Development of Bus Location System with Smartphone and Effect of Providing Regional Information added on Bus Information

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Abstract: In Japan, many local governments have recently introduced a "Community-bus" for purposes of ensuring mobility for residents, reducing the areas without public transportation services and so on. Although the bus-location system is demanded for raising the level of bus service, it is practically difficult for a local government to introduce the bus location system because of the expense to introduce and even operate the system continuously. We therefore develop a simple bus location system with a smartphone and construct a web page to provide regional information with real-time bus information. Then, we grasp the effects of providing the bus and regional information on passengers' consciousness by a questionnaire. As a result, it is found that the regional information added on the bus information obviously effects the motivation of going out. Moreover, there is also possibility of providing regional information with real-time bus information to promote bus usage.

Keywords: Real-time Information, Regional Information, Bus Location, Community-bus, Smartphone, Google Map

1. INTRODUCTION

In Japan, the number of bus passengers was over 10 billion in the 1970's and then has been gradually decreasing to fewer than 5 billion in the 2010's' (The Nihon Bus Association. 2012). The decrease is considered due, in part, to a progress of motorization. Private bus companies therefore had to limit their bus services to the routes which are profitable. On the other hand, due to an aged society in Japan, those who can't drive a car by themselves are increasing year by year. Many local governments have therefore introduced a "Community-bus" for purposes of ensuring mobility for residents, reducing the areas without public transportation services and so on. The community-bus service is provided as a part of residential services so that the service is financially supported by the local government. The community-bus therefore runs throughout in the local area in order to ensure the mobility for all residents equally. Consequently, it becomes very complicated for passengers to remember the bus routes and the timetable so that residents seem to avoid using the community-bus. Delay of bus arrival caused by traffic congestion may also lead to reduction of bus passengers.

Some bus companies therefore provide real-time bus information so as to improve the bus services and raise the customer satisfaction. Passengers are able to obtain the information on the bus route, the timetable and also the location where the bus is now running.

Necessity of real-time bus information has been revealed (Lei and Piyushimita. 2012; Kari et al. 2011; Stuart and Daniel. 2001). Moreover, several researchers have addressed studies by using data from a location information system. Bo et al. (2010) and Bin et al. (2011) predict the bus arrival time at the bus stop for bus location system, and Steven et al. (2002) develop and apply a model to predict bus arrival time using automatic vehicle location (AVL) data. However, there are few analyses that relate to the needs focused on buses like a community-bus in Japan.

Although the bus-location system is demanded for raising the level of bus service and also using as management measures of bus operation, it is practically difficult for a local government to introduce the bus location system because of the expense to introduce and even operate the system continuously. An inexpensive bus location system is desired by a local government and also passengers of the community-bus.

The common bus location system provides only bus information. However, it is important for a community-bus to provide regional information as well as bus information because a community-bus stops at not only principal stations but also the local groceries, hospitals, welfare facilities and so on in the city. Furthermore, if a local government introduces a bus location system, it is expected that the system has an effect on regional vitalization rather than only providing bus information.

Therefore, in order to develop a bus location system which is suitable for a community-bus, we first grasp needs of community-bus passengers for bus information contents (e.g. timetable, route map and real-time bus information) by a questionnaire survey. Based on the survey results of passengers' needs, we develop a bus location system using an android smartphone available commercially which is inexpensive for introducing and also operating. Through the operational test of the developed bus location system on real buses, we verify the feasibility of the system and improve it more convenient according to requirements of operators and passengers. Then, we make web pages to provide the bus information using the developed bus location system. In the web pages, we provide not only bus information but also regional information. Finally, we clarify the effects of providing the regional information added on the bus information on intention to use a bus and also regional vitalization based on results of another questionnaire survey.

2. NEEDS FOR REAL-TIME BUS INFORMATION

We distributed questionnaires to passengers on community-buses operated in Nisshin City, Japan at November 16 and 17, 2011. Since the number of passengers of this community-bus is more than those of almost other community-buses, we select this community-bus for the survey and can obtain many samples. This survey focuses on communication circumstance of the community-bus passenger over the Internet and needs for real-time bus information.

