Analysis of tram users' behavior and evaluation of operation by using smart card data

Shoshi Mizokami, Takumasa Morita and Yosiaki Nakamura
Department of Civil and Environmental Engineering, Kumamoto University
2-39-1 Kurokami, Chuoh-ku, Kumamoto, Japan, 8608555
Email: smizo@gpo.kumamoto-u.ac.jp

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ABSTRACT

The use of smart cards as ticketing tools for public transportation systems has grown rapidly around the globe. Particularly, this technology is extensively used by Japan Railways in almost all big cities of Japan. The use of smart cards in Kumamoto city was launched in March-2014 by Kumamoto City Transportation Bureau which can be used for both bus and tram systems. Besides their effectiveness in easing the ticking process, these smart cards are valuable tools in terms of recording transportation related data such as station to station travel time, delays, weekend and peak hour fluctuations etc. Using the smart card data obtained from Kumamoto City Tram, this paper investigates the characteristics of ridership and their behavior of the tram system in Kumamoto City. Similarly, the operational characteristics i.e. delays of the system has also been evaluated.

1. Introduction

In Japan, motorization has advanced and the number of public transport users is decreasing year by year. As a result, some social and environmental problems such as air pollution and traffic congestion occur and most public transport operations are forced to run a deficit in Japan. In order to increase the number of public transport users and to maintain sound management of public transport operators, it is necessary for operators to provide public transport services with high convenience, punctuality and reliability for users. The operator must accurately grasp the operation and usage characteristics, analyze them and design the appropriate level of service. However, actual observation of the number of passengers and preference surveys that have been carried out for many years are not extensive and only a specific day or a small number of users' responses can be grasped.

On the other hand, the spread of transportation IC cards as tickets for public transport is rapidly progressing, and the number of issued cards and available areas are increasing year by year. As announced by Ministry of Land, Infrastructure and Transport 1), more than 100 million cards have been issued as of the end of 2016. As part of efforts to increase the number of foreign tourists visiting Japan to 20 million, the government plans to enable the use of exchangeable IC cards in prefectures nationwide by the time of holding the 2020 Tokyo Olympic Games. With reference to the records of IC cards, a huge amount of usage history data is collected and accumulated in many railway companies, and it is expected that the number of data will continue to increase in the future. In March of 2014, Kumamoto City introduced IC card named "Denden nimoca" to city tram system that can be mutually used nationwide. In April 2015, the IC card, named "Kumamon no IC CARD", was introduced to the local-wide bus and train services.

In Japan, IC cards are mainly used as a means of settlement, but overseas, useful information obtained from IC card data is utilized for demand analysis and public transport planning. In the reviewed paper (e.g., [1]-[3]) overseas researches are divided into three categories such as 1) strategic (long-term network planning and demand forecasting etc.), 2) tactical (adjustment of diagram and continuous movement pattern analysis etc.), and 3) operation (demand and performance index for each public transport line, optimal operation method of IC card etc.), and the number of researches belonging to the tactical category is high and it is expected to utilize their research results.

As an example of domestic researches in Japan (e.g., [4]-[5]), 4) public transport users in Kochi City was classified into several user classes by using their temporal and spatial usage information obtained from IC card data. From the analysis on the behavioral change by each class, in order to increase the number of users, it is effective to encourage users who have not purchased a commuter ticket to use it. Using the IC card data of the bus in Shizuoka City, 5) the characteristics of users who do not use the bus much was clarified and measures to promote their bus use was suggested.

In this research, by using the data of IC card introduced in the Kumamoto City Tram, we will clarify the actual usage of the tram. We classify all users into several classes using cluster analysis and identify the characteristics of each class. Furthermore, we analyze the behavioral change of the user before and after purchasing the commuter pass. Finally, by comparing the actual traces of all services in any day which are created by the method developed independently using the IC card data with the regular schedules, it is possible to investigate causes of the delay from the regular schedule and we propose a method to reorganize the timetable.

2. Outline of usage data

(1) Data resources used for analysis

From April 1, 2014 to March 31, 2015, the Kumamoto City Transportation Bureau accumulated about 1.7 million processing data of nationwide IC cards. In this research, we use about 1.65 million effective samples without some kinds of error and missing. The possibility that one user is using plural cards is also conceivable, but in this research we treat data of one card as data of one user. Currently, the area IC card "Kumamon no IC CARD" introduced for payment of the bus fare inside Kumamoto prefecture is also available in the Kumamoto City Tram.

(2) Card attributes

10 types of nationwide IC card such as “Suica” and “nimoca” can be identified from the data item "card ID". In this research, these 10 types of cards are reclassified into 3 types, those are “nimoca” which is sold inside Kumamoto prefecture, “inside Kyushu card” which is sold inside Kyushu Island outside Kumamoto prefecture and “outside Kyushu card” which is sold outside Kyushu Island to roughly distinguish the user’s

residential area shown by Table 1. Figure 1 shows the number of usage and the number of people for each card type. The number of times of use per user (number of times of use / number of people used) was the largest 24.0 times/person in “nimoca”, followd by inside Kyushu card 7.81. For outside Kyushu card this number is only 3.64.

Figure 2 shows the distribution of annual times of use and the cumulative ratio for all users by each card type. There are 137,567 users, which are 65% of the total, who used the card only once or twice per year. Approximately 70%, which is 98,234 users, of them used cards outside Kyushu area, so it became clear that the proportion of visitors from the wide area to the total number of tram users is rather large.

