Original Article

Toward utilizing mobile phone users' location data in tourism

Masahide Yamamoto (Faculty of Foreign Studies, Nagoya Gakuin University, myama@ngu.ac.jp)

Abstract

This study aims to identify the number of visitors in different periods and their characteristics based on the location data of mobile phone users collected by the mobile phone company. The sites studied in this survey are tourist destinations in Ishikawa Prefecture and Toyama city, including Kanazawa city, which became nationally popular after the Hokuriku Shinkansen opened in 2015. The opening of the Hokuriku Shinkansen brought more visitors to many areas. However, it also led to fewer visitors in some other areas. Its positive effect was remarkable in Kanazawa.

Keywords

mobile phone, location data, tourism, big data, visitor

1. Introduction

In recent years, the so-called "*big data*" have been attracting the attention of companies and researchers worldwide. For example, convenience stores now can quickly predict sales of new products from the enormous amounts of information collected by cash register terminals and thereby optimize their purchases and inventories. Several governments and researchers have implemented such mechanisms in tourism.

In Japan, many people have struggled to promote tourism in their regions to vitalize their local economies. The low-cost carriers have boosted competition in the transportation industry, and domestic transportation costs have declined in several regions. Therefore, tourism is likely to become increasingly important to local economies. Initially, Japan's tourism industry suffered significant volatility in demand depending on the season and day of the week. In addition, there was significant loss of business opportunities because of congestion during the busy season.

To cope with such volatility, tourism facilities, such as inns and hotels, have been trying to level the demand through daily and/or seasonal pricing adjustments. For example, room rates on the days before holidays are usually more expensive than they are on other days. Despite these efforts, the differences between on-season and off-season occupancy rates of rooms and facilities are still large. In other words, attracting customers in the off-season is an important challenge for tourism. Various events have been held to eliminate the seasonal gap.

2. Aim of this study

Numerous events are currently held to attract visitors in Japan. Many events are newly launched. To date, it has been difficult to accurately grasp the extent to which these events attract visitors and the types of people who visit. However, by employing the recently provided Information and Communication Technology (ICT) services, it is possible to verify the number and characteristics of visitors to a particular event.

This study attempts to identify the number of visitors in different periods and their characteristics based on the location data of mobile phone users collected by the mobile phone company. In addition, it also attempts to demonstrate an alternative method to more accurately measure the number of visitors attracted by an event.

3. Previous Studies

Previous tourism marketing research has primarily focused on the ways service promises are made and kept, mostly generating frameworks to improve managerial decisions or providing insights on associations between constructs (Dolnicar and Ring, 2014). Big data have become important in many research areas, such as data mining, machine learning, computational intelligence, information fusion, the semantic Web, and social networks (Bello-Orgaz et al., 2016). To date, several attempts have been made to use large-scale data or mobile phone location data in tourism marketing studies.

3.1 Studies using big data

Most studies dealing with big data in tourism were published after 2010. Fuchs et al. (2014) presented a knowledge infrastructure that has recently been implemented at the leading Swedish mountain tourism destination, Åre. Using a Business Intelligence approach, the *Destination Management Information System* Åre (DMIS-Åre) drives knowledge creation and application as a precondition of organizational learning at tourism destinations.

Xiang et al. (2015) tried to apply big data to tourism marketing. The study aimed to explore and demonstrate the utility of big data analytics to better understand important hospitality issues, namely, the relationship between hotel guest experience and satisfaction. Specifically, the investigators applied a text analytical approach to a large number of consumer reviews extracted from Expedia.com to deconstruct hotel guest experiences and examine the association with satisfaction ratings.

These studies are similar to this study in that they attempted to utilize big data in tourism. However, the research methods and objectives of these studies are different from that of the present study.

