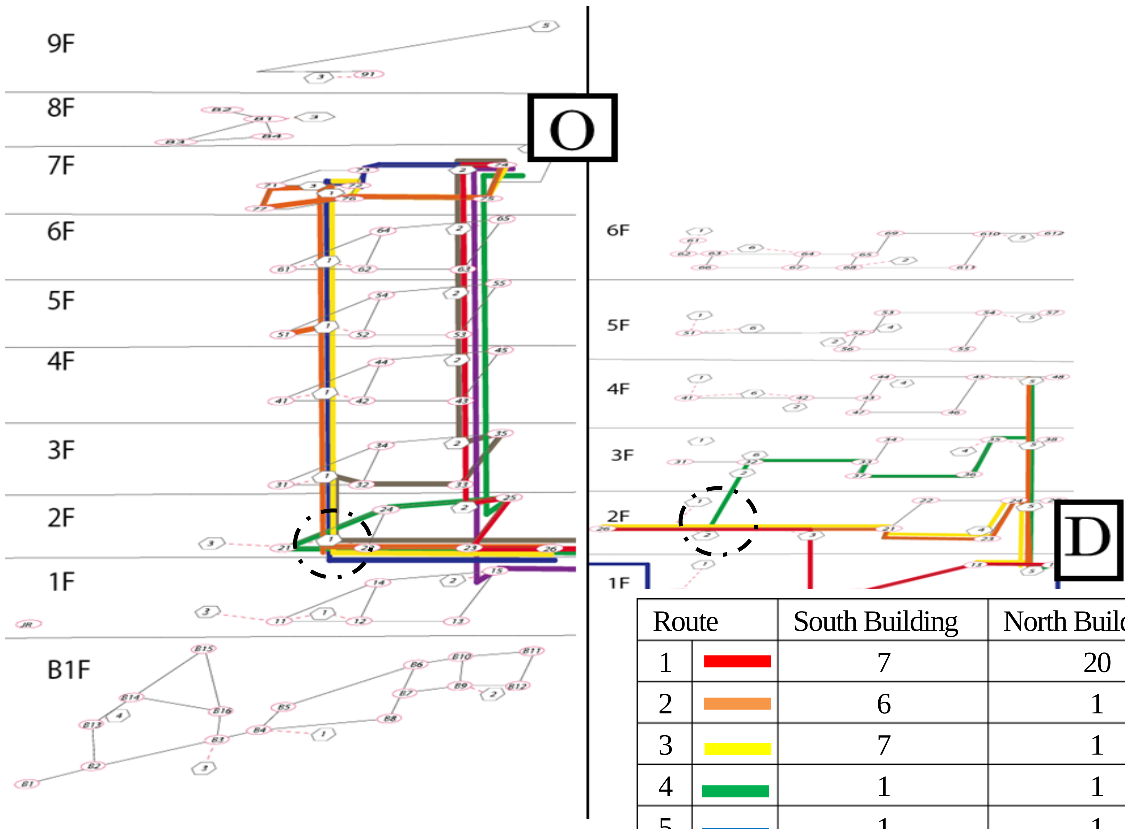
5.5 Evaluation of Pedestrian Sign System in a Shopping and Business Tower Complex

High standard of walking environment in city centers and their transport hubs is important to stimulate urban activities. This requires urban planners to ensure improvements to pedestrian infrastructure as well as sign systems to assist destination search and route choice processes of users. A measure to explain the relative number of pedestrians who sight a particular sign has been developed with the view of understanding the type of signs that are more useful to users. Routes selected by experiment subjects were compared to minimum distance routes that could have been selected by pedestrians with complete information about the network layout. To achieve this aim, an investigation was practiced at a newly developed shopping and business complex (Grand Front Osaka) next to a large transport hub (Osaka Transport Hub).