Table 1 Information obtained from of City Transport tram IC card data

	contents
term	April 1, 2014 - March 31, 2015
the number of processing	1,707,103
the effective number	1,652,648
the number of cards	209,494
Card type	1. nimoca 2. inside Kyushu: Hayaka-ken, SUGOCA 3. outside Kyushu: TOICA, Suica, Kitaca, ICOCA, PASMO, PiTaPa, manaca
Items of IC card data	card ID, date/time, boarding station, getting off station, Vehicle number, line at.al.
pressings	Perches, boarding/getting off, charge, return

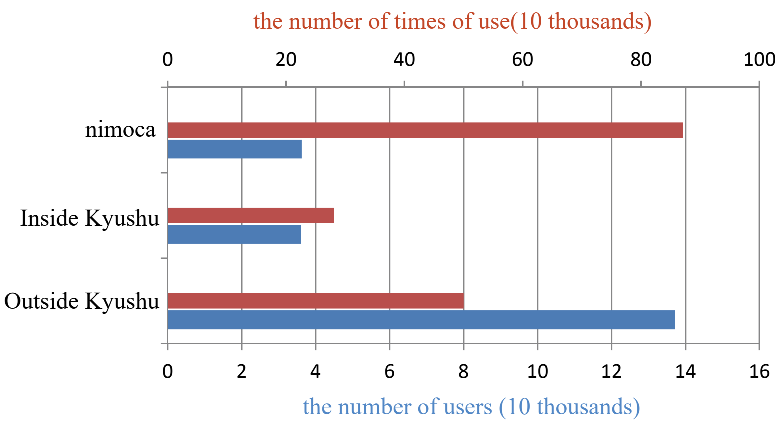


Figure 1 the number of times of use and users by Card type

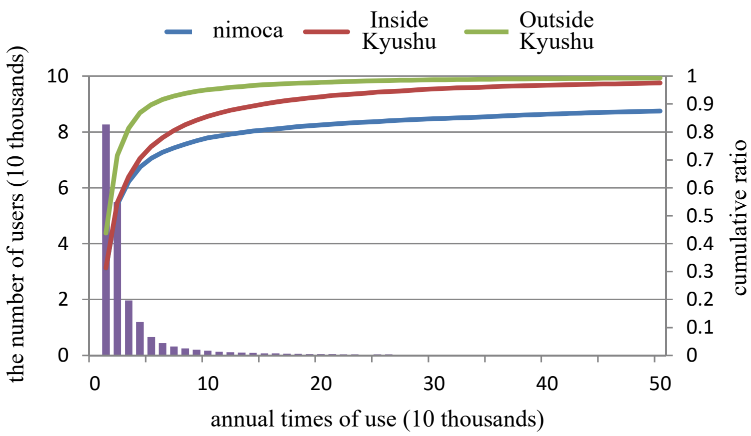


Figure 2 distributions of annual times of use and the cumulative ratio

(3) Number of days of use / hours of use

Figure 3 shows the number of daily usage in a week for one year. Although the number of times of use on weekend and holidays is smaller compared to those on weekdays, the number of times of use both by "inside Kyushu" area and "outside Kyushu" area IC cards has scarcely decreased. It can be seen that only the number of times of use by "nimoca" user, who are living in Kumamoto prefecture, has decreased.

Figures 4 (a) and (b) show the ratio of the number of users by card type by time period on weekdays and holidays. On weekdays, the number of "nimoca" users has a high-density morning peak for a short period of time from 7 to 9 o'clock and a low-density evening peak for relatively long term from 16 to 20 o'clock. On the other hand, on holidays, as in "inside Kyushu" card and "outside Kyushu" card are used without significant temporal fluctuations throughout a day. Although it was sensually known from the past that the number of users on holidays may be less than that on weekdays and there may be several temporal peaks in the number of users. By analyzing the IC card data, these actual conditions are objectively clarified.

