Analyzing Kumamoto City Tram Users' Usage in COVID-19 Using Smartcard Data

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Abstract: Recently, the number of public transportation users has declined owing to the COVID-19 pandemic. Previous studies have attributed the overall decrease in public transport users to the pandemic; however, only few have examined shifts in time-of-day usage at public transportation stops. This study aims to assess the impact of COVID-19, with a focus on time-of-day usage using smartcard data from the Kumamoto City Tram in Japan. We interpret the characteristics of the smartcard data through visualization and cluster analysis. The results reveal a decline in usage during the evening, and the stop usage characteristics are divided into three distinct clusters. The decline in a stop's usage suggests a decrease in evening activities in the downtown area.

Keywords: Smartcard data, Kumamoto City Tram, COVID-19, trip behavior, cluster analysis

1. INTRODUCTION

The utilization of public transportation in rural areas of Japan has experienced a marked decline. For example, the annual ridership of streetcars operated by the Kumamoto City Transportation Bureau, known as the "Kumamoto City Tram", in 2019 was approximately 11 million. This is merely a quarter of the patronage in 1963, which represented the peak of its usage[1]. The recent COVID-19 pandemic has further amplified this downturn. Simultaneously, public transportation systems have witnessed the widespread adoption of efficient smartcard payment technologies. Japan's Suica smartcard is a renowned example, with over 200 million cards issued[2]. Similarly, the Kumamoto City Tram launched the "Denden nimoca" on March 28, 2014[3]. Ten varieties of smartcards, collectively referred to as "National IC", can be utilized for payment, with nimoca being one of them.

Smartcards offer a host of advantages including long-term cost reduction, the potential for information sharing, and enhanced revenue management (Pelletier *et al.*, 2011). Additionally, smartcard data can be utilized to analyze public transportation usage patterns. Therefore, this study aims to examine the smartcard data of the Kumamoto City Tram.

Research employing smartcard data has been conducted globally. Pelletier *et al.* (2011) and Shimamoto *et al.* (2012) surveyed studies that utilized smartcard data, categorizing them into strategic, tactical, and operational studies. Strategic studies focus on long-term network planning and demand forecasting, whereas tactical studies encompass schedule adjustments and longitudinal and individual trip patterns. This study explored the changes in user behavior using long-term and individual data, and hence can be classified under strategic and tactical studies.

[1] http://www.kotsu-kumamoto.jp/common/UploadFileDsp.aspx?c_id=57&id=818&set_doc=1
[2] https://www.jrem.co.jp/common/pdf/202109.pdf
[3] https://www.nimoca.jp/oldrelease/pdf/140306_denden.pdf

Numerous studies have explored the significant societal impact of the COVID-19 pandemic. For example, Zheng *et al.* (2020) investigated the correlation between the mobility of Wuhan residents and the number of COVID-19 cases, thereby determining a link between public transport frequency and case numbers. Similarly, Laosunthara *et al*. (2022) established analogous results in Bangkok, asserting that public transportation could potentially facilitate the spread of COVID-19. Furthermore, Thomas *et al.* (2022) analyzed COVID-19 infection rates and public transport usage, and they found that areas with higher public transport usage tended to have higher infection rates. Nonetheless, these studies relied solely on aggregated data.

Nakamura and Kanda (2020) analyzed smartcard usage data across six bus routes in the Hiroshima Prefecture, Japan. Owing to the first emergency declaration, the number of passengers decreased to half of the previous year's average. Subsequently, commuter pass users rebounded to pre-pandemic levels, whereas pay-as-you-go users remained at approximately 80% of the normal rate. Their examination of usage by time of day showed a substantial decrease in daytime users. However, the study did not consider the individual or bus stop attributes. Jenelius and Cebecauer (2020) analyzed public transportation usage in Sweden, noting a significant decline in the number of active users. Remarkably, the average number of trips per card in Stockholm remained constant before and after the COVID-19 pandemic. In addition, they observed a change in payment patterns, with users transitioning from monthly passes to single tickets. Short-term ticket sales dropped to almost zero.

Mützel and Scheiner (2022) investigated the impact of COVID-19 on commuters in Taipei. They documented a decrease in passenger numbers and a considerable reduction in usage of some sections owing to the cancellation of fairs. However, they did not examine the personal attributes of users.