2.1 Outline of "Kururin-bus" Operated in Nisshin City, Japan

Nisshin City is a city located in the central part of Aichi prefecture in Japan. The area of the city is 34.9 km^2. The population of the city is about 82,700 as it is a commuter town to Nagoya city of more than 2 million populations. The ratio of the elderly is about 17 % which is lower than the ratio of whole Japan.

"Kururin-bus" is a community-bus operated by Nisshin City for supporting mobility of residents from April, 1996 with the purpose of accessing which has bus stops near the stations, the city hall, hospitals, groceries, welfare facilities, the library and also residential in the city

Table 1. Ratio of respondent attribute

male over 64	male under 65	female over 64	female under 65
12.8%	15.6%	36.7%	35.0%

Table 2. Ratio of devices to use Internet at home

PC	Smartphone	Tablet	Several	No use
48.5%	2.2%	0.5%	7.0%	41.8%

Table 3. Necessity for getting bus information by place to obtain it

		Necessary	Rather necessary	Average	Rather unnecessary	Unnecessary
Timetable	Home	58.8%	17.0%	11.4%	6.4%	6.4%
	Outside	50.2%	16.9%	16.3%	7.2%	9.4%
Route map	Home	42.6%	16.8%	19.8%	11.1%	9.6%
	Outside	32.1%	17.2%	23.0%	13.9%	13.9%
Route guidance to destination	Home	44.9%	18.9%	21.3%	7.2%	7.8%
	Outside	36.3%	17.0%	27.0%	8.7%	11.1%
Information on bus delays	Home	34.9%	15.7%	23.2%	12.0%	14.2%
	Outside	42.2%	22.8%	17.8%	7.9%	9.2%
Information whether bus leaves upper stop	Home	18.8%	11.2%	29.1%	18.8%	22.1%
	Outside	24.7%	16.7%	28.1%	13.4%	17.1%
Estimated arrival time at bus stop	Home	21.7%	15.1%	28.6%	14.8%	19.9%
	Outside	17.0%	11.3%	25.0%	19.7%	27.0%
Information whether bus leaves this bus stop	Home	18.7%	11.0%	29.1%	15.0%	26.1%
	Outside	24.6%	15.5%	27.3%	12.8%	19.9%
Current location of bus	Home	14.0%	10.6%	32.6%	16.1%	26.7%
	Outside	19.0%	14.6%	30.6%	16.3%	19.4%

for the elderly and also handicapped person. Kururin-bus has 7 routes (North, South, East, West, Central, Southwest and Southeast routes) which depart from the city hall simultaneously and Central Liner which connects stations located at the north and the south of the city. Each route is operated 11 times between 6:50 and 20:25. The fares are 100 yen for routes except Central Liner and 200 yen for Central Liner. The elderly pass is sold at 2,000 yen a month for the elderly of 65 years old and over. At that time of the survey, there is no service on real-time bus information.

2.2 Result of Questionnaire Survey

The questionnaire survey was carried out for all passengers on Kururin-buses. The number of distribution was 945 and 406 answers were collected. Table 1 shows the respondents' attributes. Aged male/female is defined as 65 years old and over.

Table 2 shows the ratio of devices by which the passengers use the Internet at home. The ratio of the passengers using the Internet at home by any devices is 58%. This means that more than half of the passengers can obtain bus information through the Internet at home.

Table 3 shows the necessity for obtaining bus information at home and outside home respectively. At home, "Route guidance to destination" is necessary more than 63%. "Information on bus delays" is necessary by 64% passengers outside home. These figures show that static bus information such as a timetable and a route map is more needed at