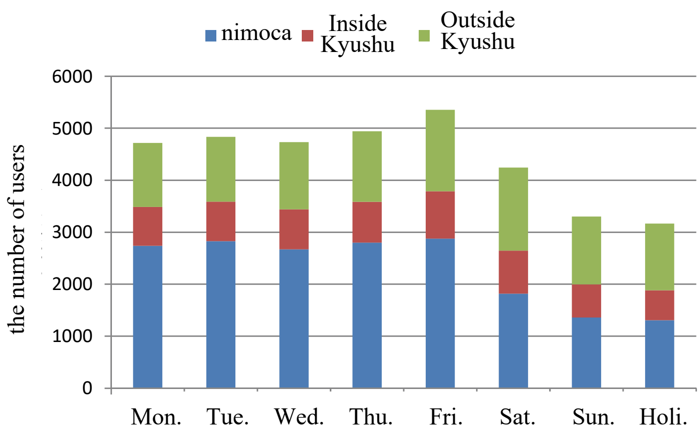


Figure 3 the number of times of use day by day in a week

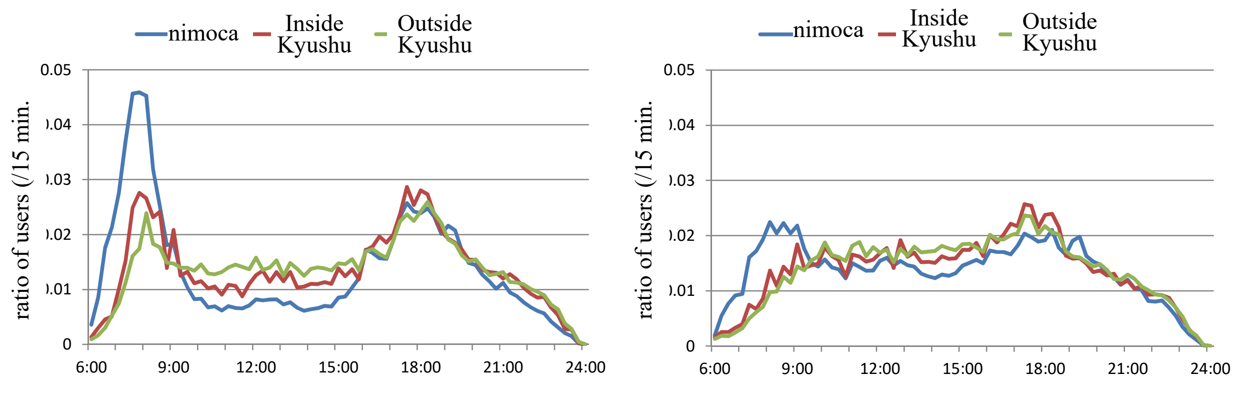


Figure 4 ratio of the number of users by card type by time period

3. Reliability of IC card data

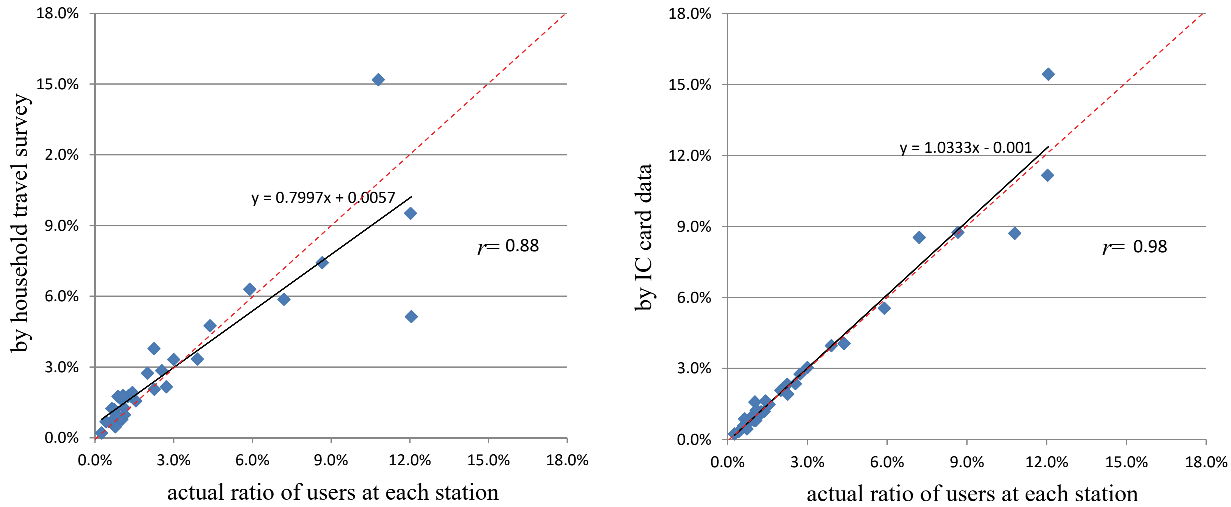
(1) Accuracy of estimates of number of passengers between stations

Since fares for Kumamoto City Trams can be paid in cash as well as IC cards, the data obtained from the payment by the IC card is sample data. Therefore, it is necessary to grasp in advance the difference in characteristics of usage between the real and the samples obtained from the IC card. Using the results of some kinds of passenger counting survey conducted by the Kumamoto City Transport Bureau each year, we estimated the number of passengers between stations and analyzed its reliability.

First of all, based on the real number of passengers which is counted at every station on weekdays in October 2014 by the Kumamoto City Transport Bureau and the number of passengers between every combination of stations which is obtained from the samples extracted by approximately 20%, we estimated the number of passengers between stations by the Fratar method which is the most popular growth factor model.

The number of tram passengers between stations can also be estimated by aggregating trips using trams obtained from the conventional household travel survey. However, it is pointed out that estimates have a large difference from the true values because the number of samples using public transport in the household travel survey is extremely small. On the other hand, since the number of samples obtained from IC card data has dramatically increased, we can estimate the number of passengers which is closer to actual number.

The vertical axis in Figure 5 (a) shows the ratio of the number of passengers at every 35 station to the total number of passengers that can be calculated using the estimated number of passengers between stations as mentioned before. The vertical axis in Figure 5 (b) shows the same ratio estimated using the trip data obtained from the household travel survey conducted in 2012. The horizontal axis in both figures shows the true ratio obtained from the observation survey. In the case of using an IC card as a priori information of the Fratar method, the correlation coefficient is 0.98, which is bigger than that in the case of using data from the household travel survey. Moreover, when F-test was carried out based on the difference in tram utilization rate by station, the F-value was 4.37, and there was a significant difference between the two distributions. Therefore, it can be said that the reliability is higher in the tram utilization rate by station estimated from the IC card data as a priori of the household travel survey data.



(a) by household travel survey (b) by IC card data

Figure 5 the ratio of the number of passengers at every 35 station

(2) Error and utilization rate of IC card

Figure 6 shows the utilization rate of IC cards between all stations. These values are ratios of the average number of users between stations obtained from all IC card data of weekdays in October to the estimated value of the number of users between stations which is previously obtained. The usage rate of the IC card with respect to the total number of users is about 15.6%, and it cannot be said that the utilization rate is never high. This value is considerably lower than our expectation, but the number of times which cards are processed is increasing month by month. The number of settlement data collected from IC card in March 2015 is about 1.7 times higher compared to that in October 2014. It is expected that the usage rate of IC card will further increase in future.

