

A study on forecasting methods of Potential Demands for Local Public Transportation Service by utilizing Big Data
-From perspectives of both Daily life and Tourism Aspects-

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Abstract Big data have been utilized in various fields and these data have a huge potential to formulate public transportation plan more efficiently and effectively. In order to understand the potential and issues of big data, case studies were carried out in local cities in Japan. It was discovered that big data serve as an effective tool for evidence-based approaches and it also can provide the possible ways to explore potential demands with regard to daily life and tourism aspects by evoking customer's potential needs. This study argues that more emphasis should be placed on objective data as a tool in order for local communities to discuss ways for improving local public transportation services.

Key words Big Data, Local Public Transportation Service, Potential Demand, Daily life, Tourism

1. Background and purpose of the study

The evolution of service networks and devices is accelerating the creation, accumulation and distribution of enormous amounts of digital data. Vast amounts of unstructured data in addition to structured data are generated and the use of these data is thought to create new social and economic value through the analysis of data.

Big data is expected to resolve social issues and arouse customer's potential needs as an essential infrastructure for daily life and economic activities. In the field of transportation, revitalizing local public transportation is important policy issues as population aging advances. Furthermore, the development of policies promoting attractiveness for domestic and foreign tourists has also been expected in both urban and local areas. Transport policy fundamental plan decided in Cabinet meeting (February 2015) mentioned that the progress of service-based economy contributes to more effective formulation of transportation plan. In accordance with technological innovation, the field of transportation has witnessed an upsurge of potentials of big data

regarding strengthening transportation service through creating and combining objective data.

Big data are thought to have an enormous potential to formulate public transportation plan more efficiently and effectively. In order to understand the potential and issues of big data, case studies were carried out in local cities in Japan by the Ministry of Land, Infrastructure, Transport and Tourism (MLIT). This study examined the strength and issues of big data and explored the possibility for setting up the framework to provide low-cost, convenient method for grasping population movements and potential needs for public transportation.

2. Literature regarding big data for local transportation plan

The previous researches of big data regarding public transportation are mainly divided into three categories. These are; 1) researches which aim to estimate travel patterns, including demands between stations, means of transportation used and OD patterns; 2) analysis of applicability by kinds of big data such as smart card data, GPS, sensitive cameras and sensors; 3) analysis of the applicability for service improvement and transportation plans. In regards to third category, Yamazaki, T. et al (2014) investigated the effectiveness of smartphone application software in local cities and demonstrated the availability of big data as a monitoring method of urban activities. Morita, T. et al (2016) analyzed the behaviors of city tram passengers by utilizing smart card data and studied the applicability of formulating actual diagram. Matsumoto, H. et al (2015) examined the methods of estimating potential demands utilizing smart card. This research specified and visualized the areas with low bus passenger numbers, but this analysis could not grasp the behaviors of people who don't use buses. Regarding the investigation of the actual movements of inbound tourists, guideline was released from Tourism Agency in 2017 and it offers the methodology to use ICT data (mobile station data, SNS and GPS data) based on the analysis from comparative perspectives about the strength of each ICT data.

As noted above, previous researches relating to the evaluation methods of potential demands are limited to only a few cases or specific viewpoints. Moreover, these studies have focused on technical aspects and have not yet covered the collaborative viewpoints which relating entities look at common targets and directions for the future. This study reviewed the current status of big data and the relating issues based on the survey of MLIT (2014, 2015) which author joined as a director of MLIT. It

examined the possibility of combining data and the applicability for actual cases, considering the purpose and roles of local transportation plan. It also analyzed the methodology of estimating potential demands of both daily life and tourism aspects, taking into account personal data protection rules and technological issues.

3. Study framework and methodology

3.1 Identification of strength and issues of big data

MLIT study is based on interview and case study surveys. Interview surveys were undertaken during Nov 2013 to Jan 2014 with 12 local governments and 6 public transportation service operators regarding the issues of present survey methods of local transportation plan and requirements for big data.