Almöf *et al.* (2021) combined smartcard data and sociodemographic data in Stockholm, Sweden, to identify the characteristics of users who maintained their use of public transportation throughout the COVID-19 pandemic. Their findings suggested that social factors such as age, income, and education level influenced decisions to cease using the service. Although this study considered individual attributes, it did not focus on aspects like trip purpose and time-of-day usage.

Nishiuchi *et al.* (2021) analyzed 11 years' worth of smartcard data from the urban area of Kochi, Japan. They developed a Cox proportional hazards model to demonstrate the likelihood of returning to pre-pandemic usage levels. The model indicated that activities such as commuting to work or school, visiting municipal or post offices were more likely to revert to their original levels. By contrast, commuting to tourist facilities, hospitals, transporting children, and long-distance usage were unlikely to return to their original levels. However, this study focused exclusively on frequent users, neglecting the behaviors of travelers and occasional users. By contrast, our study analyzed the entire user population, including travelers, the elderly, and individuals with disabilities.

Some studies have examined the travel mode change by the COVID-19 pandemic. The share of public transportation and pedestrian user decreased significantly in Stockholm (Jenelius and Cebecauer 2020). Similarly, in Korea, the pandemic has led to a reduction in public transport use, whereas the use of public bicycles and cars remained steady or even increased (Kim et al., 2021). These studies hint at a shift from public transportation to other modes. Understanding the public transportation usage during a pandemic could be valuable for future policy development.

Several studies have focused on the Kumamoto City Tram and its public transportation. Morita *et al.* (2017) analyzed data from the fiscal year 2014. Their cluster analysis revealed differences in usage according to the type of smartcard used. However, this study took place

during an introductory phase, and trends may have evolved over time—this necessitates further examination using data over a more extended period. Additionally, this study analyzed only the National IC card usage, essentially omitting users of other cards. Liu (2022a, 2022b) explored the impact of the COVID-19 pandemic on buses in Kumamoto Prefecture. The study found that bus stops in daily use maintained their patronage, although usage decreased around food, beverage, and accommodation facilities. However, the characteristics of specific cards, such as commuter passes, were not analyzed.

Although these studies demonstrate the impact of the COVID-19 pandemic, including changes in usage and personal attributes, they have not thoroughly analyzed time-of-day usage. Therefore, this study aimed to discern the characteristics of Kumamoto City Tram users during the COVID-19 pandemic. We examined smartcard data, with focus on the time-of-day usage at each stop. The insights derived could aid in marketing strategies aimed at promoting public transport.

The structure of this paper is as follows. **Section 2** outlines the data used for the analysis. **Section 3** characterizes the data. **Section 4** examines the changes in the tram usage during the COVID-19 pandemic. **Section 5** describes the changes in services during the pandemic. Finally, **Section 6** presents our conclusions and highlights areas for further investigation.