	健軍町			健軍校前			商業高校前				新水前寺駅前				水道町		熊本城		辛島町					熊本駅前		田崎橋		洗馬橋			段山町		本妙寺入口		上熊本駅前		O
健軍町			9	5	9	6	18	8	5	15	19	10	9	12	10	12	10	12	14		17	11	25	12	15	10		14			13				31		12.3
健軍交番前											29	4	18		12	17	11	5	8																		13.8
動植物園入口										5	21	5	24	6	15	13	9	24	18					21													13.7
健軍校前	4									14	17	14	14	14	12	13	18	43	14					17													15.5
市民病院前	13								22	8	18		9	16	19	15	30	21	13		17	2		18							11						16.2
八丁馬場	4										9				17	18	11	4																			13.4
商業高校前	11										36		7	16	20	15		8	9					3													17.2
市立体育館前	8										33		30		12	13	7	17	20			7		7													15.1
水前寺公園	8	4				7					13		5		13	11	8	15	22		4			19													13.7
国府	12			10	20	4								21	12	11	17	23	12								7										14.2
新水前寺駅前	15	36	11	24	26	19	23	29	42	3			16	33	22	16	16	19	21	32	18	11		8	1			58			4		5		16		18.8
味噌天神前	11				13	8		4							14	26	17	15	11			8		16										0			13.5
交通局前	10			8	12	9	12		12	11	51				39	15	3	13	9			14		16						12					15		14.6
九品寺交差点	14	18	15	27	10		5	36	14	5	18	5			19	17	7		14			14		20					7	4					14		15.7
水道町	9	18	11	21	16	19	13	8	14	17	19	16	31			7	8	13	9		23		12	20		15			9						10		14.9
通町筋	13	16	18	10	18	14	12	8	20	13	13	12	8	8				15	11	7	9	9	12	19		9	8	16	10	17	7		7	9	16		13.9
熊本城	11	19		16	13	10		22	11	5	15	7		27					14		7	9	29	18	17	6		10	13	12	12		6		6		14.5
花畑町	15	15	7	29	9	7	12	23	8	33	20	23	14	21		5					9		13	22		25				8			3	7	24		16.8
辛島町	13	15	39	17	15	29	19	11	7	12	17	7	14	10	6	9	8	7			15	17	28	22	31	11		14	13	15	17	17	9	9	13		15.2
慶徳校前	26										26			10	7	14	11	10						29													22.1
河原町	21				5				9		16				12	27	5	9	20					26													15.7
呉服町											14		9	8	10	12	14	36	7					26													14.9
祇園橋														7	5	14	14	6	14																		12.8
熊本駅前	18		8	8	16		13	18	10		9	52	36	20	17	23	18	15	22	34	35	32	11														20.4
二本木口	13													9	11	25	84		21	18																	21.9
田崎橋	10			9	11			2					17			10	18	17	17	3				5													11.8
西辛島町									7		17					7															3				18		13.9
洗馬橋	20										60		8		10	5	11	6	14														14	13	19		16.7
新町							1				9				8	15	17	21	10								5						5		5		11.2
蔚山町	9														14	7	19	21	27								26						3	2	12		14.6
段山町	20				20									25		23			12								7	4	2						4		15.3
杉塘	0																		14								4										14.1
本妙寺入口	1													9	11	5	7		10									12	6		1	0					10.3
県立体育館前																			5								5										10.0
上熊本駅前	17										17	4	13	14	20	13	15	13	12								28	31	6	7	18						16.0
D	13	20	14	17	16	14	18	14	13	13	18	13	14	16	14	15	14	15	16	25	17	14	17	19	19	13	15	19	12	13	13	13	8	13	16		15.6

Figure 6 the utilization rate of IC cards between all stations

4. Behavior characteristics of users

By analyzing the data of the IC card having the same ID, it is possible to analyze the usage characteristics and temporal behavior change of a specific user. We classified all tram users into several segments by cluster analysis and estimated attributes of each segment from their usage characteristics. We also analyzed their behavioral changes before and after purchasing commuter passes.

(1) User classification by cluster analysis

We attempted to classify 35,670 IC card users who took Kumamoto City Tram during February 1, 2015 to February 28, 2015 into several segments according to their usage characteristics. The statistical technique for classification is non-hierarchical cluster analysis. Table 2 shows the explanatory variables used for classification. The Gap statistic was used as a criterion for systematically determining the number of clusters. Based on the results shown in Figure 7, we wanted to introduce as many clusters as possible to analyze the detailed characteristics of each cluster, so we adopted the minimum number of clusters k=6 where the continuously decreasing Gap statistics increase again.

Table 2 explanatory variable of Cluster analysis

explanatory variable	meanings
card type	card type among nationwide cards
total time of use	total number of times of use during whole period
weekday use	use ratio within a day on weekdays
weekend use	use ratio with in a day on weekends
morning peak	use ratio during morning peak hours (7:00-9:00)
evening peak	use ratio during evening peak hours (16:00-20:00)

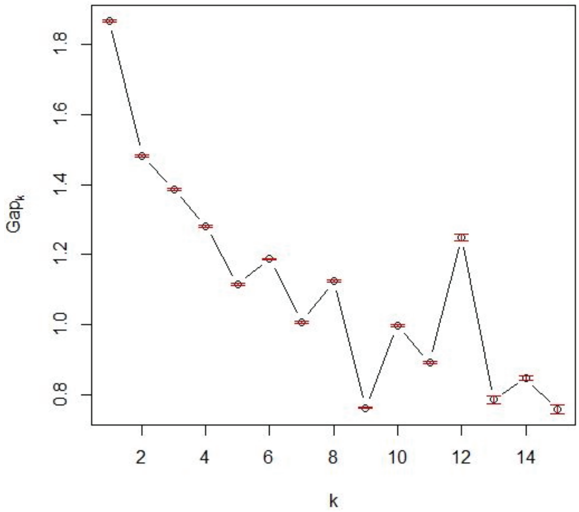


Figure 7 Gap statistic

Table 3 the number of users belonging to each cluster and the average value of explanatory variable

	cluster					
	1	2	3	4	5	6
the number of samples	1,325	7,138	12,226	10,277	2,101	2,693
nimoca	1,240	1,022	0	4,862	1,892	551
Inside Kyushu	40	1,831	0	5,415	124	607
Outside Kyushu	45	4,285	12,226	0	85	1,535
total time of use	43.53	1.78	2.34	3.13	32.66	3.20
weekday use	1.65	0.06	0.08	0.11	1.56	0.13
weekend use	1.36	0.06	0.09	0.11	0.32	0.07
morning peak	0.23	0.01	0.01	0.02	0.36	0.71
evening peak	0.29	0.95	0.14	0.18	0.32	0.13

Table 3 shows the number of users belonging to each cluster and the average value of each explanatory variable for each cluster. The features of each cluster are summarized in Table 4. We investigated the characteristics of users belonging to each cluster as follows;

Cluster 1: Most of the users belonging to this cluster use “nimoca”. Not only the number of times of use and the weekday usage rate but also the holiday utilization rate is the maximum. The morning peak utilization rate and the evening peak utilization rate is also considerably large. They are considered to be regular daily users who frequently use holidays as well as weekdays commuting and using school attendance.

Cluster 2: More than half of users are from “outside Kyushu” area, and the number of times of use is not large at 1.78 times. Evening peak utilization rate is very high, i.e. 0.95, mainly used during evening peak hours. It is a user who uses it several times a month in the evening.