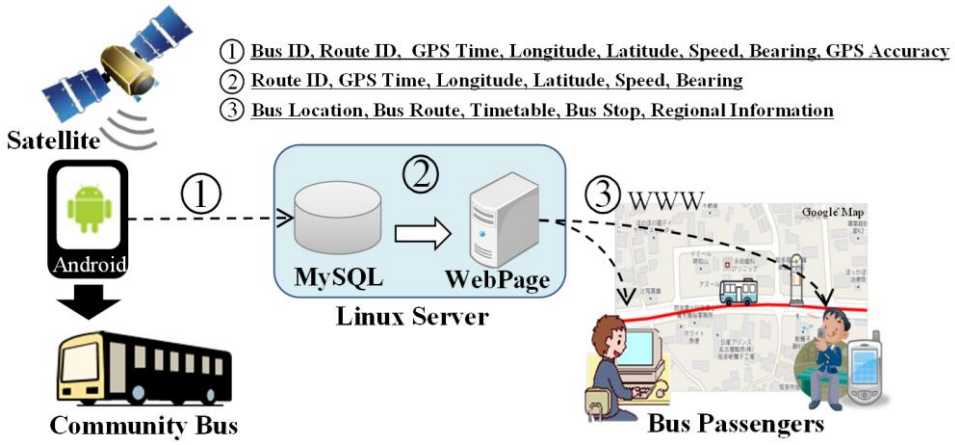

Figure 1. Illustration of developed bus location system

home. On the other hand, real-time bus information is more required outside home. Especially, "Information on bus delays" is the most necessary outside home among the real-time bus information.

3. DEVELOPMENT OF BUS LOCATION SYSTEM

We develop a bus location system based on the results from our questionnaire survey on the needs of bus passengers for real-time information, which has been conducted at Kururin-bus operated by Nisshin City.

3.1 Structure of Developed Bus Location

A bus location system is management system that monitors the current location of buses with a wireless network and the GPS. The developed bus location system in this study is for the use through the Internet. Since more than 75% passengers are able to use the Internet outside home according to the result of our questionnaire survey, this bus location system is useful for the passengers of community-buses. In the developed system, we use a smartphone on the market which has the GPS and some sensors and is operated by Android 2.2.

Figure 1 is a simplified illustration of the system we develop. First, the smartphone which is put inside a bus communicates with GPS and gets the current location of the bus. Then, through the 3G mobile network and the Internet, the smartphone sends the data on the location and the movements of the bus to a database server located our laboratory. The database server takes out the newest information of the current bus location from the database and provides it to a web server. Furthermore, the web server communicates asynchronously with the provided newest information and plots the bus location on a map of web page periodically. As a result, the location of the buses can be seen on Google map with bus icons. The left of Figure 2 shows GUI of the internet Web browser on the developed bus location system. It is easy to understand the location of the bus, a bus stop and a bus route on Google map. As the location data of the bus is updated continuously, the bus icon blinks by 2 seconds. The right figure of Figure 2 shows the developed page for a mobile phone. The names of a bus stop are displayed and the bus icon is shown between the names where the bus runs at the current time. It is also possible to confirm the delay time. The name color of the bus stop already passed by the bus changes to grey from red.

Figure 2. GUI of developed bus location system

3.2 Using Data of Bus Location and Movement

The developed system provides not only the location of a bus but also static information such as a bus route map, timetables and pictures around a bus stop. In addition to the information on static and real-time bus information, we store the information on public facilities, supermarkets and retail shops in the area around a bus stop.

3.3 Method for Judging Passage of Bus

Passengers likely desire to receive simplified real-time bus information such as only the section on which the bus is now running. We have to judge which bus stop the bus already passed through and identify the section where the bus is now running accurately. Therefore, we propose a method of data processing for judging if the bus passed a certain bus stop or not. Only two kinds of information of the coordinates and the speed of the bus are used for the judgement.

Figure 3 shows a flow chart of the proposed method of data processing. The method consists of two stages. The first stage judges if the second stage is implemented or not and the second stage judges if the bus passes a target bus stop or not. A certain distance R is set in advance and a target bus stop which will be passed next is focused for the judgements. If the bus runs within the circle with the radius of R, this means the bus is now near the target bus stop and the second stage is started.

In the first stage, the distance between the target bus stop and the current bus location, defined as D_c, is computed. If D_c is smaller than R, the system proceeds to the second stage. If D_c is larger than R, the system returns to the start of the first stage.

In the second stage, the system substitutes D_c for D_p. The D_p denotes the previous distance between the target bus stop and the current bus location. One second later, the program gets a new coordinates of the current bus location. The distance between the target bus stop and the current bus location, defined as D_c, is updated. If D_p is larger than D_c, the system returns to the start of the second stage. This means that the bus is approaching the target bus stop. If D_p is smaller than D_c, the system judges that the bus passed the target bus stop and leaves for the next bus stop. When the bus is judged to pass the last bus stops of the route, the system proceeds to the next bus departure. Consequently, it is possible to determine the two bus stops where the bus runs at the current time between. This provides bus location information to a mobile phone like the right of Figure 2.