Interviews with local government were conducted in Asahikawa city, Hirosaki city, Niigata city, Hitachi city, Tsukuba city, Kashiwa city, Fujisawa city, Fuji city, Toyama city, Kanazawa city, Kurashiki city, Miyakonozyo city and surveys for operators were conducted for Fukushima Kotu, Ibaragi Kotu, Iwate Kenpoku Jidousya, Kanto Jidousya, Aizu Noriai Jidousya, Tokyu bus company. The issues identified are: 1) there remain several issues to acquire data sufficiently regarding passenger movements according to the following factors: purpose, routes, transportation modes as well as time-series data of time/day/season, 2) it requires a lot of time, cost and staff to implement a large scale survey, 3) OD survey has a limitation in which it is difficult to gather information about how often passengers transfer as well as their requirements, 4) it is challenging to obtain categorized data sufficiently since elderly people receive welfare support and don't need to use ordinary IC card, for example.

It was also discovered that objective evidence for policy planning based on objective data has become increasingly required such as in depth traffic movement data to solve local issues. The results have revealed that data handling guidelines which include personal data protection, data processing/analysis are highly demanded by local entities.

3.2 Issues regarding Personal Data Protection

The current Act on the Protection of Personal Information in Japan defines personal information that should be protected as any personally identifiable information. The degree of privacy is thought to vary depending on the circumstances and situations where the personal data are used. Taking into account the expansion of big data usage and growing awareness of privacy, the revised bill was examined in the IT strategic headquarters and the law went into effect in May 2017. The new concepts introduced

■ Table – 1 Basic Frameworks of Case Studies	
① Estimates of population movements and situation of transportation services in case study area	
Combination of Static Data	Estimates of population movements in case study area (Visualization of OD and public facilities distribution)
	Estimates of major traffic routes by the data of population distribution (National Census)、workplace distribution (Economic Census)、commercial/medical/public facilities distribution
	Estimates of transportation services by setting up bus stop sphere (area with a 300 m radius from bus stop)
	Utilizing the position information of bus routes and bus stop and estimates of the number of population of each bus stop sphere
Newly used Big Data (Dynamic Data)	Estimates of traffic inflow/outflow by time zone in bus stop sphere
	Utilizing the population movement estimates of mobile station information by time periods (commuting hours (3am–9am), 9am–12am, 12am–15pm) and age groups (people older than 65, etc)
② Evaluation of transportation service provision and estimates of potential demands	
Combination of Static Data	Estimates and evaluation by the percentage of usage of public transportation service in each bus stop sphere
	Calculated components; population in bus stop sphere, bus passengers in each bus stop
Newly used Big Data (Dynamic Data)	Estimates of bus passengers and potential demands (population of bus stop sphere – bus passengers) by time periods
	Calculated components; population of bus stop sphere, bus passengers (data of bus operators) by each bus stop and time periods
③ Estimates of substantial potential demands and evaluation of service improvement measures	
Static Data	Estimates by questionnaire survey of conventional type
Newly used Big Data	Estimates through ICT questionnaire survey utilizing SNS (Facebook)、Web site and Tablet. Local people are asked regarding conditions of improvements of bus services from cars to buses

are; 1) it is possible to use data without personal agreement when data is processed in which the distinguishability of data is sufficiently reduced; 2) the precise definition of personal data will be clearly set up; 3) the third party conference will be established in order to ensure appropriate procurement, administration and operation of revised system.

In utilizing data, the risk of privacy should be carefully considered and it is necessary to reduce these risks by incorporating adequate measures into the analysis scheme.

4. Research Framework

In order to grasp the potentials and issues of big data, case studies were carried out in Tsukuba city area (Ibaragi Prefecture) and Fukushima area (Fukushima