5.5.1 Routes selected by subjects of the experiment

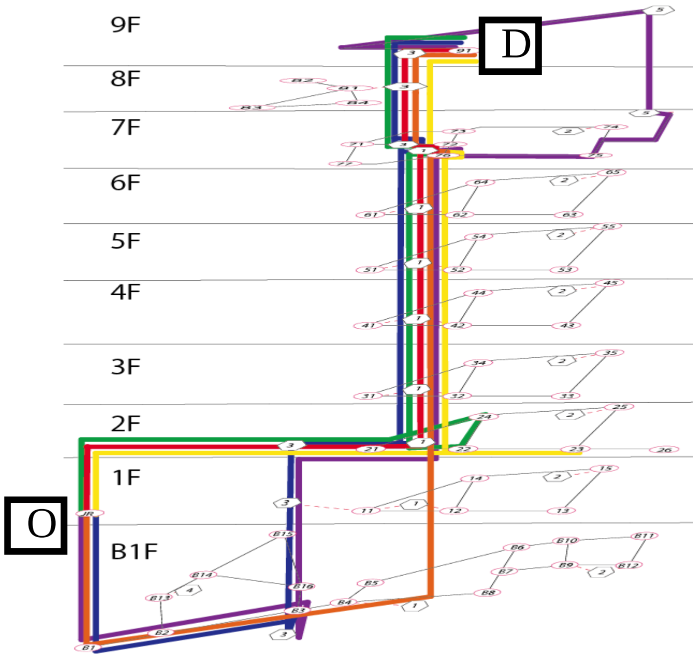
As mentioned in Section **5.3**, six OD pairs were picked out for investigation. Waling paths of some OD pairs are illustrated in the following figures by way of example. Routes followed by the 24 subjects when they walk making use of the sign system from the location 3 to location 4 (i.e. Trip 3 shown in Section **5.3** are shown in Figure 5-27. The two right hand side columns of numbers on the figure show how many subjects followed the particular path. There were seven alternative paths subjects have followed within the South Tower to reach the connector to the other tower. Then, there were five alternative paths within the North Tower to reach the destination. Routes selected by subjects have no excessive detours and appear to be reasonable selections. However, users' decisions were made at each turning point with imperfect information beyond that point, partly because map type signs only show the layout of most facilities on the floor, and do not provide the best route to their destination. Therefore, pedestrians had to obtain complete information from other signs along the routes.

Figure 5-28 shows travel paths of subjects from location 1 to location 2. That is the experiment for Trip 1 (see Section **5.3**. 50% of respondents followed the first path indicated on the figure. Only one route (yellow route in Figure 5-28) shows overreaching on the horizontal plane and experienced some deviation from shorter paths.



Route		South Building	North Building
1	(red)	7	20
2	(orange)	6	1
3	(yellow)	7	1
4	(green)	1	1
5	(blue)	1	1
6	(purple)	1	-
7	(grey)	1	-

Figure 5-27 Walking paths selected by subjects for the experimental Trip 3 in Section 5.3



Route		South Building
1	(red)	12
2	(orange)	8
3	(yellow)	1
4	(green)	1
5	(blue)	1
6	(purple)	1

Figure 5-28 Walking paths selected by subjects for the experimental Trip 1 in Section 5.3

5.5.2 Route selected under the complete information

Our previous studies clarified that pedestrians are not always select shortest path to a destination, namely pedestrians are likely to use paths shorter than 1.4 times of the shortest path. But there are multiple shortest paths in a large shopping complex such as Grand Front Osaka. Therefore, our discussion is focused on the shortest paths.

There is more than one shortest distance path to a destination in tower structures where there are many corridor networks on the horizontal plane and vertical shafts and escalators to facilitate movement in the vertical direction. There are two particular routes from these shortest paths that are of interest to planners of sign systems particularly when we deal with networks on a single surface (Tsukaguchi et al. (2013), Tsukaguchi and Vandebona (2010), and Vandebona et al. (1999)):

1) A shortest path that has the least number of turns requires less direction instructions to be given. Therefore, they need less signs to direct pedestrians. Thus, such sign systems have a low construction cost. The emphasis in such systems is to maximize straight through movements. Pedestrian flows with such guidance information have low probabilities associated with left and right turns and behave as if the individual pedestrians behave under the influence of momentum concept (or inertia) in physics.
2) The other shortest path of significance stays close to the straight line connector between origin and destination. From behavioral viewpoint, in studies done on horizontal networks, it has been observed that humans tend to minimize the angle of orientation with destination when they are regular users of a network. These pedestrians attempt to minimize the geometric angle between the current movement vector and the imaginary vector that connects the present location to the destination.

Previous research on walking between origins and destinations in different floors of buildings and terminals has shown a tendency of pedestrians to make use of the first available set of stairs and escalators to reach the destination level (Tsukaguchi, Shibata and *et.al.*). This behavioral trait of trying to reach the destination level as soon as possible can be now incorporated to the two route choice strategies mentioned above.

The above route selection strategies allowed researchers to select two different shortest paths from the many shortest paths that maybe available to compare with the route taken by the experiment subjects. Figure 5-29 provides a summary of the two strategies. The first method is referred to as the simple shortest distance route because it has less turns. The other method is referred to as the natural shortest distance route because it is similar to the path often followed by regular users of pedestrian networks.