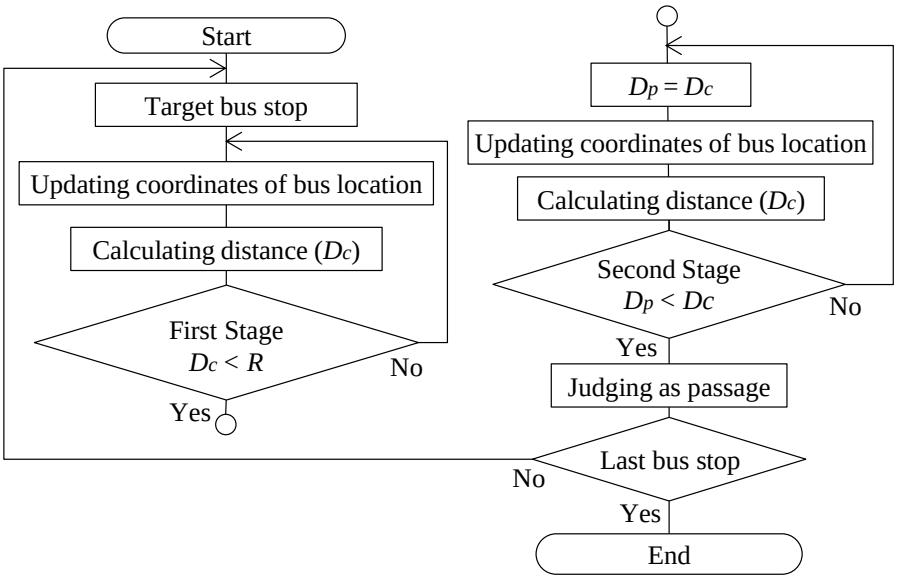

Figure 3. Flow chart of proposed method

4. OPERATIONAL TEST AND DATA COLLECTION

We conducted an operational test of the developed bus location system on community-buses operated by Chita city, Japan, from November 28 until December 25, 2011. Although the real-time bus information system was not introduced to buses in Chita city at that time of the operational test, we provided the bus information by the developed system. This community-bus in Chita City was seemed to be suitable for the operational test because the number of smartphones used for the test was limited to two in this study. Passengers were therefore able to obtain the real-time bus information and also regional information such as public facilities and local shops through the Internet. As a result, the system was confirmed to run actually and correctly, and to be feasible to be operated with inexpensive cost.

4.1 Outline of "Aiai-bus" Operated in Chita City, Japan

Chita City is a city located in the northwestern part of Aichi Prefecture in Japan. The area of the city is 45.7 km^2. The population of the city is about 85,000. The ratio of the elderly is about 18 % which is lower than the ratio of whole Japan.

"Aiai-bus" is a name of a community-bus operated by Chita City supporting motilities of residents from September, 2005. The Aiai-bus consists of an east route and a south route. The fares are 200 yen for adults and 100 yen for children. The elderly pass is sold at 2,000 yen a month for the elderly of 75 years old and over. At that time of the survey, there is no information service on real-time bus information. Since the number of android smartphones available for the operational test was limited, the bus location system could not be introduced to Kururin-bus in Nisshin city. Aiai-bus, which has a less route than Kururin-bus is therefore selected as a subject of the study. As the urban scale (e.g. population and area) and the development of railways of Chita city are similar to Nisshin city, the needs of Chita residents to bus location system seems to be same as the needs of Nisshin residents.