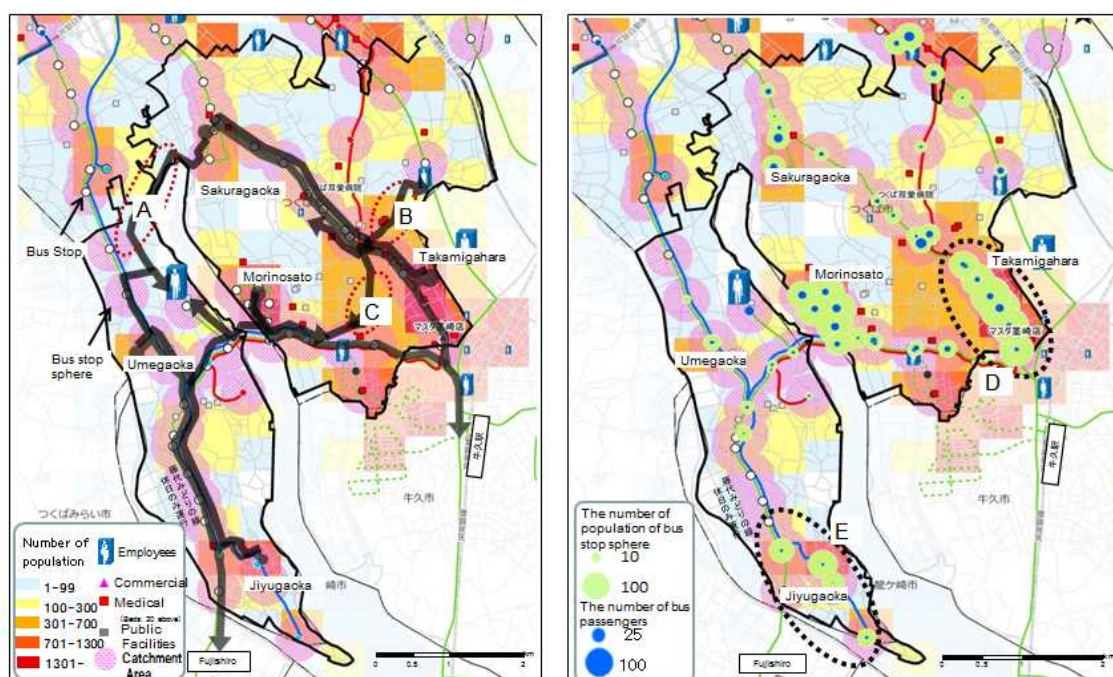
■ Table—2 Strengths and issues by types of ICT questionnaire			
Types of Data	1) Survey utilising SNS(Facebook)	2) Web site questionnaire	3) Survey utilising Tablet
Survey methods	Survey information was provided by SNS with cooperation of local entities.	Registered members of research company answered.	Respondents were directly asked by survey experts.
Strength of Data Analysis	<ul style="list-style-type: none"> • Wide range of users' needs can be acquired easily including needs of potential tourists. • Realtime reaction information can be acquired when events or traffic congestion occurred. • Analysis from wider viewpoints can be made through setting up various keywords in Facebook. 	<ul style="list-style-type: none"> • A wide range of users' needs can be acquired easily including needs of potential tourists (In case studies, respondents are limited to only registered members of Web research company) • Efficient answers could be expected. 	<ul style="list-style-type: none"> • The purposes and backgrounds of survey are explained carefully when survey is conducted. Therefore, it is possible to get answers efficiently (In case studies, survey was conducted in local community meeting facilities for two days and sufficient number of samples were obtained).
Issues of Data Handling	<ul style="list-style-type: none"> • Respondents are limited only to SNS users and answers can be biased by sex or age groups. Answers are on a voluntary basis, so reliability is influenced by specific factors and they may include answers which are different from actual movements • In handling data, it is necessary to consider personal data protection rules. 	<ul style="list-style-type: none"> • Answers are on a voluntary basis, so reliability is influenced by various factors and answers can be biased by sex or age groups. • There is risk that sufficient number of samples are not acquired and suitable analysis can not implemented. • In handling data, it is necessary to consider personal data protection rules. 	<ul style="list-style-type: none"> • In order to obtain reliable data, it needs understanding and cooperation of local people in addition to budget and human resources. • Efforts needs to be made to ensure the participation of as many tourists as possible, including those with little interest in questionnaire
Users' evaluation	<ul style="list-style-type: none"> • Young generations responded that ICT questionnaire methods are easy to answer and understand. The percentages of answers which ICT surveys are easy to answer were 52% in Tsukuba, 75% in Fukushima respectively. 		

Prefecture) in Sep 2014 – March 2015 (Table-1).

In case studies, population movement estimates using mobile station information and ICT questionnaire were utilized in two different aspects; 1) visualization through combination of both static and dynamic data; and 2) estimates of potential needs and demands. In case study of Tsukuba city area, the area of population aging was selected and targets of research were established to improve local bus services through the effective use of combined data. In case study of Fukushima area where a lot of hot spring spots are located in the suburb of Fukushima city, it was designed to analyze the possibility for both the development of new tourism activities and the improvement of local bus services within the city area.