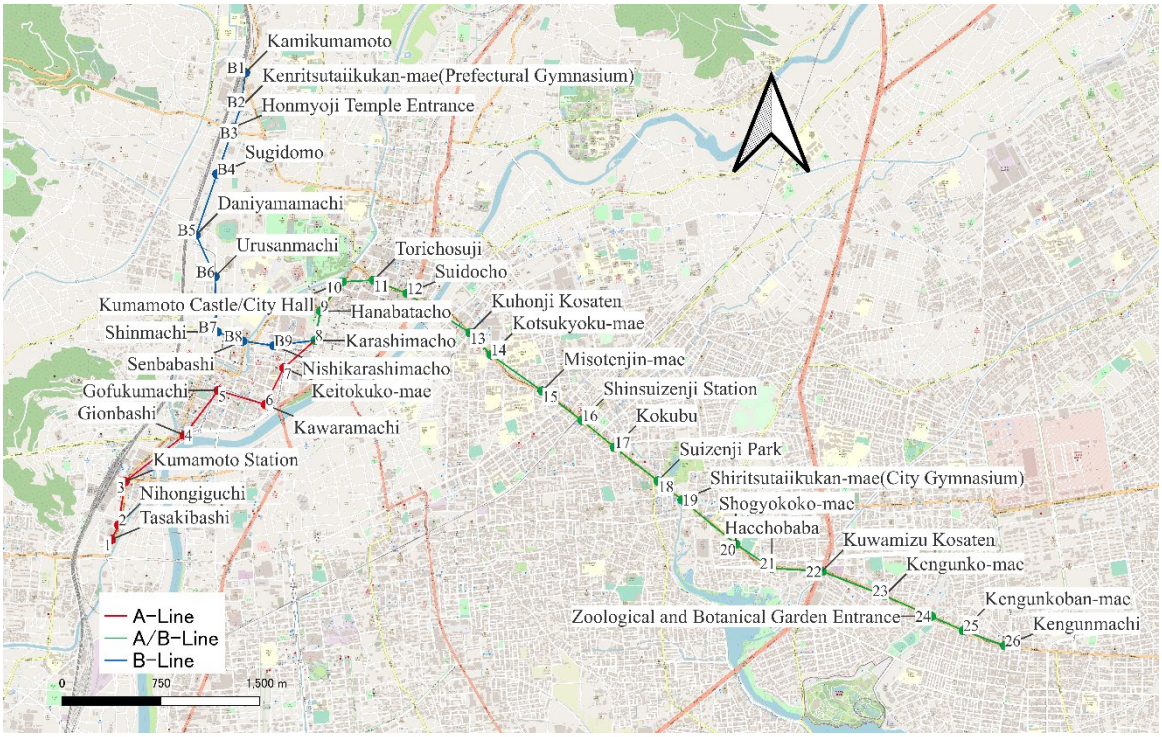


Figure 1 Kumamoto City tram stops

2. DATA SUMMARY

2.1 Target Area

This study is focused on the Kumamoto City Tram system, which operates in the heart of Kumamoto City. **Figure 1** illustrates the various tram stops throughout the city. The tram system comprises two main lines: the **A-Line** (9.2 km) extending from Kengunmachi to JR Kumamoto Station, and the **B-Line** (9.4 km) connecting Kengunmachi to JR Kamikumamoto Station. These lines have a combined total length of 12.1 km[1]. Kamitori and Shimotori Streets—which

are downtown areas—are on the route. the Kumamoto City Tram provides access to tourist hotspots such as Kumamoto Castle, the Zoological and Botanical Gardens, and Suizenji Park. Consequently, it experiences considerable patronage from tourists. In addition, its proximity to the City Hall, prefectural government offices, and numerous high schools makes it a preferred mode of transportation for the local commuting population.

2.2 Explanation of Data Used

This study employed smartcard usage data sourced from the Kumamoto City Transportation Bureau (**Table 1**). Four principal smartcard types are used on the Kumamoto City Tram: National IC pay-as-you-go, National IC commuter pass, Local IC, and SSIC. The National IC pay-as-you-go card, first introduced on March 28, 2014, is the most frequently used card on the tram. Compatible with public transportation systems across numerous Japanese cities, it is a popular choice among both local inhabitants and tourists. The National IC commuter pass, launched on October 1, 2014, is primarily utilized by regular commuters such as workers and students. Introduced on August 7, 2015[4], the Local IC card is predominantly favored by individuals holding bus commuter passes. Given its usability within Kumamoto Prefecture, it is likely to be extensively used by the local populace. Finally, SSIC cards are tailored for the disabled and elderly. This card was rolled out on March 1, 2016, as a welfare policy initiative of Kumamoto City. By presenting the Sakura Card—Kumamoto City's concession card—along with the SSIC card, disabled individuals and the elderly can avail of city fares at a reduced rate of 10% and 20%, respectively. Thus, SSIC cards are typically used by those with restricted access to other forms of transportation.

The analysis conducted in this study includes data spanning 2,557 days, from April 1, 2014, to March 31, 2021. Over this period, approximately 1.98 million unique IDs were observed, from which IDs were extracted based on specified conditions. Note that a single ID may be associated with multiple attributes; for example, a given ID may be linked to both National IC pay-as-go and National IC commuter pass.

Table 1 Summary of smartcard data

Type	National IC pay-as-you-go (nimoca, Suica)	National IC commuter pass	Local IC (Kumamo IC Card)	SSIC disabled (Odekake IC)	SSIC elderly (Odekake IC)
Period	4/1/2014–3/31/2021	10/1/2014–3/31/2021	8/7/2015–3/31/2021	3/1/2016–3/31/2021	
Number of IDs with trip (ID/7 years)	1,814,295			150,668	
	1,797,855	23,661	88,972	9,779	52,270
Item	(Annonymized) ID, payment date and time, board and get-off time, board stop, get-off stop, fare, kind of commuter pass type, vehicle numbers, number of payers, payment attribute, etc.				