Figure 4. Developed web pages regional information added

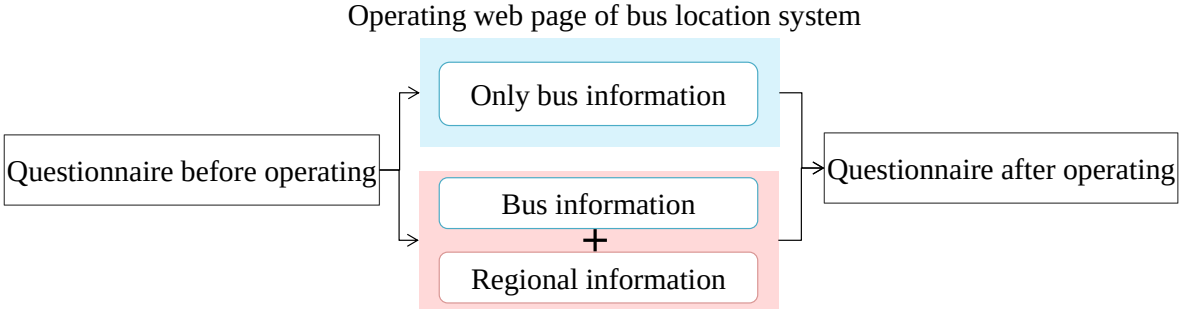

Figure 5. Survey flow of subjects' consciousness

5. QUESTIONNAIRE SURVEY

In order to grasp passengers' consciousness on the information provided by the developed bus information system, we conducted a questionnaire survey at Chita city on December 10, 2011.

5.1 Method of Questionnaire Survey

For this survey, we brought some PCs which could communicate to the Internet to the Chita Civic Gymnasium where we conducted the survey. Two web pages were provided to subjects by Google Maps in order to grasp an effect of providing regional information in addition to the bus information on promotion of bus usage and regional vitalization. One page provided only static and real-time bus information and another page provided regional information in addition to the bus information. When a bus stop icon on the map is clicked, bus stop name, timetable of the bus stop and facility information around the bus stop are displayed (the left of Figure 4). When a facility icon on the map is clicked, facility name, address, telephone number, a picture of the facility and business hours are popped up (the right of Figure 4).

Figure 5 shows a survey flow of subjects' consciousness. First, we asked subjects' attributes and their consciousness on a bus before operating the bus information system. Next, we separated the subjects into two groups in which the numbers of subjects were equal. Each subject operated one of two pages, in which "Only bus information" page provided "real-time bus location", "bus route" and "location of a bus stop" and "Regional information added" page provided regional information in addition to the bus information. The regional

Table 4. Ratio of subjects' attribute

	male over 64	male under 65	female over 64	female under 65
Only bus information	57.1%	14.3%	23.8%	4.8%
Regional information added	52.2%	17.4%	26.1%	4.3%

Table 5. Evaluation terms of bus information

Evaluation term	Abbreviation
Routes are understandable	Route
Bus stops are understandable	Bus stop
Timetables are understandable	Timetable
Bus passages are understandable	Passing
Delays are understandable	Delay
Transfer information is understandable	Transfer

information was obtained from the Chita chamber of commerce and Industry. After operating the Web page of the bus information system freely, the subjects evaluated the developed system and their consciousness about going out by bus.

5.2 Results of Questionnaire Survey

Fifty five subjects participated in the survey. Among them, 27 subjects operated "Only bus information" page. The other 28 subjects operated "Regional information added" page. Since the subjects operate the web page actually and personal computers we could prepare to be operated by the subjects are limited, it is difficult to obtain many samples. Accordingly, the survey results of each question are assessed by the statistical significance using the Cronbach's alpha.

Table 4 shows the subjects' attributes. An elderly male/female is defined as 65 years old and over. More than half of subjects are a male. The elderly occupies about 60% to 70% of subjects.

First, the questionnaire before operating the web page is analyzed here. Table 5 shows the evaluation terms on bus information and the abbreviation of each evaluation term. Table 6 indicates the level of satisfaction to the bus information. The value of Cronbach's alpha using evaluation terms of bus information is 0.827, which means the survey results are reliable. The most difficult term among the bus information in Table 5 for subjects is "Delay", "Passing" or "Transfer", in which 60% of subjects feel difficult to understand. Because "Delay" and "Passing" are able to be provided by the real-time bus information, the subjects cannot obtain such information without the bus location system. Similarly, because transfer information was not provided at that time, the subjects had to check a transfer ways by gathering all information of transportation modes such as a timetable, routes and fares. Therefore, the subjects feel delay information, pass information through a bus stop and transfer information as hard to understand. Conversely, it's easy for the subjects to understand "Route", "Bus stop" and "timetable" information because a route map and a timetable can be obtained on the Internet and also available by a printed one. However, about 50% of the subjects think such bus information as hard to understand overall. Thus, it is shown that the bus information is not provided enough to passengers of Aiai-bus.