4.1 Population movement estimates using mobile station information

Mobile stations are the places where these stations catch radio waves and



■ Fig-1 Visualization of Static Data Combination ① (Major population movements and bus routes, public facilities)
Quoted from Nakano (2015), translated by author

■ Fig-2 Visualization of Static Data Combination ② (Distribution of population and bus passengers)
Quoted from Nakano (2015), translated by author

■ Table-3 Potential demands by time zones in Kukizaki area

	1) 3 am - 9 am	2) 9 am - 12 am	3) 12 am - 3 pm
Bus passengers (a)	363	124	83
Actual population movements of bus stop sphere (b)	2676	2001	1120
Ratio of utilization (a/b)	13.60%	6.20%	7.40%
Potential demands (b-a)	2313	1877	1037

communicate with mobile terminal devices. By collecting and utilizing positional information, information of population at a certain time can be obtained. In case studies, “Mobile spatial statistics” which are managed by NTT docomo were utilized. This system has approximately 70 million contracted users and it covers almost 70% of population in Japan. Thereby both inflow and outflow of population in a specific time zone can be obtained and actual population movements can be estimated. By utilizing characteristic of information, for example, population movements during commuting hours (3 am -9 am) were estimated by the differences of these populations when the population at 3 am is regarded as the population at night and the population at 9 am is regarded as the population at the final time of commuting.

4.2 Efficient questionnaire utilizing ICT

Questionnaire was implemented by three categories in order to collect answers

more efficiently and effectively. These are; 1) Survey utilizing SNS (Facebook); 2) Web site questionnaire; 3) Survey utilizing Tablet (Table-2). Regarding first type survey, users tend to be limited to SNS users. The announcement was made through face-book in cooperation with Tsukuba city government and Tsuchiyu hot spring tourism conference in order to get answers from wide age groups from young generations to the elderly. In regards to second type survey, answers from various age groups can be expected even though sample size is limited to

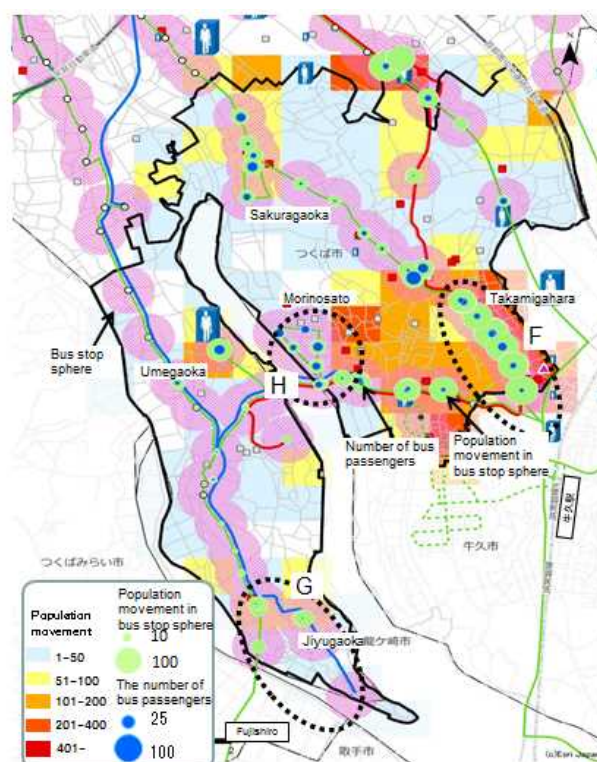


Fig-3 Visualization of both Static and Dynamic Data Combination (Population movement in bus stop sphere area and bus passengers(3am-9am)) Quoted from Nakano (2015), translated by author

registered members of a research company. With respect to third type survey, answers from elderly people can be expected who will not normally be willing to answer questionnaire because these surveys are implemented by directly enquiring residents in bus stop or public facilities, local community meeting in cooperation with Tsukuba city government. Comparative advantages and issues of these surveys are shown in Table-2.

5. Case Study Survey

The processes of case study surveys are shown in Table-1. Population movements, the distribution of public transportation service, substantial traffic flows were visualized and possible potential demands were estimated.