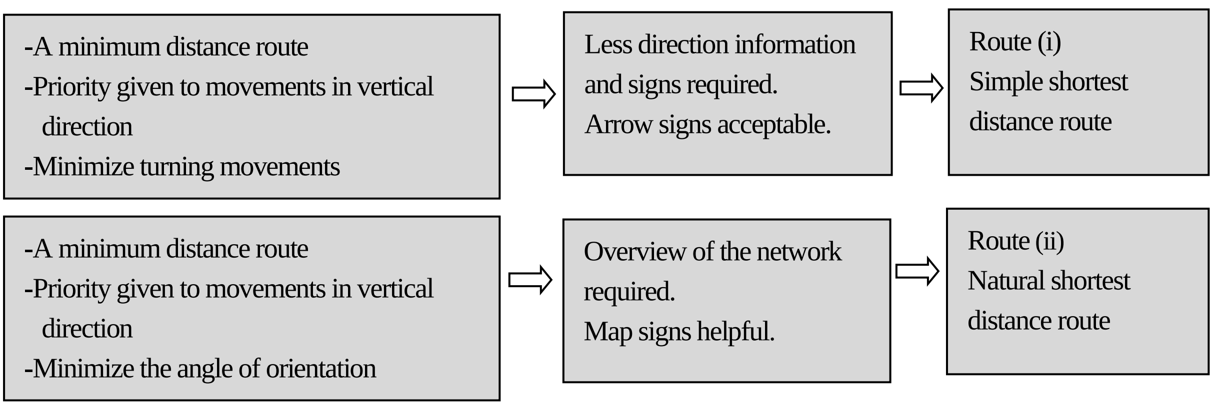


Figure 5-29 Two shortest distance routes considered

It is interesting to note that the Route 1 in Figure 6-1 followed by majority of subjects solely by using signs to perform the Trip 3 was the simple shortest distance route computed during the analysis. Similarly, Route 1 in Figure 5-28 using Trip 1 field data was also the simple shortest distance route. 50% of subjects performing that trip have followed that route to perform the Trip 1. These results indicate that the sign system has some success in providing information effectively to direct them to less complex routes. Also, the Trip 1 data route distribution shows that about 1/3 of subjects have been able to develop a reasonable overview of the spatial distribution of the network to be able to behave in a manner similar to regular user of the network. The availability of map signs may have been a contributing factor.

At this stage, an attempt was made to quantify the level of success of the sign system in directing pedestrians to their destinations according to the intended routes of planners. For the example given below, the intended route is assumed to be simple shortest distance route which should require less direction information and therefore less cost for sign installation (i,e. Route (i) in Figure 5-29). The proposed measure is focused on computing the amount of overlap between the intended route and user selected route. It was decided to perform this calculation using distance measurements of the routes and overlap sections. This measure referred to as compliance rate is given by:

$$\text{Compliance rate} = \frac{\text{Sum of overlap length of recommended route and user selected route}}{\text{Total length of the recommended route}} \quad (5\text{-}6)$$

This measure calculated for all origin and destination pairs covered during the experiment are shown in Table 5-13. The values spread between 30% and 95%. When there are more alternative shortest distance routes, the compliance rate is relatively low as expected.

One third of signs in this complex were map type signs which had provided opportunities for pedestrians to trial alternative routes to reach their destinations. This could have been acceptable to the tower managers as the sign system has exposed their customers to a wide range of retail outlets.

Table 5-13 Compliance rates based on simple shortest distance route

Trip number	Compliance rate (%)	Number of other shortest distance routes
1	50.0	5
2	54.2	4
3	29.2 (South Tower), 83.3 (North Tower)	6 (South Tower), 4 (North Tower)
4	54.2	7
5	62.5	6
6	95.8 (South Tower), 66.7 (North Tower)	1 (South Tower), 3 (North Tower)

In forks where not few alternative routes exist, map type signs are frequently installed. Such signs only show the layout of most facilities on the floor, and users have to make decisions at each turning point with imperfect information beyond that point. Therefore, compliance rates of routes including larger number of map type signs may be lower than the routes mainly supported by arrow type signs.

5.5.3 Utilization of signs

An indicator of productivity of a sign is how many individuals actually see the particular sign. Some signs are actively noticed by almost everyone whereas others could be rarely noticed. A measurement method is suggested here based on the proportion of pedestrians who see a given sign. Data for this calculation was primarily from the head mounted camera worn by the experiment subjects. Index related to visual perception of the sign displays, using the experimental data.

$$\text{Recognition rate of each sign} = \frac{\text{Number of passengers who noticed the sign}}{\text{Total number of passengers who passed the sign location}} \quad (5\text{-}7)$$

Table 5-14 shows the recognition rates of most used signs at forks on pedestrian paths covered by experiment subjects. Eleven such locations are listed in the table. These are locations where at least fifty percent of subjects have seen the sign. Signs located near entrances were more likely to be perceived.