Cluster 3: Users belonging to this cluster are users from “outside Kyushu” area, and the number of times of use is as low as 2.34 times. It is considered to be a visitor from outside the Kyushu area during the target period.

Cluster 4: The types of cards of users are only from “nimoca” and from “inside Kyushu” area and the number of times of use are only 3.13 times. It is considered to be a visitor living in Kyushu area.

Cluster 5: Characteristics are similar to those of cluster 1, but holiday utilization rate is low. The utilization rates of morning peak and evening peak are larger than those of cluster 1. It is considered to be a daily user who regularly uses it on commuting, going to school, but does not use it during holidays much.

Cluster 6: Various cards are used by users, and the average number of times of use is 3.20 times. Peak utilization rate in the morning is as high as 0.71, it is a user riding in the morning rush several times a month. There is a high possibility of getting on the commute peak.

Table 4 characteristics of each cluster

cluster	the number of samples (ratio)	characteristics
1	1,325 (3.71%)	Most of them use ”nimoca”, and the number of annual uses of tram is very large. They will be citizens who frequently use trams on weekdays and holidays for commuting or going school or for other purposes.
2	7,138 (19.96%)	They are visitors from outside Kumamoto prefecture, which mainly uses trams at the evening peak.
3	12,226 (34.19%)	They are not used frequently and are not used during the morning and evening peaks, so they will be visitors to Kumamoto City from outside Kyushu.
4	10,277 (28.74%)	They live in Kumamoto prefecture or inside Kyushu and use tram sometimes, but they will be residents who hardly use trams at the morning peak.
5	2,101 (5.88%)	They seem to be citizens who are using trams frequently for the purpose of commuting or going to school on weekdays using “nimoca”.
6	2,693 (7.53%)	Although they do not use tram many times and seem to be visitors from outside of Kyushu which use very concentrated at peak time of weekday morning

(2) Behavior change due to the use of commuter pass

In October 2014, the commuter pass service function was introduced to “nimoca”. Users who purchased the “nimoca” commuter pass can now ride the tram several times with prepayment of flat fee. We analyzed changes in usage behavior on weekdays and holidays before and after commuter pass was purchased by the same user.

From October 1, 2015 to October 31, 2015, 190 users who added the commuter pass service function to the “nimoca” card were extracted as samples for analysis. We considered 1.0 times / day as the threshold value, users who use more frequently are regarded as high frequency and users lower than that are considered as low frequency. All these samples are classified into Type A: low frequency user both on weekdays and holidays, Type B: high frequency user on weekdays but low frequency on holiday, Type C: low frequency user on weekdays but high frequency on holidays, Type D: high frequency user both on weekdays and holidays.

Figure 8 shows the distribution of the average difference in usage times per day between weekdays and holidays one month before and after the commuter pass purchase date. The average number of times of use of the whole sample before and after the commuter ticket was purchased increased by 1.25 times / day on weekdays and 0.61 times / day on holidays.

Users of type A increased their number of times of use of tram not only by 1.40 times / day on average on weekdays but also 0.68 times / day on holidays. This type of user is considered to be a low frequency user who did not use trams for commuting or attending school. After purchasing a commuter pass, they started to use trams not only for commuting to work on weekdays but also for going out on holidays.

Users of type B have increased their number of times of use only by 0.18 times / day on average on weekdays and only 0.12 times / day on holidays. Users of this type frequently use trams on weekdays before buying commuter passes, but the frequency of using trams on holidays was low. They were expected to use trams on holidays if they purchase a commuter pass, but it turned out that not everyone always did. No user of type C existed. There were only five users of type D, the average number of times of use on weekdays was 0.20 times / day, and the average number of times of use on holidays increased only 0.11 times / day. Users of this type are users who use tram frequently both on weekdays and holidays before buying a commuter ticket, so there was not much change in behavior.

Table 5 shows the number of people of each type before and after using the commuter pass service. The number of type A decreased by 147, the number of type B increased by 96, the number of type C increased from 0 to 7, and type D increased by 44 people. After using the commuter pass service, 91% (51 people / 56 people) of users who switched to type C and type D which use trams frequently on holidays belonged to type A before purchasing the commuter ticket. Most of the users who increased the number of holiday use by the commuter pass service were found to be users who seemed to have not used trams to commute or go to school before.

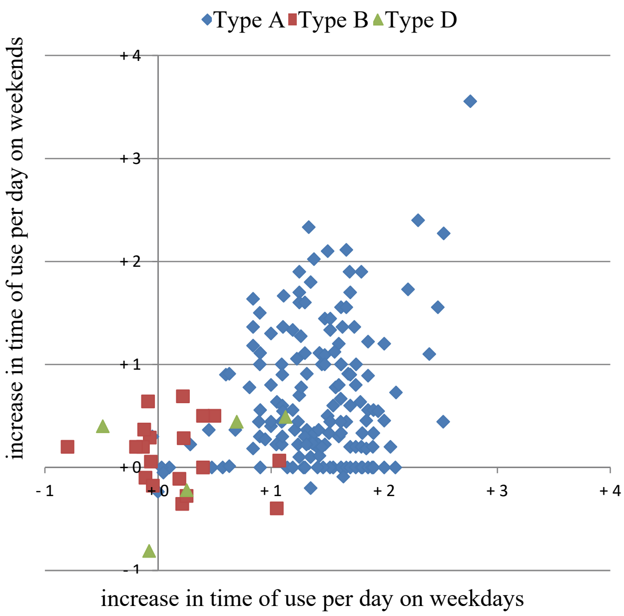


Figure 8 distribution of the average difference in usage times per day between weekdays and holidays

Table 5 the number of people of each type before and after using the commuter pass service

		after				
		A	B	C	D	total
before	A	18	97	6	45	166
	B	1	17	0	1	19
	C	0	0	0	0	0
	D	0	1	1	3	5
	total	19	115	7	49	190
differences		-147	+96	+7	+44	

5. Analysis of operation and demand

(1) Possibility of analyzing operation and demand by IC card data

Since the location system can obtain operational trajectory data for each vehicle, it is possible to analyze their running condition such as when and where the delay is occurring on the route. However, unless it is matched with actual demand data such as the number of passengers, we cannot analyze the cause of the delay due to getting on and off and it cannot be used as basic data for improving the operation schedule. On the other hand, by assuming that the earliest getting-in time or getting-off time for each station obtained from the IC card data is the arrival time and the latest getting-in time or getting-off time is the departure time, it is possible to approximately create the vehicle trajectory data. Using this data, delay time which is the difference between the arrival time on the timetable and the actual arrival time, the stopping time which is the difference between departure time and arrival time, the number of passengers at each station and passengers between stations can be calculated easily. In this way, since the IC card data can grasp not only the vehicle operation but also the actual situation of utilization in detail, it is also possible to analyze the mutual relation between operation and demand.