5.1 Static analysis of the relationship between population movement and bus service distribution

Local data such as distributions of population, workplaces and public facilities, public transportation service data including road map and bus routes were combined by geographical information system (GIS). Thereby the big pictures of traffic flows can be grasped (Table-1 ①).

Based on this information, the location of bus stops and bus routes, bus stop

■ Table-4 ICT questionnaire survey in Tsukuba city and Fukushima city area			
Types of Data	1) Survey utilising SNS(Facebook)	2) Web site questionnaire	3) Survey utilising Tablet
Tsukuba city	3rd Feb – 28th Feb in 2015 Facebook of Tsukuba City	2nd Feb – 8th Feb in 2015 Registered members of Web research company who live in Kukizaki area	31st Jan, 3rd Feb in 2015 9 bus terminals, 2 facilities in Tsukuba City 31st Jan in 2015 Interviews in district committee
Fukushima city area	21st Jan – 20th Feb in 2015 Facebook of Destination Promotion Committee of Tutiya hot spring area	26th Jan – 1st Feb in 2015 Registered members of Web research company who have visited Tutiya hot spring area for sightseeing for the past five years	24th Jan, 7th Feb in 2015 Interviews in Hotel, Tourism committee, bus stop

spheres (area within the radius of 300m from bus stop) were added and it was evaluated how the bus service are offered in survey area. Thereby the area where bus routes are not sufficiently delivered compared with the number of population were identified (A~C area in Fig 1).

5.2 Static analysis of the population in bus stop sphere and bus passengers

Based on the information of bus service distribution, the population in bus stop spheres and bus passengers were added (Table-1 ②, Fig-2). As a result, the number of bus passengers is relatively low compared to the number of people of bus stop sphere were identified (D, E area in Fig 2). Through the analysis of comparative study between areas, the area where the number of bus passengers is relatively low can be extracted and the factors of these situations can be investigated in order to improve public transportation service.

5.3 Analysis using mobile station statistics and combining static data and dynamic data

Population movement estimates using mobile phone station information enable us to calculate substantial inflow and outflow of population within certain period of times by 1 km mesh. Both the population of bus stop sphere and bus passengers in a specific time zone was calculated (Table-1 ②, Fig-3). Thereby the areas where the levels of bus passengers are relatively low were extracted as compared to the population of bus stop sphere (F, G area in Fig-3). In comparison with the analysis mentioned in 5.1, the substantial population movements in a specific time zone were estimated. When potential demands are defined that local people who don't use bus at present, these amounts were estimated by the differences of substantial population movements minus

bus passengers in a certain time zone. Considering the volumes of substantial population movements and the number of bus passengers in each bus stop, the strategies of public transportation service can be analyzed. These data are useful to formulate the effective schedule taking into account the changes of the number of passengers based on the time/day/week/season, and also the possibilities of strategic demands development.

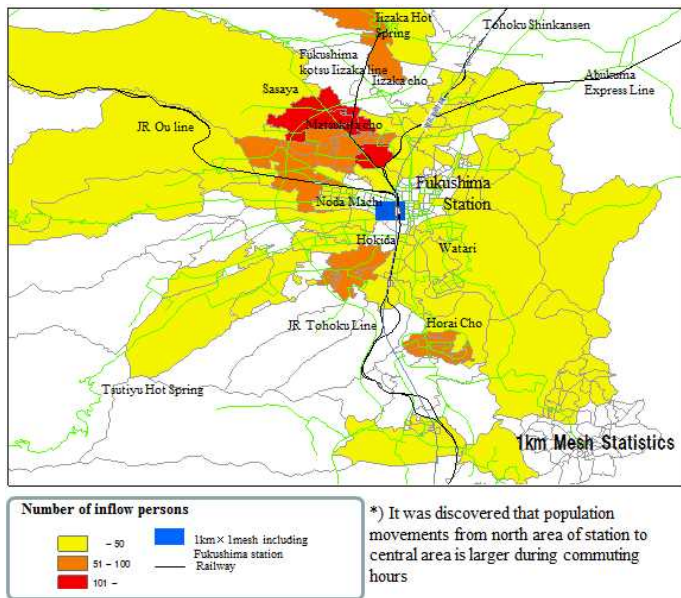
It is also confirmed that population movements data which cannot be kept anonymous must be confidential and therefore is unavailable due to privacy regulations. The disparities in the number of passengers unavailable were identified by contrasting the differences of map meshes.