3. BASIC ANALYSIS OF DATA

Data from the Kumamoto City Tram smartcards were used to examine daily fluctuations in the number of users, smartcard attributes, and behavioral patterns.

[4] https://corona.go.jp/news/pdf/kinkyujitaisengen_gaiyou0416.pdf

3.1 Changes in The Number of Users

The usage records of the smartcards were compiled daily to analyze the smartcard utilization status. Given that the Kumamoto City Tram operates between 05:00 and 25:00, a 'day' was defined as the 24-hour period from 03:00 to 27:00. **Figure 2** depicts a consistent increase in the number of smartcard users. After initial growth following their introduction, the number of National IC commuter pass users, SSIC disabled users, and SSIC elderly users plateaued, leading to a decline in the number of Local IC users. Cyclical fluctuations, such as variations tied to days of the week, were also observed. In April 2016, a significant drop in the number of paying users occurred, attributable to the Kumamoto earthquake on April 16 of the same year. User numbers returned to pre-earthquake levels roughly a month later. Additionally, an event named "Kumamoto Bus and Train Free Day" was held on September 14, 2019. Imagama et al. (2021) noted a 2.54-fold increase in overall public transportation users on this day. However, as smartcards were not utilized during this event, no corresponding data was recorded.

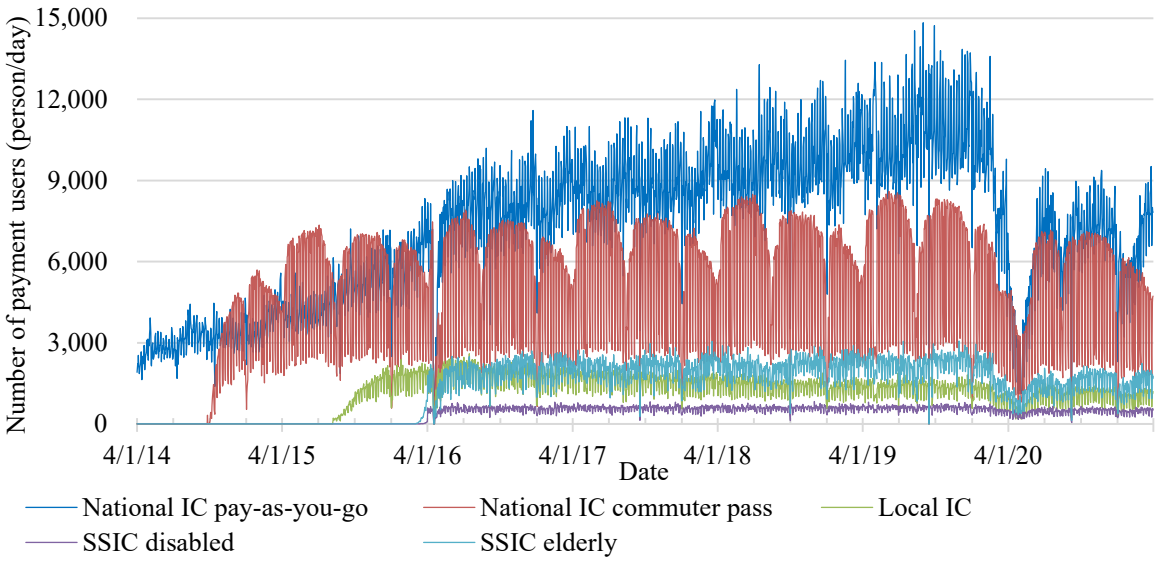


Figure 2 Daily number of smartcard users

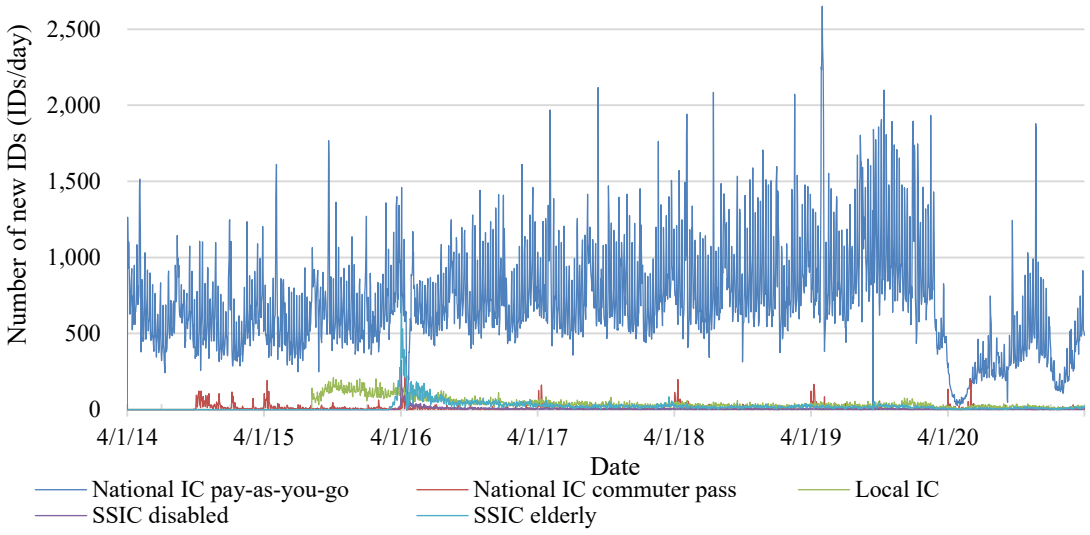


Figure 3 Daily usage of new IDs

Figure 3 displays the number of IDs for which each smartcard was used for the first time during the study period. Herein, individual counts for different payment types were tallied, even when associated with the same ID. The usage of the National IC pay-as-you-go card was extraordinary, with an increase of approximately 500 new IDs per day. A noticeable surge in the number of new Local