Here, the actual traveling situation was visualized by using the tram movement trajectory obtained from the IC card data. Furthermore, by comparing this with the timetable, the relationship between the number of passengers and the delay time of the tram was analyzed. As a result, we were able to find some problems in the operation of the Kumamoto City tram.

(2) Analysis of operation and demand

Systems that support the creation of timetables for buses and railroads are offered for a fee by numerous software development companies. In this research, we used "Sono-suji-ya" which is a free system to visualize the traveling trajectory and analyze it afterwards. We show both of the time schedules and actual movement trajectory of the A-line upstream and downstream of 6:00 to 9:00 in the morning and of the night from 17: 00 to 20:00 in the evening on February 19 (Thursday), 2015, respectively. The weather on this day was partially sunny in the morning and sunny in the afternoon. The maximum temperature was 6.4°C, and it was a cold day compared with the usual year.

Figure 9 shows the number of passengers and Figure 10 shows the delay time in the morning peak period from 6:00 to 9:00. As the color of the line is redder than blue, the number of passengers is more and the delay is larger. Also, black line shows the time schedule, the difference between the black and colored line shows the delay. From around 7:20, we can recognize heavy morning congestion inside cabins due to an increase in the number of passengers around the sections of Kumamoto station – Kuhonnji and Shin-Suizennji – Shogyo-Koukou-Mae on the upstream line, and Kengun-Machi – Toricho-Suji on the downstream line clearly from Figure 15. However, it can be seen from Fig. 16 that only 7 flights, those are 4 flights in the upstream at the section of Suido-ch- - Kengun-machi from 7:15 to 7:35 and Shin-Suizenji – Kengun-machi from 8:00 to 8:45, and 3 flights in the downstream at the section of Toricho-suji – Nihongi-guchi from 6:40 to 7:30 and 8:30 to 9:00, had a large delay in the morning peak period. The delay of these seven flights is occurring in the section where the number of passengers is not too high. This suggests that delay in the morning tram does not occur due to an increase in the number of passengers, but rather due to road congestion.