After operating one of two web pages, the subjects evaluated changes of their consciousness and rated their intentions to use the bus location system. Table 7 shows the result of the intention to use the bus location system. The upper of the graph shows the result by the operating "Only bus information" page and the lower part is the result by operating

Table 6. Evaluation of each bus information

	Strongly agree	somewhat agree	neither	somewhat disagree	strongly disagree
Route	25.5%	19.6%	27.5%	19.6%	7.8%
Bus stop	18.4%	26.5%	20.4%	24.5%	10.2%
Timetable	18.0%	22.0%	34.0%	14.0%	12.0%
Passing	32.7%	28.6%	28.6%	6.1%	4.1%
Delay	42.9%	28.6%	20.4%	8.2%	0.0%
Transfer	34.7%	24.5%	22.4%	10.2%	8.2%

Table 7. Intention to use bus location system

	Want to use	Sometime use	Won't use	Never use
Only bus information	40%	45%	10%	5%
Regional information added	56%	36%	8%	0%

Table 8. Evaluation terms of using the system

Evaluation term	Abbreviation
Not irritated by waiting bus	Waiting
Easy to find out the way to reach destination	Finding way
Want to use bus	Using bus
Intend to use bus when going out	Going out
Want to visit shop around bus stop	Visiting
Want to know more about regional information	Information

"Regional information added" page. The subjects who want to use the bus location system are about 40% for "Only bus information" page and about 60% for "Regional information adde" page. It's obvious that adding the regional information on the bus location information impresses all the users as a useful system. About 90% of the subjects evaluated positive for the bus location system with the regional information.

Changes of their consciousness after operating the system were evaluated by 5 ranks. The 6 evaluation terms on using the system are shown in Table 8. The result of the evaluation is illustrated in Table 9. The value of Cronbach's alpha using evaluation terms of using the system is 0.887, which means the survey results are reliable. The ratios of positive evaluation for "Regional information added" page are more than those for "Only bus information" page and are all over 60%. Especially, there are large differences in the evaluations for "Visiting" and "Information" between "Only bus information" page and "Regional information added" page. The evaluations of "Regional information added" page for "Waiting" and "Using bus", which have no relation with the providing regional information, are rated higher. This means there is possibility of providing regional information added on real-time bus information to promote bus usage. However, the ratios of negative answers of "Finding way" and "Information" for "Regional information added" page are higher than those for "Only bus information" page. It's conceivable that the pages with the added regional information provide too much information for some subjects, which affected the page operation by the subject.

5.3 Evaluation of developed bus location system

The developed bus location system was evaluated by the subjects. Table 10 shows the evaluation terms of the developed bus location system and the abbreviation of each evaluation

Table 9. Consciousness on using the system

		Strongly agree	Somewhat agree	Neither	Somewhat disagree	Strongly disagree
Waiting	Only bus information	10%	45%	25%	20%	0%
	Regional information added	32%	40%	16%	8%	4%
Finding way	Only bus information	0%	40%	40%	20%	0%
	Regional information added	36%	20%	20%	24%	0%
Using bus	Only bus information	5%	35%	40%	20%	0%
	Regional information added	28%	36%	20%	12%	4%
Going out	Only bus information	15%	45%	25%	15%	0%
	Regional information added	32%	32%	32%	4%	0%
Visiting	Only bus information	25%	30%	35%	10%	0%
	Regional information added	68%	28%	0%	4%	0%
Information	Only bus information	25%	40%	30%	5%	0%
	Regional information added	54%	21%	13%	13%	0%

Table 10. Evaluation terms of developed bus location system

Evaluation term	Abbreviation
Understandability of bus position	Understandability
Update interval of bus position	Update interval
Easy to use	Usability
Information of surrounding facilities	Surrounding information

term. Table 11 shows the result of evaluating the developed bus location system. The evaluation of “Understandability” and “Update interval” are about 70 % positive. “Usability” is evaluated as about 50% positive from both of the web pages. Because the both web pages use Google Map, there are few differences of the evaluation between two pages. In terms of “Surrounding information”, the ratio of the positive evaluation for “Regional information added” page is twice larger than that for “Only bus information” page. However, the ratio of positive evaluation of "Understandability" for “Regional information added” is lower than that for “Only bus information”. This is considered the map becomes too complex for subjects to understand easily when the regional information is added on the page of the bus information.