3.2 Studies on using mobile phone location data

Studies on using mobile phone location data for tourism sur-

veys can be traced back to 2008. Ahas et al. (2008) introduced the applicability of passive mobile positioning data for studying tourism. They used a database of roaming location (foreign phones) and call activities in network cells: the location, time, random identification, and country of origin of each called phone. Using examples from Estonia, their study described the peculiarities of the data, data gathering, sampling, the handling of the spatial database, and some analytical methods to demonstrate that mobile positioning data have valuable applications for geographic studies. Japan Tourism Agency conducted a similar study using international roaming service in December 2014 (Japan Tourism Agency, 2014).

Since the creative work of Ahas et al. (2008), several studies employing location data have emerged. Liu et al. (2013) investigated the extent to which behavioral routines could reveal the activities being performed at mobile phone call locations captured when users initiate or receive voice calls or messages. Using data collected from the natural mobile phone communication patterns of 80 users over more than a year, they assessed the approach via a set of extensive experiments. Based on the ensemble of models, they achieved prediction accuracy of 69.7 %. The experiment results demonstrated the potential to annotate mobile phone locations based on the integration of data mining techniques with the characteristics of underlying activity-travel behavior.

Alternative related studies have also been conducted. Gao and Liu (2013) attempted to examine the methods used to estimate traffic measures using information from mobile phones, accounting for the fact that each vehicle likely contains more than one phone because of the popularity of mobile phones. Steenbruggen et al. (2015) used mobile phone data to provide new spatio-temporal tools for improving urban planning and reducing inefficiencies in current urban systems. They addressed the applicability of such digital data to develop innovative applications to improve urban management.

As described above, this study surveyed previous related research. Among those studies, the present study could be characterized as similar to Ahas et al. (2008). However, Ahas et al. (2008) is based on results obtained by analyzing data roaming activity. Mobile phone users in the study are obviously limited. Therefore, whether the knowledge gained applies to the average traveler is not clear. In the present study, I analyzed data provided by NTT DoCoMo, Inc., which is the largest mobile phone service provider in Japan. Therefore, their data should be more reliable in that the parameter is quite large.

Another study needs to be mentioned here. The Project Report that Okinawa Prefecture published (2013) is of a study that used location data obtained from a domestic mobile phone network. However, that report is different from the present study in that this study examines the transitions of visitors over two years. Although the report was epoch-making, it did not contain a few experimental elements. Therefore, it will be deficient in the long term.

4. Methods

This study used "*MOBILE KUUKAN TOUKEI*™" (mobile spatial statistics) provided by NTT DoCoMo, Inc. and DoCoMo Insight Marketing, Inc. to collect the location data of mobile phone users in order to count the number of visitors at specific tourist destinations and examine their characteristics.

MOBILE KUUKAN TOUKEI™ is statistical population data created by a mobile phone network. It is possible to estimate the population structure of a region by gender, age, and residence using this service of a particular company.

The sites studied in this survey are tourist destinations in Ishikawa Prefecture and Toyama city, including Kanazawa city, which became nationally popular when the Hokuriku Shinkansen (high-speed railway) opened in 2015. Moreover, the locations and characteristics of the individuals obtained herein are derived through a non-identification process, aggregation processing, and concealment processing. Therefore, it is impossible to identify specific individuals.

The survey areas are presented in Table 1 and Figure 1. A regional mesh code is a code for identifying the regional mesh. It stands for an encoded area that is substantially divided into the same size of a square (mesh) based on the latitude and lon-

Table 1: Survey areas and regional mesh codes

	Survey Areas	Regional Mesh Code	Type of Codes
Kanazawa	Kanazawa Station	5436-6591-2	1/2
	Kenrokuen	5436-6572+5436-6573-1, 5436-6573-3	Tertiary, 1/2
	Higashi Chayagai	5436-6583-3	1/2
Nanao	Wakura Hot Springs	5536-5703	Tertiary
	Nanao Station	5536-4757	Tertiary
Kaga	Yamanaka Hot Springs	5436-2299, 5436-2390	Tertiary
Wajima	Wajima	5636-0772	Tertiary
Toyama	Toyama Station	5537-0147-1	1/2

Note: A regional mesh code is a code for identifying the regional mesh, which is substantially divided into the same size of a square (mesh) based on the latitude and longitude in order to use it for statistics. The length of one side of a primary mesh is about 80 km, and those of secondary and tertiary meshes are about 10 km and 1 km respectively.