5.4 Finding out the potential needs and demands by using ICT questionnaire

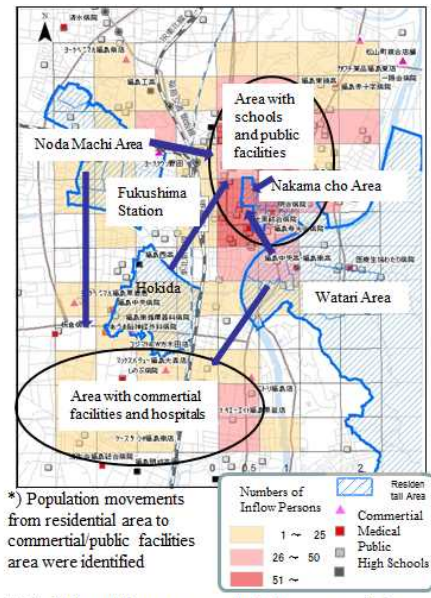
In order to forecast potential demands for local bus service, ICT questionnaire was implemented and requirements for the improvement of bus services were discovered through the effective use of ICT devices (Table-2, 4). Questionnaire was designed in the form of multiple choice questions and this method enables customers to answer easily (Table-5). As a result, major factors of conditions for users to change to using buses are discovered as follows: more detailed information on bus services; more convenient bus timetables; more punctual service through relieving traffic congestion;

■ Table-5 Designs of Questionnaire survey of potential demands for buses

Case Study Area		Tsukuba City Area	Fukushima Area
Purpose of study		Possible shift to bus from other transportation methods through the improvements of bus service	Possible increase in bus passengers for sightseeing through promotion of tourism activities
Items in Questionnaire	1) Respondents personal description	Place of residence, sex, age, presence or absence of driver's licence. These items were used to understand the trends and features of respondents through cross tabulation analysis.	
	2) Actual situation of journey	Purposes of going out, destinations, frequency, period of time, transportation mode	Number of days for stay, travel purpose, transportation methods, sightseeing spots they visited and want to visit for the future
	3) Actual situations of the use of public transportation	Actual situations of bus usage and bus routes, accessibility to bus service, requirements of customers to change transportation methods	Awareness of local buses or bus package tours, conditions of customers for bus services or bus package tours
	4) Actual situations of the use of specific transportation methods	Conditions of customers for the use of demand taxis, service items of demand taxi customers wants to improve	
	5) Requirements to increase the use of public transportation	Extra space for customers to give additional feedback and comments	
	6) ICT questionnaire feedback	Opinions about ICT questionnaire methods, frequency of ICT device usage	
	7) Sources of finding about services	Convenience of obtaining information source was evaluated from comparative viewpoints of ICT device usage	



■ Fig-4 Population movements which move to Fukushima station from surrounding areas in 3am to 9 am, Quoted from Nakano (2015), translated by author



■ Fig-5 Population movements between specific areas surrounding Fukushima station in 3 am to 9 am, Quoted from Nakano (2015), translated by author

and changes of bus routes in order to reach destinations quicker. In ICT questionnaire analysis, potential demands were estimated as substantial demands in case that certain service factors would be improved (Table-1③, Table-6). Potential demands according to time zones in Kukizaki area were estimated by the differences between actual population movements of bus stop sphere and the number of bus passengers in each time zone (Table-1 ②, Table-4).

6. The evaluation of case studies

6.1 Visualization of data combination

Data such as the spatial distribution of the population, workplaces and public facilities, the situation of public transportation services including bus routes and the location of bus stops were combined and visualized in case studies.

Population movements could be monitored on an area to area basis rather than specific point to point basis. In this analysis, close relationships between regions where the population movement is large, are identified on a quantitative basis, which has treated only qualitatively (Fig-4). These regional connections were first discovered by dynamic data of mobile spatial statistics and these demonstrate the potential to develop new bus routes (Fig-5). Through the analysis of comparative studies between areas, locations where the number of bus passengers is relatively low were discovered and detailed analysis regarding passenger behavior can be implemented.