Table 5-14 Examples of signs seen by more than 50% of pedestrian traffic

Trip number	Recognition rate (%)
1	85.7 (entrance of South Tower), 58.3
2	83.3 (restaurant avenue), 95.8 (restaurant avenue)
3	60.0, 91.3 (entrance of North Tower)
4	91.7 (starting point), 52.4
5	58.3, 58.3
6	57.1

Signs located near the entrances of both towers were most observed, because these signs were important for visitors to orient themselves and learn the spatial distribution of potential destinations. Average recognition rate of map boards was 79.5 % and those of arrow signs were 65.6 %. The map boards seem to be more perceived partly because that map boards deliver a broad range of information relevant to a wide range of destinations, particularly suitable sightseers. On the other hand, arrow signs and name boards were useful for only selected group of pedestrians. Letter size also appear to have an impact as expected, signs with relatively small letters have low utilization rates. As mentioned in Table 5-5 in Section **5.4**, recognition rates of map boards were low in the main part of the transport hub. This is a typical deference between signs in a pure transport hub and a shopping complex.

The characteristics mentioned above include some general characteristics of signs, however, the results are meaningful because they have been obtained by an experiment from a quantitative point of view.

5.5.4 Lessons from the experiment

The sign system installed in Grand Front Osaka has been able to orient visitors and efficiently guide them to their destinations. However, in this multistory complex, it is difficult to avoid having to make numerous turns even in shortest distance routes to destinations.

The signage policy within Grand Front Osaka is different from the neighboring transport hub due to differences in tenant attributes and pedestrian flow properties as discussed earlier. The tower complex relies on map signs to a certain degree as it caters for a wide range of potential destinations. The transport hub could rely on arrow signs as it is focused on serving quickly moving pedestrian streams that need to be divided to different tributaries.

It has been observed that signs located near entrances of the complex are the most perceived. Most signs in the restaurant avenue were also well perceived. In these areas, map type signs are effective, because visitors need range of information at these locations. In this study area map boards have a higher utilization than arrow signs. However, arrow signs are more efficient in guiding pedestrians to major destinations and landmarks.

5.6 Concluding Remarks

This chapter described pedestrian route choice behavior under the influence of sign systems in Nara Park and Osaka Transport Hub. The area discussed in Nara Park is the same as the area mentioned in Chapter 4.

As for the route selection behavior in Nara Park, two dimensional models (see Section **2.3**) have been developed at three deferent times including before and after sign system improvement. Using the models, parameter ratio, expressed in equation 2-3 in Section **2.3**, was calculated. If the parameter ration is smaller than 1.0, tendency keeping a straight movement is superior to minimizing the angle of orientation. On the other hand, when the parameter ration is larger than 1.0, minimizing the angle of orientation is superior. The parameter ratio after sign system is larger than before improvement. Because no information about the destination is offered, going straight movement is preferred, described in Section **2.3**. In accordance with sign system improvement, the characteristics of minimizing the angle of orientation comes to be superior. This may be a proof that realization of reasonable route choice by sign system modification.

Large transport hubs in city centers of metropolitan areas consist of railway terminals, major commercial establishments and other public facilities. As most transport hubs spread on ground and underground level, such transport hubs have complex structure. Under the circumstances, planners are required to install effective sign systems for visitors including persons familiar and unfamiliar with the area.

This project has made clear the characteristics of real movements including those between the ground level and the underground level, also those between the ground levels. Based on these analyses, this study demonstrates that passengers visited Osaka Transport Hub prefer the underground streets to the ground streets. The analysis is limited only to the above-mentioned transport hub, therefore it is not suitable to conclude that the results have the universal validity in large scale transport hubs. However, it is the useful findings based on certain observational survey.

As for the route selection model in a large transport hub, this project identified pedestrian route choice behavior in a large transport hub in Osaka which has multistory structures (see Section **2.4**). Passengers visited such hub have to conduct route choice behavior, in order to reach their destinations safely and smoothly. Since there were few observed data on pedestrian route choice movements in multistory structure hubs, this project carried out observation surveys in which a shadowing technique was adopted.

Based on several investigation and experiment, this project analyzed passenger movement in three-dimensional network. As for the route choice movements between the ground level (1F) and the underground level (B1), this project has developed acceptable models for pedestrian route choice behavior in a three-dimensional network. One of final goals of this project is to develop pedestrian route choice models which can explain pedestrian behavior including several times up-and-down movements, in multistory transport hubs. Since the models developed in this project are the part of the final model, improvement of the models is strongly desired.