Figure 1: Survey areas

gitude in order to use it for statistics. With regard to regional mesh, there are three types of meshes: primary, secondary, and tertiary. The length of one side of a primary mesh is about 80 km, and those of secondary and tertiary meshes are about 10 km and 1 km respectively.

In addition, split regional meshes also exist, which are a more detailed regional division. A half-regional mesh is a tertiary mesh that is divided into two equal pieces in the vertical and horizontal directions. The length of one side is about 500 m. Furthermore, the length of one side of a quarter and 1/8 regional meshes is about 250 m and 125 m respectively.

This study analyzed the location data collected from NTT DoCoMo, Inc. to consider the effect of the opening of the Hokuriku Shinkansen on the survey areas.

5. Results

5.1 Transition in number of visitors in each time period

In general, the number of visitors has been increasing since the *Hokuriku Shinkansen* was launched on May 14, 2015, with the exception of Nanao station. It should be noted that these "visitors" also include the residents living there, because the data cannot exclude them. Of course, I tried to exclude residential areas as much as possible when I specified the regional mesh codes. However, it was rather difficult to do that, because the mesh codes are square-shaped.

5.1.1 Kanazawa city

First, I examined the data of Kanazawa city (see Figure 2 and 3). There were two survey areas in this city: Kanazawa station and Kenrokuen Park.

I then compared the results of two larger cities, Kanazawa and Toyama. Both these cities have a station at which the Hokuriku Shinkansen stops. It should be noted that Kanazawa city and Toyama attracted more visitors in the afternoons (see Figure 8), whereas Wakura and Wajima, which are located on the Noto Peninsula, had more visitors in the mornings (8:00 a.m.–9:00 am).

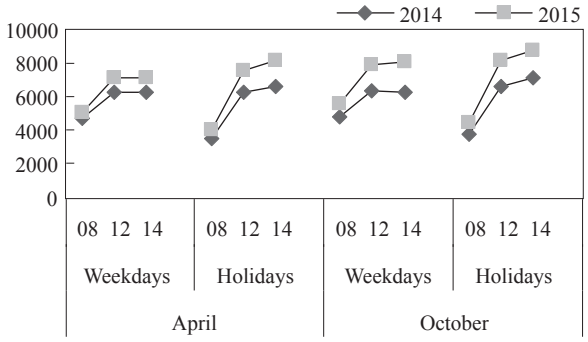

Figure 2: Visitor transitions at Kanazawa station

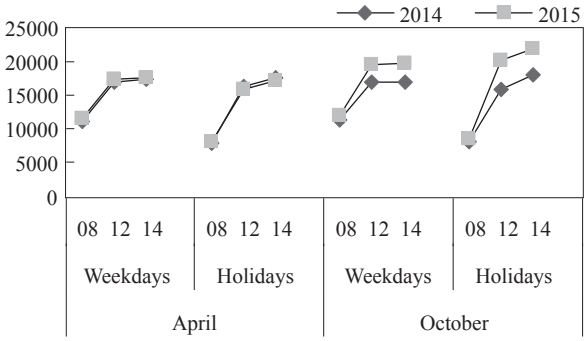

Figure 3: Visitor transitions at Kenrokuen

5.1.2 Wajima and Nanao city

Wajima is famous for its *Asaichi* (morning market). Presumably, visitors enjoy shopping at the Noto Shokusai market near Nanao Station during the daytime, move on to Wakura hot springs later in the day, and then return to the morning market the next day.