5.4 Analysis of Web Component by Hayashi’s Quantification Theory Type II

As a result of the evaluation mentioned above, it is found that the regional information added on the bus information obviously effect the motivation of going out. We therefore analyze the components of the bus location contributing for regional vitalization.

In order to analyse the relation between the evaluation of “Visiting” in Table 8 and the evaluation of the developed bus location system, we use the HAYASHI’s quantification theory type II. Hayashi's quantitative theory type II (Hayashi 1954) is a method of multivariate discrimination analysis to manipulate qualitative data as predictor variables. A criterion variable is “Visiting” and independent variables are the evaluations of the system. As a result, the correlation ratio of this analysis is 0.414. The standardized category scores and item ranges are shown in Table 12. A category score represents the weight on a criterion variable of each category. Item range is difference between the maximum and the minimum of the category scores, represents the influence on the criterion variable which of each item. It represents the influence on the criterion variable of each item.

The positive value of the category score shows the corresponding category will promote

Table 11. Evaluation of developed bus location system

		Only bus information	Regional information added
Understandability	Good	78.9%	68.0%
	Average	21.1%	32.0%
Update interval	Good	73.7%	68.0%
	Short	26.3%	32.0%
Usability	Good	52.6%	52.0%
	Average	47.4%	48.0%
Surrounding information	Good	21.1%	44.0%
	Average	68.4%	40.0%
	Bad	10.5%	16.0%

Table 12. Category score and item range for "Visiting"

	Item range of predictor variable								
Item	Understandability		Update interval		Usability		Surrounding information		
Category	Good	Average	Good	Average	Good	Average	Good	Average	Bad
Category Score	-0.15	0.39	0.22	-0.53	0.90	-0.99	0.51	-0.14	-0.73
Item Range	0.534		0.753		1.892		1.239		

the intention of the subjects to visit the shops around a bus stop. Form the figure, we find that the item ranges decrease with the following order; "Usability", "Surrounding information", "Update interval" and "Understandability", in which their values are 1.892, 1.239, 0.753 and 0.534, respectively. The contribution of "Usability" and "Surrounding information" are larger than other item categories. Therefore, in order to improve "Visiting", we should enhance "Usability" and "Surrounding information" in our web page.

From Table 11, it can be seen that less than half of the subjects are satisfied to "Usability" and "Surrounding information" of the web page. We should make some changes to improve these evaluations to promote bus usage and regional vitalization.

6. CONCLUSIONS

Many local governments in Japan have introduced a community-bus and support it financially for the purposes of ensuring residents' mobility, reducing the area without public transportation services and so on. Although the bus location system is demanded for improvement of the level of bus service, it is practically difficult for a local government to introduce the system because of the expense to introduce and operate the system continuously. According to our survey of needs for bus information, it is found that static bus information is desired at home and real-time bus information is necessary outside home by passengers of a community bus operated by Nisshin city. We therefore developed a simple bus location system using a smartphone available commercially and constructed a web page to provide real-time bus information. The operational test using real buses by the developed bus location system was conducted for 4 weeks, in Chita city and we confirmed that the system worked correctly and accurately.

In order to grasp passengers' consciousness on the information provided by the developed bus information system, we conducted a questionnaire survey at Chita city. We prepared two web pages, one is the page providing only bus information such as a route, a timetable and a real-time bus location and another is the page providing regional information

added on the bus information. After operating one of two web pages, the subjects evaluated changes of their consciousness and rated their intentions to use the bus location system. As a result, it revealed that many subjects intended to use this system and wanted to go out by bus. In addition, more subjects wanted to know regional information by providing the regional information added on the bus information. These results show that the provision of regional information can improve not only intention to go out but also promotion of bus usage.

We then analysed the components of the bus location system contributing the regional vitalization by the HAYASHI's quantification theory II. As a result, it can be seen that the terms of the usability of the page and the information of surrounding area have influences more than others. However, these terms should be improved in the current system.

Analysis based on attributes of subjects is expected by getting more subjects to use this bus location system. Furthermore, behavior changes and consciousness of passengers who actually use this bus location system are needed to be observed in the future work.

It is possible to introduce this bus location system for other provincial city if an android smartphone is available and also used with inexpensive cost. In addition, it can be expected to promote bus usage and vitalize the region by providing information of attractive facilities around the bus stops added on the bus location information because attractive regional information stimulates the intension of residents to go out by this study.

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