Several experiments in Osaka Transport Hub and Grand Front Osaka made it possible to understand which signs are more recognized. Among three types of signs such as arrow type signs, map type signs, and name board type signs, arrow signs keep highest recognition rate in the transport hub. On the other hand, map type signs are most recognized in the shopping and business complex. This may come from deferent function of a transport hub and a shopping and business complex. Arrow signs are useful for passengers whose destination may be almost determined in the transport hub, on the other hand, map boards seem to be more perceived partly because that map boards deliver a broad range of information relevant to a wide range of destinations in the shopping and business complex.

Continuity and unification are important factors for effective sign systems. This project has developed a new approach to evaluate the sign system installed in a large transport hub based on reliability concept. After discussion on recognition level of sign boards, an assessment measure on sign system reliability in the transport hub has been proposed. It can be seen that sign system reliability on each route strongly depends on recognition rate.

This study has investigated impacts of the sign system on route choice behavior of passengers based on an experiment in a newly developed large shopping and business complex in Osaka, Japan. The shopping and business complex has a sign system which has been classified into three types of signs based on their content for this study. The sign system performed adequately, and test subjects of this study arrived at nominated destinations without making long detours. The experiment was conducted in a way that subjects were constrained to make their route choices en-route.

The route selection models indicate that there is significant relationship between sign system reliability and passenger route choice behavior. As there are no long detours of passenger selected paths, it can be seen that the sign system provides important benefits to the transport hub. However, the sign system effectiveness of several paths in Osaka Transport Hub still has room for improvement, though the overall transport hub has an effective sign system to some extent.

This project puts importance on the shortest routes, although there are some passengers who visit the shopping and business complex for the purpose of window shopping, sight-seeing and so on. For them, shortest distance path selection may not be so important. However, even for such passengers, sign systems which make them possible to visit particular facilities with less effort must be preferable.

It has been observed that the proportions of different types of direction signs provided are different in different developments. In particular, a noticeable difference was observed in the composition of signs in the transport hub next to the tower complex. It was possible to derive useful guidelines based on investigation of the differences in composition of signs in the two types of land-use. The methodology presented provides a basis for evaluating the suitability of the existing composition of types of direction signs and development of new signage policies if the current system could be improved. Another quantitative measure developed during this analysis specifically addresses the usefulness of individual sign boards. This allowed the research project to identify the locations where certain types of signs are most effective in the study area.

Chapter 6 Summary

The series of projects presented in previous chapters has provided an insight into techniques available for planning and design of passive sign systems formed by fixed roadside signs to efficiently direct travelers to their destinations. The underlying concept is rather simple, as the primary objective of travelers is to use a path of least cost, which could often translate to searching for a path of minimum distance to the destination. Achieving this objective with a sign system in a manner consistent with behavioral instincts of travelers has taken us in a journey through a variety of mathematical techniques such as logit model, random walk, graph theory and Entropy minimization.

Methods covered in the document are particularly useful when origin and destination pairs have more than one shortest path, where the analyst face a challenge to determine which one of the shortest paths to favor in the sign system presented to the travelers. Therefore most grid type networks present in urban road networks, city centers and within buildings can benefit from the techniques presented. The method developed in these projects use logit model technique to assess the choice probabilities at decision nodes along the routes to select the route that is logical to the majority of customer population.

Variety of observation techniques applicable for the purpose of quantifying performance of sign systems has been presented in case studies mentioned in previous chapters. There are three important performance criteria adopted in our work to evaluate the sign system. They are (a) the number of customers delivered to different destination nodes within a specified period, (b) The number of destination nodes visited per traveler and (c) the proportion of travelers getting lost.

In relation to above-mentioned criteria, it was able to establish three aims as follows;

- Aim 1: With an improved sign system, the number of individuals getting lost should be decreased,
- Aim 2: With an improved sign system, the circulation of individuals should be enhanced,
- Aim 3: With an improved sign system, a reasonable shortest route should be selected by most individuals.

Majority of discussion in the document has been based on case studies dealing with two dimensional topologies. However, in modern cities there are many buildings and facilities containing three dimensional networks handling large number of travelers on a regular basis. The pathway to application of sign planning concepts to 3D networks has been specifically covered with the use of a case study of multi-story shopping complex containing a railway interchange.

The ability to achieve above aims was substantiated using data obtained in Nara Park. Achievement of aims 2 and 3 has been proved in previous chapters. However, achievement of aim 1 has been shown to be rather difficult. In the case study presented, the percentage of visitors getting lost did not reduce sufficiently after improvements carried out to the sign system. This may appear counter-intuitive. However, this should be examined in conjunction with the achievements of aims 2 and 3. The average number of attractions visited per person also increased during this period. It may be one reason that getting lost count did not reduce after sign system improvement. However, the project team has been able to better document where getting lost actually occurred, and able to closely analyze specific local conditions that contribute toward getting lost.