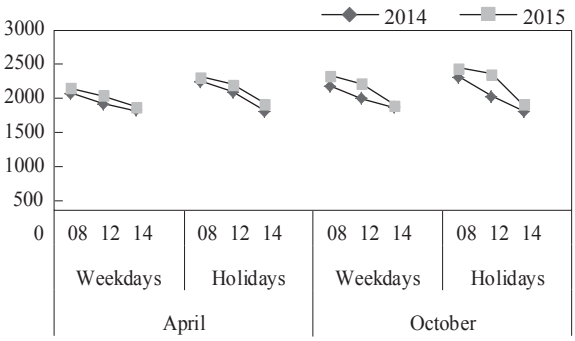

Figure 4: Visitor transitions at Wajima

Wajima is also the setting for a TV drama "Mare," which was broadcasted nationwide from April to September 2015. Visits to Wajima have slightly increased in 2015. The increase in visits could be attributed to this TV drama rather than the opening of the Hokuriku Shinkansen, because Nanao attracted fewer visitors in 2015 than in 2014 in spite of being a better lo-

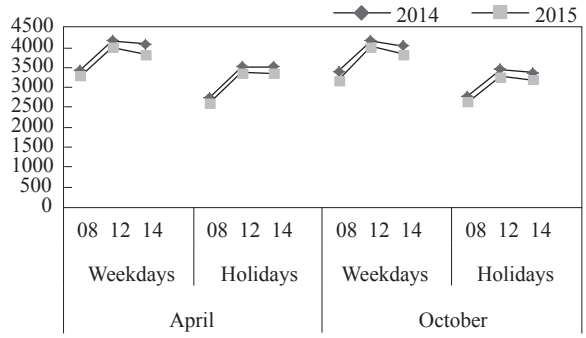

Figure 5: Visitor transitions at Nanao station

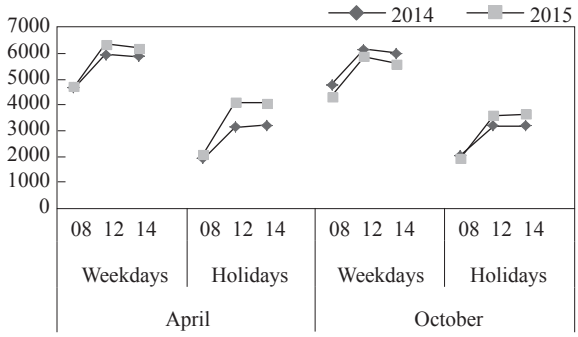

Figure 8: Visitor transitions at Toyama station

cation and nearer to Kanazawa.

5.1.3 Hot springs

Regarding Yamanaka hot springs, there was no significant difference in visits between different periods. Some visitors might have spent more than one night in Yamanaka hot springs.

Although both Wakura and Yamanaka hot springs are a little far from Kanazawa, their results were contrary. The TV drama might have increased the number of tourists in Wakura.