The results of survey were examined by local government and bus operators in case study areas. Their feedbacks inferred that objective data may be useful to find ways

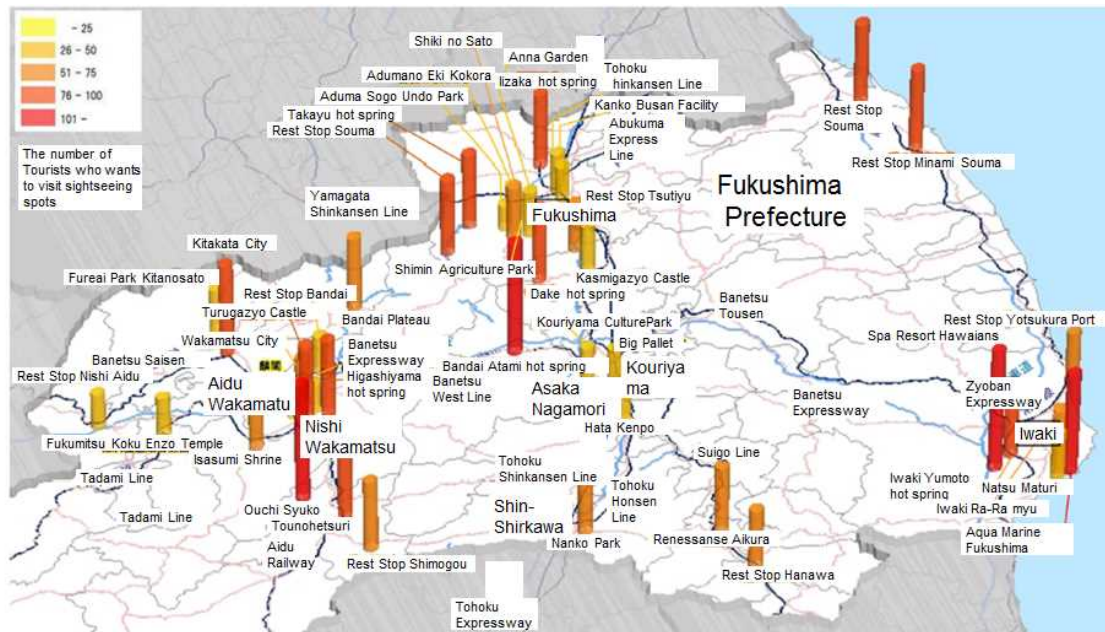
Case Study Area	Tsukuba City Area	Fukushima Area
Purpose of study	Possible shift to bus from other transportation methods through the improvement of bus services	Possible increase in bus service for sightseeing through promotion of tourism activities
Respondents of questionnaire	293 people	411 people
Actual bus users	Bus users 41 people (14%) Non bus users 252 people (86%)	Bus users who know specific package tour 38 people (9%) Non bus users 373 people (91%)
Percentage of potential users	60.90%	91.70%
Conditions of shifts to bus usage	<ul style="list-style-type: none"> • Direct access to bus more easily • Usage in earlier or later hours • Shorter time to destination • Punctuality in accordance with time schedule • Convenience in transfer to railway 	<ul style="list-style-type: none"> • Easier booking for package tour • Discount scheme for the use of families or friends • More convenient time schedule for tourists • Benefits when transportation and hotel accommodation is bounded • Benefits when we use with elderly people or children
Estimates of possible potential users per day	1400 people (2313 people (Non bus users in bus stop sphere) * 60.9%)	Weekdays 736 people/day (803 people * 91.7%) Weekends 399 people/day (435 people * 91.7%) (The number of tourists for weekdays (803 people)/weekends (435 people) are estimated from tourism statistics)

to reach a consensus and improve the communication flow among local communities. Local government mentioned that this survey method is useful because traffic movements in the scope area can be observed as a whole. Furthermore in several cases, multiple measures of service improvement such as finding the optimum bus routes and schedules can be analyzed. As a result, the effectiveness of innovative business models of bus system such as hub & spoke system can be created.

6.2 ICT-based Questionnaire

52% in Tsukuba city area and 75% in Fukushima area of respondents found no major issues to answer the ICT survey. However, 30% in Tsukuba city area and 16% in Fukushima area of respondents experienced difficulties when answering the questionnaire. The majority of those who experienced difficulties were in the age group of over 65. The positive feedback was mainly due to the instruction being clear and its user-friendliness.