The document also highlights difficulties planners face because ownership of sign system may not have a single authority. Improvement of existing sign systems owned by different proprietors is an issue faced in number of case studies and not easy to resolve. In one case study in particular, different owners of the signs were extremely powerful, and a mixture of incompatible design styles had to be reluctantly accepted. In general however, an initiative to improve the sign system receives good support particularly when a public authority commits funding. Case studies presented provide examples of successful sign modernization attempts. The projects reported also highlighted a hierarchical method to determine what destinations to be sign posted in situations where a large number of potential destinations were available. Methods to deal with the amount of information that need to be conveyed in a consistent style are also described in a case study of a tourist precinct with many important destinations.

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References

Ahn, Y. and Tsukaguchi, H. (2015), Estimation of pedestrian movements in a large transport terminal, Traffic Engineers, Vol.1No., 1-9.

Ahn, Y., Tsukaguchi, H. and Vandebona, U. (2017), Assessment of Productivity of Signs in an Indoor Pedestrian Network, journal of EASTS, Vol.12, 2268-2283.

Chan, K.S., Lam W.H.K., Ouyang, L.Q., Wong, S.C. (2007), Simultaneous Estimation of the Pedestrian Origin-Destination Matrix and Parameter of the Activity/Destination Choice Model, Proceedings of the Eastern Asia Society for Transportation Studies, Vol.6, 223.

Chanson, H. (2010). Coastal 0bservations: Tsunami warning signs on the Enshu Coast of Japan, Shore and Beach, Vol. 78-1, pp. 52-54.

Cheung, C.Y. and Lam, W.H.K. 1998), Pedestrian Route Choice between Escalator and Stairway in MTR Stations, Journal of Transportation Engineering, 277-285.

Chiyada, N. (2006), Study of temporally public signs in Matsuyama City, Bulletin of Faculty of Education, Matsuyama University, Vol.53, No.1, pp.181-193.

Cohen, J.M. (1992). Analysis of Random Walk, IOS Press Amsterdam, Netherlands.

Consultative meeting of sign planning at Osaka/Umeda Stations (2018): Common rule of sign planning at Osaka/Umeda Stations.

Council of sign system construction around Osaka-Umeda Station Area (revised in 2019): Standard specification of sign system around Osaka-Umeda Station Area (Common rule) Ver.1.01, http://www.pref.osaka.lg.jp/toshimiryoku/umeda_sign/index.html

Donald, D. (1995). Making Traffic Signs Work – An Overview of Design and Testing Procedures, ARRB-Special Report SR52, Australian Road Research Board Ltd. Vermont South, Victoria.

Doyle, P.G. and Snell, J.L. (1984). Random Walks and Electric Networks, The Carus Mathematical Monographs, 22, The Mathematical Association of America.

Francis, R.L., Mcginnis, L.F., and White, J.A. (1983). Locational analysis, European Journal of Operational Research, 12, 220-252.

Field, K., O'Brien, J., and Beale, L. (2011): Paper maps or GPS? Exploring differences in way finding behavior and spatial knowledge acquisition 2011, 25th International Cartographic Conference, Paris.

Fukami, T., 1977. A Study on Pedestrian Flow in Commercial Areas, Papers of 12 Scientific Research Meeting, The City Planning Institute of Japan.

Funahashi, K. (1991), Path choice in grid network of street, Journal of Architecture, Panning and Environmental Engineering (Transactions of AIJ), No.428, 85-92.

Garbrecht, D., 1970. Frequency distributions of pedestrian in a rectangular grid, Journal of Transport