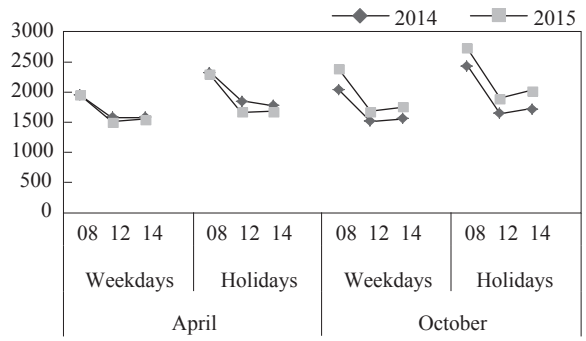

Figure 6: Visitor transitions at Wakura hot springs

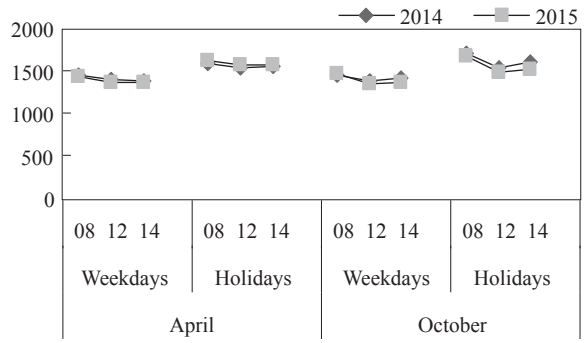

Figure 7: Visitor transitions at Yamanaka hot springs

5.1.4 Toyama city

Visitors to Toyama Station demonstrated approximately the same trend as those visiting Kanazawa Station. However, there were fewer visitors on holidays than on weekdays in Toyama.

5.2 Visitors' characteristics: Gender, age, and residence

5.2.1 Visitors' gender and age

Kanazawa city (particularly Kenrokuen) attracted a variety of visitors, including many female visitors.

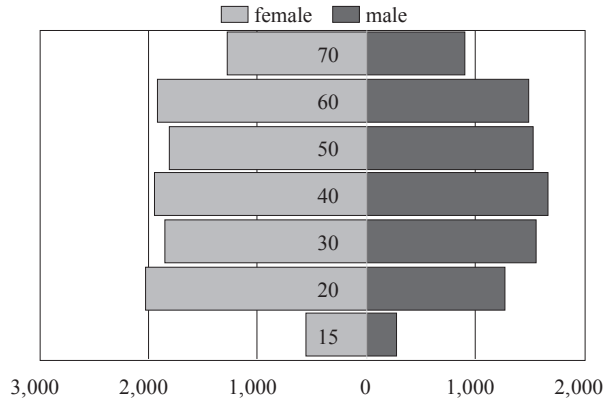

Figure 9: Visitors' gender distribution at Kenrokuen (12:00 a.m. –1:00 p.m. on holidays in October 2015)

On the other hand, many elderly people (over 60 years old) visited the hot springs and the Noto Peninsula. I presume that the local people account for a large proportion of these visitors.

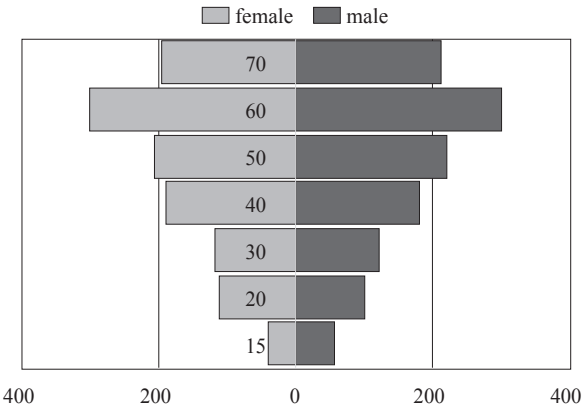

Figure 10: Visitors' gender distribution at Wajima (12:00 a.m.–1:00 p.m. on holidays in October 2015)

5.2.2 A comparison of Kanazawa and Toyama

A comparison of visitors at Kanazawa Station with those at Toyama Station found that Kanazawa Station attracted visitors from a wider area of Japan. Mobile phone users around Kanazawa Station were from 235 municipalities, including Ishikawa Prefecture, whereas those at Toyama Station were from 43 municipalities, including Toyama Prefecture (12:00 a.m.–1:00 p.m. on holidays in October 2015).