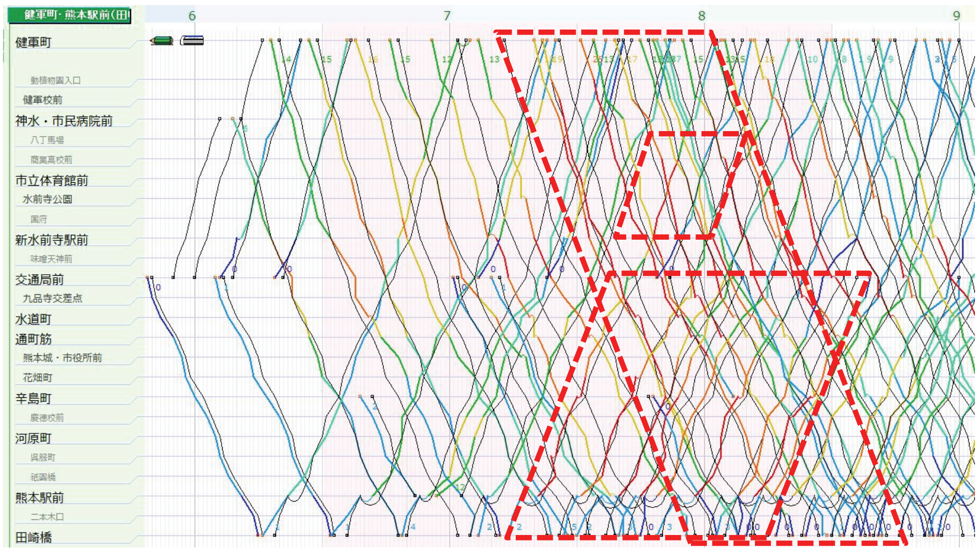


Figure 9 the number of passengers in the morning peak period from 6:00 to 9:00

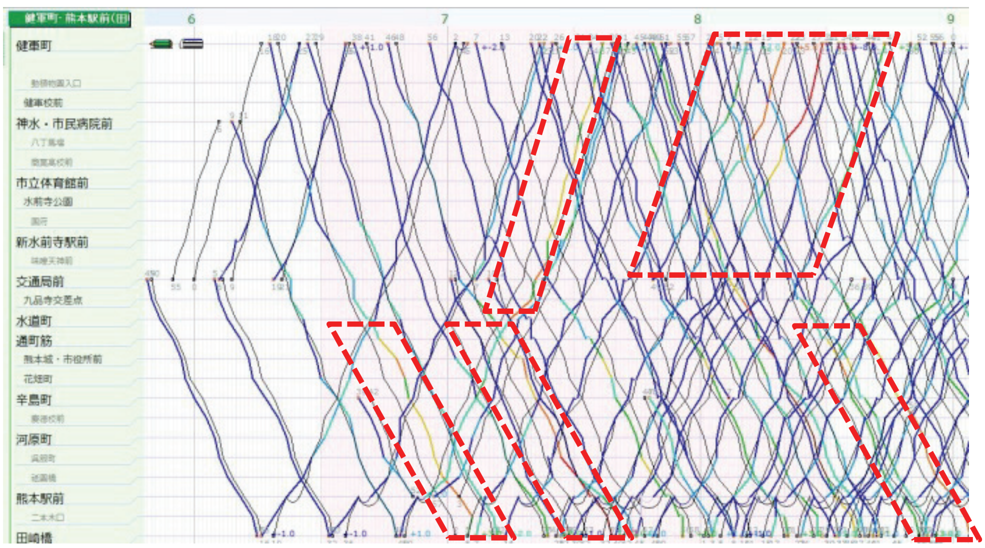


Figure 10 the delay time in the morning peak period from 6:00 to 9:00

Figure 11 shows the number of passengers and Figure 12 shows the delay time in the evening peak period from 17:00 to 20:00. In the evening peak period, it can be seen that there are many congested vehicles over a long period of time compared to that in the morning peak period. Among them, there are many congested flights at the section of Tori-cho-suji - Kumamoto Station from 17:15 to 20:0o on the downstream line. On the upstream line, there are 3 flights which generate the heavy delay at the section of Suido-cho – Kengun-machi from 18:10 to 18:55. As for the other two flights, it can be seen that the number of passengers increase rapidly at Suido-cho station and speed decrease between Suido-cho and Kujōji. It can also be seen that the delay of the other flight was caused by following the preceding vehicle which made a big delay.

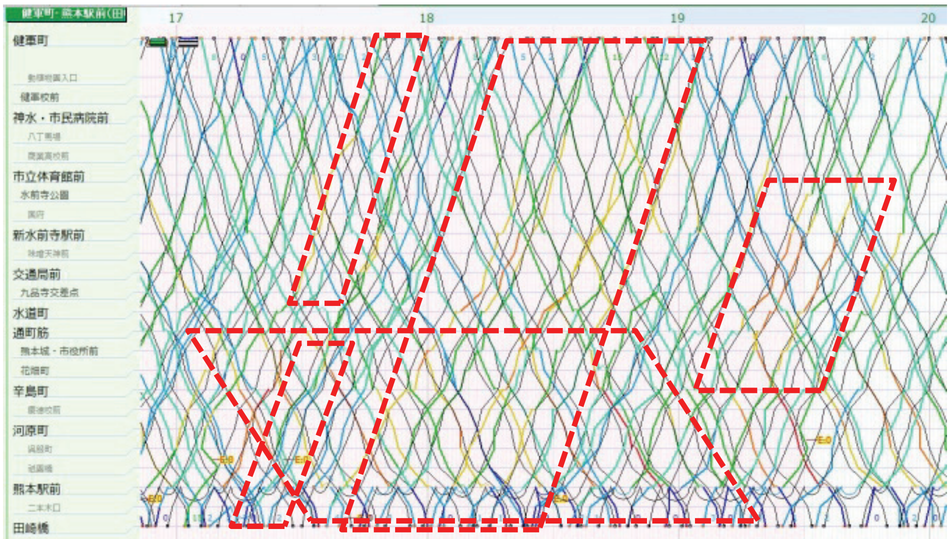


Figure 11 the number of passengers in the evening peak period from 17:00 to 20:00

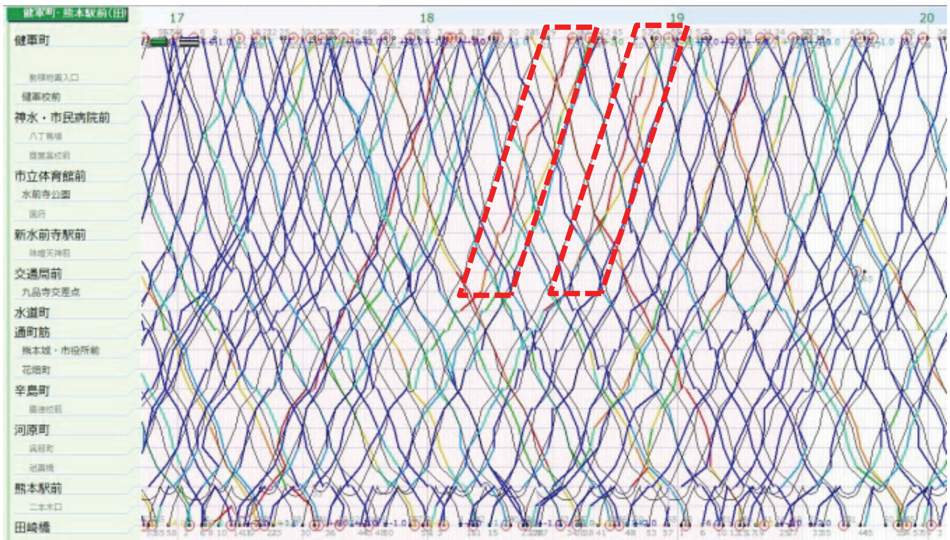


Figure 12 the delay time in the evening peak period from 17:00 to 20:00

(3) Detailed relationship between operation and use

Various information created by processing of IC card data is very useful to analyze the correlation between actual operation and demand. Here, we want to show an example of analysis.

Using the results of the cluster analysis conducted in Section 4, we tried to classify all passengers into visitors from outside and daily users and visualize the number of both passengers for each flight. Figure 13 shows cluster 1 (daily user) and figure 14 shows cluster 3 (visitor). A redder color line indicates a flight on which a user belonging to each cluster is riding. Cluster 1 uses flights from 8: 00 to 9: 00 and after 19:00 on sections which cover whole line. On the other hand, Cluster 3 is taking from 9: 00-17: 00, and it is concentrated only from Kumamoto station to Tori-cho-suji. These pieces of information are useful for making an operation planning such as providing special vehicles and announcement services inside the cabins for visitors while the number of visitors increases.