Economics and Policy, (1), 66-88.
Garbrecht, D., 1971. Pedestrian paths through a uniform environment, Town Planning Review, 42(1), 71-84.
Hanai, S., Tsukaguchi, H., and Ahn, Y. (2012), Analysis on Pedestrian Route Choice Behavior in Three-Dimensional Space at Large-scale Transport Terminals, Smart City and Urban Renewal, International Symposium on Urban Planning 2012
Hirata, H. (2012), Study on characteristics of pedestrian route choice behavior and pedestrian sign system planning, Master thesis of Ritsumeikan University.
Hoogendoorn, S.P. and Bovy, P.H.L. (2004), Pedestrian Route-choice and Activity Scheduling Theory and Models, Transportation Research Part B 38, 169-190.
Ishikawa, T., Fujiwara, H., Iwai, O., and Okabe, A (2008): Way finding with a GPS-based mobile navigation system - A comparison with maps and direct experience, Journal of Environmental Psychology 28, 74-82.
Kamino, Keijin and Funahashi, K. (1974), On Space Cognition and Pedestrian Movement, Research paper report collection of Architectural Institute of Japan, No. 217.
Kim, H.、Asano, S., Kajishima, K., Horigoshi, Y., Goto, H., and Tonuma, K. (1990), An Investigation into the State of Improvement Plans for Public Signs: Proposals for and themes of public signs in Setagaya Ward, Tokyo, Journal of Architecture, Planning and Environmental Engineering (Transactions of AIJ), No.415.
Kolen, A. and Tamir, A. (1990). Covering Problem, in Discrete Location Theory, Eds. Mirchandani, P.B. and Francis, R.L., John Wiley and Sons Inc, New York.
Mitchell, D.H. and Smith, J.M. (2001). Topological network design of pedestrian networks, Transportation Research Part B 35, 107-135
Misty, R. (2002): Vail offers visitors new direction, The American City & County; Vol. 117, 7; pp. 24. ProQuest Central
Mori, M. and Tsukaguchi, H., 1979. Characteristics of Pedestrian Route Choice Behavior, Proceedings of Annual Conference of Civil Engineers, JSCE Kansai Chapter (in Japanese).
Mori, Y., and Iida, K. (1997), Analyses of Pedestrian Behavior for Constructing Better Pedestrian Guide Systems in Urban Area, Traffic Science, Vol.26, No.2,79-86.
Mukai, H., Tsukaguchi, H., Ahn, Y., and Hayashi, I. (2011) Improvement of pedestrian sign system based on behavioral analysis -A case study in Nara Park, Proceedings of Infrastructure Planning, Vol.43, No.185.
Mukai, H., Tsukaguchi, H., Ahn, Y., and Hayashi, I. (2012): Study on effects of sign system improvement in Nara Park based on analysis of travel behavior, Proceedings of Infrastructure Planning, Vol.44.
Mukai, H., Tsukaguchi, H., Ahn, Y., and Hayashi, I. (2013) Study on effects of sign system improvement in Nara Park based on analysis of travel behavior, Proceedings of Infrastructure Planning, Vol.45, No.385.
Nagoya Housing and City Bureau (2002): Pedestrian sign manual of Nagoya, Second revision
Nakamura, T. (2018), Study of Sign System Improvement in a Large Transport Hub, Master Thesis of Ritsumeikan University, Japan.
Nara Local Government: Special district for regional revitalization, http://www.kantei.go.jp/jp/singi/tiiki/sogotoc/sinsei/dai3/121012sinseisho/t5-1_nara.pdf
Nara Local Government (2009): Guideline for improvement of tourist sign system.
Nara Keizai Shimbun (2010): Visitors to the 1300 anniversary event of relocation of ancient Nara Capital, http://nara.keizai.biz/headline/517/ , Dec 13, 2010.
Nara Local Government: Present situation and problem in Nara Park, http://www.pref.nara.jp/secure/94065/shiryo1-2.pdf.
Ogata, S. and Zaino, H. (1995), A Study on Urban Sign System: A behavior for sign and space information collection, Journal of Architecture and Planning (Transactions of AIJ), No.473, 113-119.