Survey have shown that it is possible to estimate potential demands by conducting three types of ICT questionnaire. Answers can be acquired more easily as surveys are carried out in local community meetings and surveyors are able to offer



■ Fig-6 Sightseeing Destinations where tourists wants to visit in Fukushima next time according to the results of questionnaire Quoted from MLIT (2015), Translated by author

concise explanation of the surveys.

It was also discovered that questionnaire utilizing ICT is an efficient way as it saves time and is cost efficient, and therefore the higher response rates may be expected. However, there is a possibility that the potential demands estimated are larger than the actual ones because respondents tend to answer questions on a wish basis. Therefore, answer sheets should be carefully designed. For example, choices should infer the image of actual service changes such as bus routes, bus frequency and changes of fares.

7. Summary of Case Studies

Case studies have shown that big data become useful tools for evidence-based approach to formulate public transportation service plans and explore potential demands for public transportation. ICT questionnaire is more time efficient and convenient than conventional survey methods. Objective data formulated by big data will help improve the services and also determine which services should be offered. It will also be helpful to show the benefits of the bus service to the local community and reach a consensus.

The issues and limits relating to the accuracy of processed data and the applicable areas should be recognized and consideration of both technological and personal data protection issues must be given. In order to apply objective data more effectively, the manuals should be prepared for local governments and transportation operators while taking into consideration the balance between data usage and personal data protection. It

is recommended that these manuals include how to design and analyze questionnaire in order to estimate potential demands effectively.

Fig-4 shows the findings obtained from the survey in Fukushima area and these results will help create a round trip tour that would benefit among local businesses, bus operators and customers.

8. Potentials of Big Data for local public transportation service

When examining current trends of local transportation markets in Japan, it is identified that some local transportation companies have succeeded in constructing new business models. Regarding the advantages for public transportation operators and local governments, objective data are useful for the more efficient management/operations, taken into account the features of customers' behaviors. In addition, from the middle/long term viewpoints, dynamic data of population movements are vital to formulate effective local economic and land-use plan as well as transportation aspects. Constructing win-win frameworks among local residents, local government and operators are expected from now on.

8.1 Strength of Big Data

It is a burgeoning field in the past few years that big data will create a strategic value for regional redevelopment through revitalizing public transportation. Constructing a unified database is vital for formulating local transportation plans because the information of each content significant for users is displayed intelligibly and vital points can be followed from an objective and comparative viewpoint. As mobile phones are becoming user-friendly and convenient, the number of users will also continuously increase. As a result, these platforms enable us to analyze peoples' behavior more effectively in both planning and operational aspects. Awareness for the strengths of big data among local governments and operators are expected to enhance in accordance with the advancement of technology. The following issues are important to intensify the strength of big data.

- 1) Demands for public transportation service can be estimated by dynamic data objectively in response to a collective outcome of social benefits. Mobile devices are widely used in Asian developing countries and these data can be used strategically to design pictures towards desirable local transportation patterns.
- 2) Methodologies of analysis should be developed in consideration of both daily and non-daily demands including tourism activities. This is because public transportation services can be maintained and improved only through well-balanced operations of both

demands under the volatile conditions of local economies.

3) Big data can become a useful tool for relating parties to discuss issues in a logical way and reach a consensus on local policy issues. It is expected to construct local cooperative platform regarding the optimum use of public transportation service and local resources.

8.2 Issues of Big Data

Effective and strategic use of big data is in a process of technological and institutional developments. When static and dynamic data are used, unified database should be prepared in order to establish customer-oriented platform according to various types of users. Taking into account the following issues and limits, future directions of big data should be considered through the collaborative efforts of relating entities according to the types of projects.

- 1) The investigation framework should be carefully designed with regard to the strengths and issues of big data. Social measures should be constructed on a step by step basis with the cooperation of local entities. These processes should be designed to fully demonstrate the value of big data by attracting local attention to the actual situations and desirable directions.
- 2) The types of data should be selected based on whether the obtained data was authentic and meaningful considering the purpose of surveys and social measures. Critical factors will be effectively singled out and research will require pursuing a course of selection and concentration in terms of survey resources of time and labor.
- 3) Certain conditions must be carefully considered such as the detailed passenger movement with respect to personal data protection rules. This includes the risks of identifying individuals, for example, data of behaviors of specific age groups are unavailable due to personal data protection principles.

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