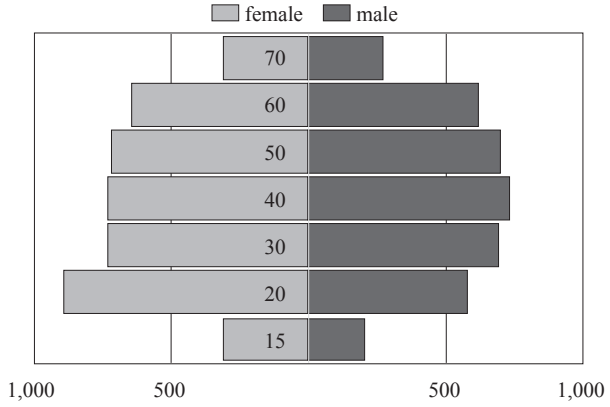

Figure 11: Visitors' gender distribution at Kanazawa station (12:00 a.m.–1:00 p.m. on holidays in October 2015)

Although the Hokuriku Shinkansen stops at both stations, the results suggest that Kanazawa has been more successful so far in attracting visitors (see Table 2 and 3). The number of visitors from Tokyo (gray column) increased in both the cities. Despite the fact that Toyama is nearer to Tokyo than Kanazawa, the latter successfully attracted more visitors from Tokyo.

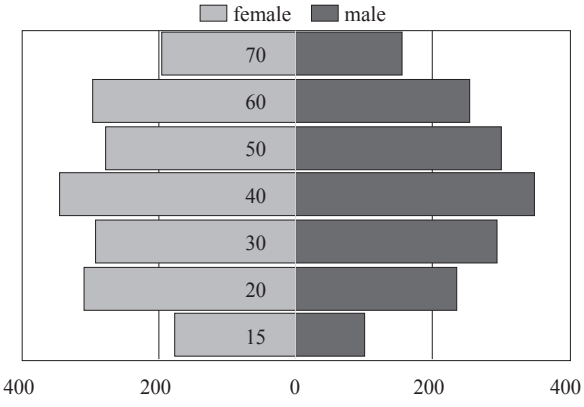

Figure 12: Visitors' gender distribution at Toyama Station (12:00 a.m.–1:00 p.m. on holidays in October 2015)

Regarding the two prefectures, Ishikawa and Toyama, they both do have many wonderful tourist attractions. However, as for the two cities, it seems that Kanazawa is more attractive to tourists.

6. Conclusion and future challenges

This study attempted to identify the number of visitors at two points in time at various places in Japan and their charac-

Table 2: Visitors' residential distribution at Kanazawa Station (except for Ishikawa Prefecture) (12:00 a.m.–1:00 p.m. on holidays in October 2014 and 2015)

	2015	2014
Toyama, Toyama Pref.	131	147
Takaoka, Toyama Pref.	93	94
Fukui, Fukui Pref.	91	80
Myoko, Niigata Pref.	47	n/a
Nanto, Toyama Pref.	34	31
Setagaya-ku, Tokyo	34	17
Imizu, Toyama Pref.	34	42
Oyabe, Toyama Pref.	33	39
Sakai, Fukui Pref.	32	30
Omachi, Nagano Pref.	30	n/a
Ota-ku, Tokyo	28	12
Tsubame, Niigata Pref.	28	n/a
Bunkyo-ku, Tokyo	27	n/a
Nagano, Nagano Pref.	24	n/a
Hiratsuka, Kanagawa Pref.	24	n/a
Sanda, Hyogo Pref.	23	n/a
Tonami, Toyama Pref.	23	26
Suginami-ku, Tokyo	22	16
Nerima-ku, Tokyo	22	10
Tsu, Mie Pref.	22	n/a

Note: Numbers less than ten are represented as "n/a."

Table 3: Visitors' residential distribution at Toyama Station (except for Toyama Prefecture) (12:00 a.m.–1:00 p.m. on holidays in October 2014 and 2015)

	2015	2014
Kanazawa, Ishikawa Pref.	67	60
Fukui, Fukui Pref.	18	13
Setagaya-ku, Tokyo	16	n/a
Suginami-ku, Tokyo	15	n/a
Yamagata, Yamagata Pref.	14	n/a
Takayama, Gifu Pref.	14	n/a
Nakamura-ku, Nagoya, Aichi Pref.	13	n/a
Minami-ku, Niigata, Niigata Pref.	13	n/a
Gifu, Gifu Pref.	12	n/a
Hakusan, Ishikawa Pref.	12	20
Ota-ku, Tokyo	12	n/a
Himeji, Hyogo Pref.	12	n/a
Nagano, Nagano Pref.	12	n/a
Nerima-ku, Tokyo	11	n/a
Shinagawa-ku, Tokyo	11	n/a
Hida City, Gifu Pref.	11	10
Joetsu, Niigata Pref.	11	n/a
Kawaguchi, Saitama Pref.	10	n/a
Adachi-ku, Tokyo	10	n/a
Takatsuki, Osaka	10	n/a