IC users was observed immediately following its introduction; however, this subsequently subsided over time. In August, the number of new National IC pay-as-you-go card users increased, indicating greater usage for sightseeing. The number of new users decreased considerably from late February 2020, likely due to the impact of COVID-19 pandemic restrictions on outdoor activities, thus reducing the number of travelers. The number of National IC commuter pass users increased in early April, likely corresponding to the start of their renewal period.

3.2 Basic Analysis by Type of Smartcard

Data were analyzed using a classification of five payment types as delineated in **Table 1**. **Figure 4** illustrates a box-and-whisker plot of payment counts to examine potential variances across payment type. The vertical axis is displayed on a logarithmic scale, underscoring a substantial difference across the five types. The distribution of payments follows a long-tail trend. The median frequency of payments was highest among National IC commuter pass users, followed by SSIC disabled and elderly users. The lowest median corresponded to National IC pay-as-you-go users, which predominantly represents travelers.

An approximate Kruskal–Wallis test, a nonparametric test involving five sample groups, was conducted to elucidate median differences. The resulting chi-square value was 156,310 with four degrees of freedom, and the p-value was 2.2×10^{-16}. This result signifies a significant difference among the payment types. Consequently, multiple comparison tests were conducted, with the approximate Wilcoxon rank-sum test—a nonparametric test—being performed for all payment types using a Bonferroni correction. Across all payment types, the p-values were less than 0.05, indicating significant differences between the two groups. This confirms that the number of payments varies depending on the specific attributes of the smartcard.