Okita, R., and Uchida, T. (2008): A Sign System Designated for Busy Pedestrian Facilities and its Evaluation by Digital Image Experiments, Infrastructure Planning Review, Vol.25, No.2.
Osaka Municipal Government (2003): Osaka City Sign Systems for Visitors, Osaka and Its Technology, Vol. 43, pp. 23-30.
Osaka Municipal Government (2003): Development of Osaka visitor-friendly sign system: Osaka and Its Technology, Vol. 43, pp. 31-39.
Osaka Municipal Government: Historical promenade, http://www.city.osaka.lg.jp/kensetsu/page/0000008550.html
Pooler, J.A. (1995). The Use of Special Separation in the Measurement of the Transportation Accessibility, Transportation Research, 29A (6), 421-427.
Quebec Road Department (1968). Road Signs: Manual on uniform traffic control for Quebec, Quebec Province Road Department, Ottawa.
Ramsay, E.D. and Luk, J.Y.K. (1997). Route choice under two Australian travel information systems, ARRB-312, December 1997, Australian Road Research Board Ltd. Vermont South, Victoria.
Reagin, M. (2002), Vail offers visitors new direction, The American City & County, Vol.117, pp.24.
Takegami, N. and Tsuakguchi, H. (2006): Modeling of pedestrian route choice behavior based on the spatial relationship between the pedestrian's current location and the destination, Journal of JSCE D, Vol.62, No.1, pp64-73.
Takegami, N. and Tsukaguchi, H. (2006), Modeling of pedestrian route choice behavior based on the spatial relationship between the pedestrian's current location and the destination, Journal of JSCE, D Vol.62, No.1, 77-86.
Takeuchi, D., (1977). A Study on Pedestrian Route Choice Behavior, Proceedings of JSCE, No.259, 91-101.
Tsukaguchi, H. Vandebona, U. and Matsuda, K., 2003. Modeling of Pedestrian Route Choice Behavior for Development of Information Systems Architecture, The selected proceedings of the 9th WCTR.
Tsukaguchi, H. and Ohashi, Y. (2007), Modeling pedestrian route choice behavior and its application to the planning of underground shopping streets, 11th ACUUS International Conference, Underground Space, Expanding the Frontiers, 527-532.
Tsukaguchi,H., Li,Y., and Yeh, K. (2009), A new method for estimation of pedestrian flow in underground shopping streets, 12th ACUUS International Conference.
Tsukaguchi, H., Shibata, H., Hirata, H., and Ahn, Y. (2013): Three-Dimensional Pedestrian Route Choice Behavior in a Large Transportation Terminal, Journal of JSCE, D3Vol.69, No.2, 135-145.
Tanaka, S., T. Hashimoto, Hayashi, I., and Tsukaguchi, H. (2009): Proposal of pedestrian sign system based on analysis of tourist's behavior -A case study in Nara Park, Proceedings of Infrastructure Planning, Vol.40.
Tanaka, Y., Mukai, H., Tsukaguchi, H., Ahn, Y., and Hayashi, I. (2014): Behavioral change of tourists by sign system improvement, Proceedings of Infrastructure Planning, Vol.50.
Tsukaguchi, H., Shibata, H., Hirata, H., and Ahn, Y. (2013): Three-Dimensional Pedestrian Route Choice Behavior in a Large Transportation Terminal, Journal of JSCE, D3Vol.69, No.2, 135-145.
Tsukaguchi, H., Vandebona, U., and Mukai, H. (2013): Study of sign system improvement in a historical park based on before and after comparisons, Proceedings of World Conference on Transport Research.
Tsukaguhi, H., Vandebona, U., Mukai, H., and Ahn Y. (2015) Analysis of path finding errors of pedestrians following introduction of a new direction sign system, Journal of the Eastern Asia Society for Transportation Studies, Vol.11, pp.1221-1239.
Tsukaguchi, H., Miyamoto, T., Ahn, Y., and Hayashi, I. (2015): Circulation and way finding behavior of tourists in a historical park, Proceedings of Infrastructure Planning, Vol.51.
Tsukaguchi, H. (2016): Analysis of tourist behavioral change by pedestrian sign system improvement in a large historical park, Journal of the City Planning Institute of Japan, Vol.51, No.2, pp.174-183.

Under wood, R.T. (1995). Road Engineering Practice, Macmillan Education Australia Pty, Ltd. South Melbourne.
Vandebona,U. and Yossyafra, (1999): Analysis of Signage Requirements for Pedestrian Movements, Roads and Transport Research, Journal of the Australian Road Research Board Transport Research, **8 - 4**, 55-67.
Vandebona, U. and Richardson, A.J. (1985). Transit Route Animation and Modelling by Simulation, Journal of Advanced Transportation, 19(2), 153-177.
Vandebona, U. and Yossyafra, (1999), Analysis of Signage Requirements for Pedestrian Movements, Roads and Transport Research, Journal of the Australian Road Research Board Transport Research, 8-4, 55-67.
Vickerman, R.W. (1974). Accessibility, Attraction, and Potential, A Review of Some Concepts and Their Use in Determining Mobility, Environment and Planning, 6A,675-691.
Wakagayashi, H. (1989), Basic Study on Reliability Analysis on Road Network, Dissertation of Kyoto University.
Wu, H., Miyamoto, T., Ahn, Y., and Tsukaguchi, H. (2016): Analysis of tourists getting lost at Nara Park, Proceedings of Infrastructure Planning, JSCE, Vol.53, pp.2243-2249.
Yamauchi, S. (2012): Research on the spatial perception and guidance method in underground space, Hosei University Bulletin.
Yokohama Urban Development Bureau (2017): Guideline for public signs of Yokohama City.
Yokota, M., Funahashi, K., Oku, T., Koura, H., and Kida, M. (1997), A Study of Spatial Cognition of Underground Paths: A case study of Osaka Ekimae Diamond Chikagai, Summaries of technical papers of annual meeting, 865-866.
Zacharias, J., Bernhardt, and Montigny, L. (2005), Computer-Simulated Pedestrian Behavior in Shopping Environment, Journal of Urban Planning and Development @ASCE, 2005.
Zacharias, J. (2006), Exploratory spatial behavior in real and virtual environments, Landscape and Urban Planning 78,1–13