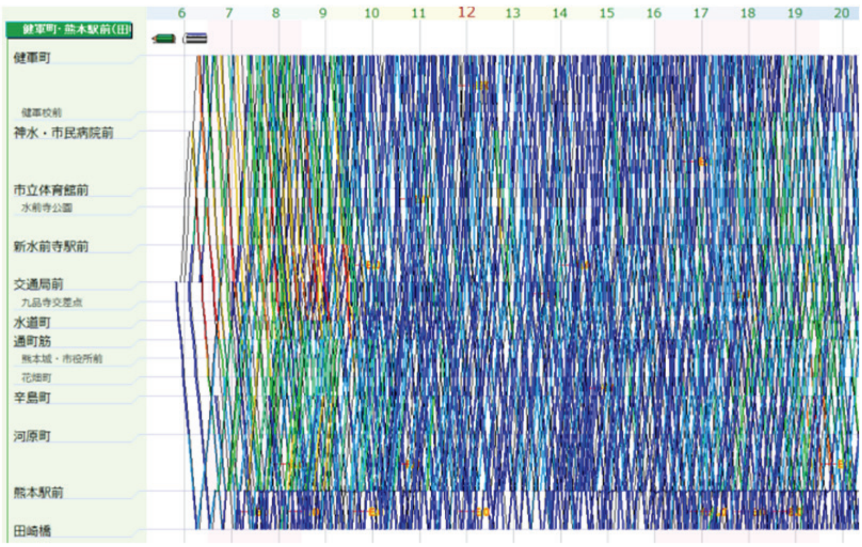


Figure 13 actual condition in use of tram by cluster 1 (daily user)

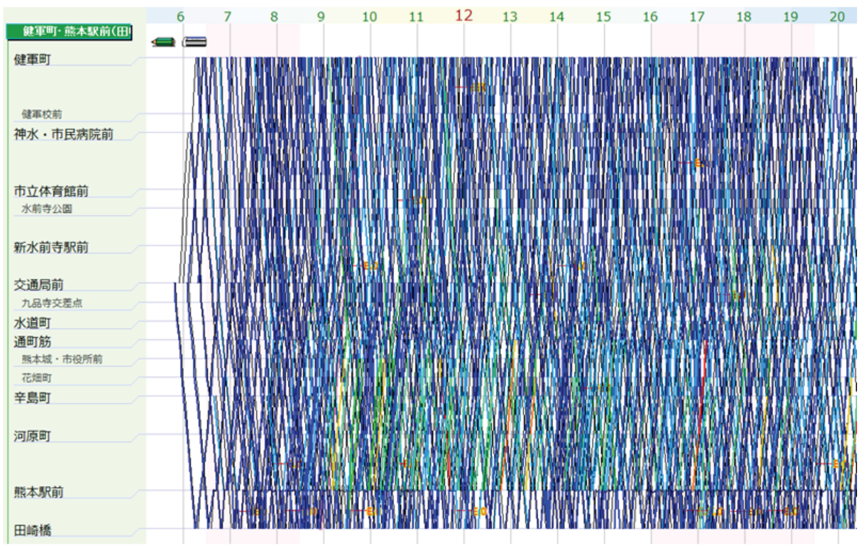


Figure 14 actual condition in use of tram by cluster 3 (visitor)

6. Conclusion

In this research, we first showed that IC card data is useful data for analyzing the actual demand of

Kumamoto City tram by comparing it to the data of Kumamoto area household travel survey. Secondly, we carried out the analysis on actual demand, characteristics of passengers and visualized the movement trajectory of trams using IC card data. Some interesting findings and future subjects clarified by this research are summarized as follows;

1) From the number of nationwide IC cards categorized into three categories according to the issued area, the number of Kumamoto City tram users and their frequencies of use for each residential area could be clarified. As a result of estimating the number of passengers between stations by the Fratar method based on the observation number of getting-on and off passengers at every station, it is better to reproduce actual number of passengers with IC card data as a prior probability than with household travel survey data. IC card data is useful for analyzing the actual use of public transport.

2) Several characteristic values obtained by processing information accessed from IC card data could allow us to classify all tram users into six categories with their own characteristics in usage. In addition, it was found that there were groups that changed little from usage after introducing a commuter ticket and groups that hardly changed. The data of the IC card can not only clarify the attributes of the user but also can evaluate the change of behavior to the policy.

3) IC card data can allow us to give not only delay time from time schedules and the stopping time at stations as well as the number of passengers at each station and between stations. Also, by visualizing the traveling trajectory of all the trams of the day, it was possible to clarify where and when the problems such as early departure, dumpling due to delay of the starting vehicle, delay of the first operation due to arrival delay of the train occurred. In this way, since the IC card data can grasp not only the vehicle operation but also the actual situation of usage in detail, it is also possible to analyze the mutual relation between operation and demand.

There are many types of public transport IC cards in Japan, from IC cards that can be used nationwide like “Suica” and “nimoca” to IC cards limited to specific areas like “Kumasan no IC CARD”. As These IC cards are mainly used for payment of fees, the data is not open to the public except for the specific purpose of research because the settlement information clarifies the business situation of the operators. The IC card data contains a lot of useful information for formulating operation plan such as adjustment of time schedule and examining suitable services which should be provided to various kinds of passenger. To extract this useful information from the original IC card data, the cooperation of experts is necessary, so card data should be released in Japan.

References

1. Bagchi, M. And White, P. R. : The potential of public transport smart card data, Transport Policy, 12, 464-474 (2005).
2. Utsunomiya, M., Attanucci, J., Wilson, N.: Potential Uses of Transit Smart Card Registration and Transaction Data to Improve Transit Planning, Transportation Research Record: Journal of the Transportation Research Board, 1971, 119-126 (2006).
3. Pellertier, M., Trépanier, M. and Morency, C.: Smart card data use in public transit: A literature review, Transportation Research Part C, 19, 557-568 (2011).

4. Nishiuchi, H., and Todoroki, T.,: Behavior Analysis of Public Transport Passengers for discussing Transport Marketing Scheme using Smart Card Data, Journal of Japan Society of Civil Engineers F3, Vol. 68, No. 2, II_8-II_17 (2012).
5. Matsumoto, H., Ishigami, T., Harada, C., Makimura, K., Iwamoto, T.,: A study on method to extract potential bus-user with smartcard data, Proc. Of Infrastructure Planning, 51, CD- No. 17 (2015).