Note: Numbers less than ten are represented as "n/a."

teristics using the location data of mobile phone users collected by the mobile phone company.

As explained above, the opening of the Hokuriku Shinkansen increased the number of visitors to many areas. However, it also led to fewer visitors in some other areas. Its positive effect was remarkable in Kanazawa.

Numerous events have been recently held in Japan to attract visitors. In addition to using the *MOBILE KUUKAN TOUKEI*™, combining it with other ICT services, such as Google Trends, can help better predict the number of visitors at new events. Specifically, by combining the *MOBILE KUUKAN TOUKEI*™ and the transition of the search results for a particular tourist destination, it would be possible to more accurately predict the number of tourists. If we can realize more accurate demand forecasting, it would be possible to optimize the necessary goods and number of non-regular employees in advance. Moreover, understanding consumers' characteristics beforehand could enable us to optimize the services, which could influence customer satisfaction.

Acknowledgements

This work was supported by JSPS KAKENHI Grant Number 15K01970.

References

Ahas, R., Aasa, A., Roose, A., Mark, Ü., and Silm, S. (2008). Evaluating passive mobile positioning data for tourism surveys: An Estonian case study. *Tourism Management*, Vol. 29, No. 3, 469-485.

Bello-Orgaz, G., Jung, J. J., and Camacho, D. (2016). Social big data: Recent achievements and new challenges. *Information Fusion*, Vol. 28, 45-59.

Dolnicar, S. and Ring, A. (2014). Tourism marketing research: Past, present, and future. *Annals of Tourism Research*, Vol. 47, 31.

Fuchs, M., Höpken, W., and Lexhagen, M. (2014). Big data analytics for knowledge generation in tourism destinations: A case from Sweden. *Journal of Destination Marketing & Management*, Vol. 3, No. 4, 198-208.

Gao, H. and Liu, F. (2013). Estimating freeway traffic measures from mobile phone location data. *European Journal of Operational Research*, Vol. 229, No. 1, 252-260.

Japan Tourism Agency (2014). Keitaidenwa kara erareru ichijouhou tou wo katuyousita hounichi gaikokujin doutaichousa houkokusho [Foreign visitors' dynamics research report utilizing mobile phone location information]. Retrieved from http://www.mlit.go.jp/common/001080545.pdf.

Liu, F., Janssens, D., Wets, G., and Cools, M. (2013). Annotating mobile phone location data with activity purposes using machine learning algorithms. *Expert Systems with Applications*, Vol. 40, No. 8, 3299-3311.

Okinawa Prefecture Culture, Sports, and Tourism Department (2013). Senryakuteki repeater souzou jigyou houkokusho [Report on strategic creation of repeaters]. Retrieved from http://www.pref.okinawa.jp/site/bunka-sports/kankoseisaku/kikaku/report/houkokusixyo/documents/07dairokusiyou.pdf.

Steenbruggen, J., Tranos, E., and Nijkamp, P. (2015). Data from mobile phone operators: A tool for smarter cities? *Telecommunications Policy*, Vol. 39, No. 3-4, 335-346.

Xiang, Z., Schwartz, Z., Gerdes Jr., J. H., and Uysal, M. (2015). What can big data and text analytics tell us about hotel guest experience and satisfaction? *International Journal of Hospitality Management*, Vol. 44, 120-129.

(Received March 15, 2016; accepted May 7, 2016)