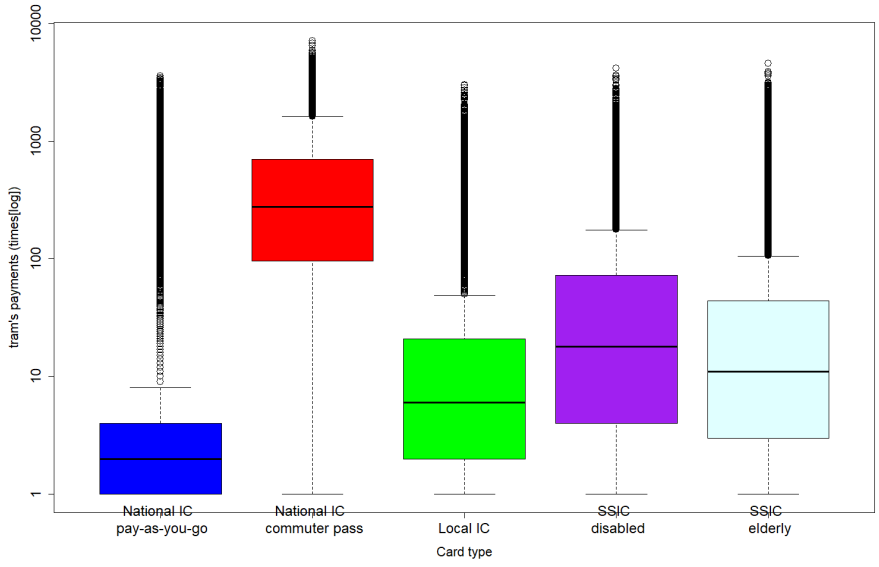


Figure 4 Number of payments by type

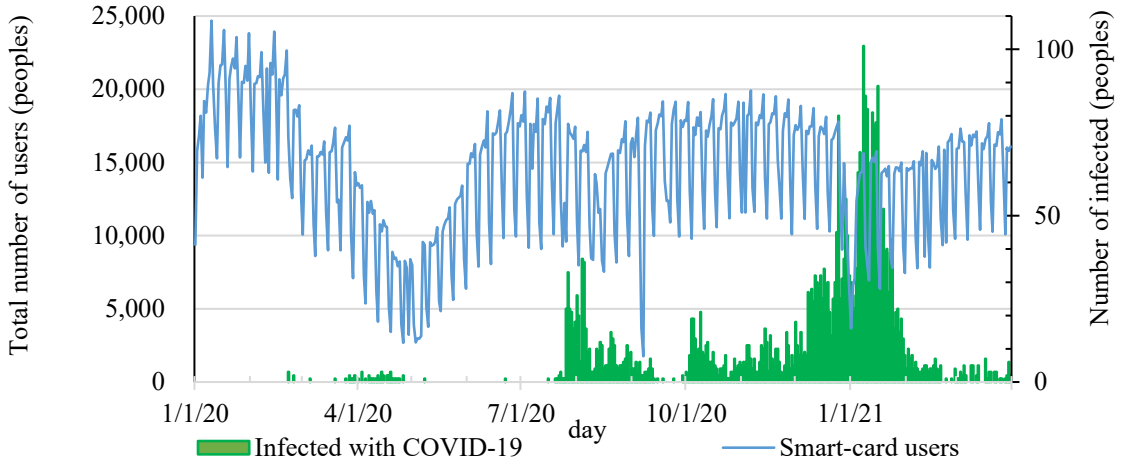


Figure 5 Changes in the number of COVID-19-infected people and the number of smartcard users

4. CHANGES IN USAGE DURING COVID-19

4.1 Effects of the COVID-19 Pandemic

Amid the global spread of COVID-19 in 2020, numerous countermeasures against the infectious disease were enacted. In Japan, the government took various steps—including the declaration of a state of emergency—to mitigate the strain on medical care delivery systems. Specifically, a state of emergency was declared on April 7, 2020, owing to the COVID-19 pandemic. By April 16, every region in Japan was under specific restrictions. On May 14, Kumamoto Prefecture was exempted from the emergency declaration. In January 2021, another state of emergency was declared in selected areas. Although Kumamoto Prefecture was not included, it issued its own local emergency declaration from January 18 to February 7, 2021[5]. **Figure 5** depicts the number of infected individuals and the total number of smartcard users in Kumamoto Prefecture.

The number of infected individuals was derived from publicly available data provided by the Ministry of Health, Labor, and Welfare[6]. The first confirmed case of infection in Kumamoto Prefecture was recorded on February 22, 2020. The number of users began to increase on weekdays following consecutive holidays in May, and remained stable in June, irrespective of the infection count. The number of users did not significantly drop during Kumamoto Prefecture's emergency declaration in January 2021.

Figure 6 displays the infection status in tandem with the number of new smartcard users. The number of new users declined considerably from late February, coinciding with the first recorded cases of COVID-19. A temporary surge was observed during three consecutive spring holidays around March 20. New general users could be identified on April 1 and June 1, following which the count declined. This downward trend continued during the emergency declaration, with a minimum of 34 users being recorded. The number of new users of the National IC commuter pass was confirmed on June 1. This outcome corresponds to the reopening of schools in Kumamoto City[7]. Moreover, the number of new users increased at the start of the emergency declarations.

[5] https://www.pref.kumamoto.jp/soshiki/0/81481.html
[6] https://www.mhlw.go.jp/stf/covid-19/open-data.html
[7]https://www.city.kumamoto.jp/common/UploadFileDsp.aspx?sub_id=8&prvck_cat_id=5&prvck_kiji_id=28374&c_id=5&id=28374&sub_id=1&flid=208407

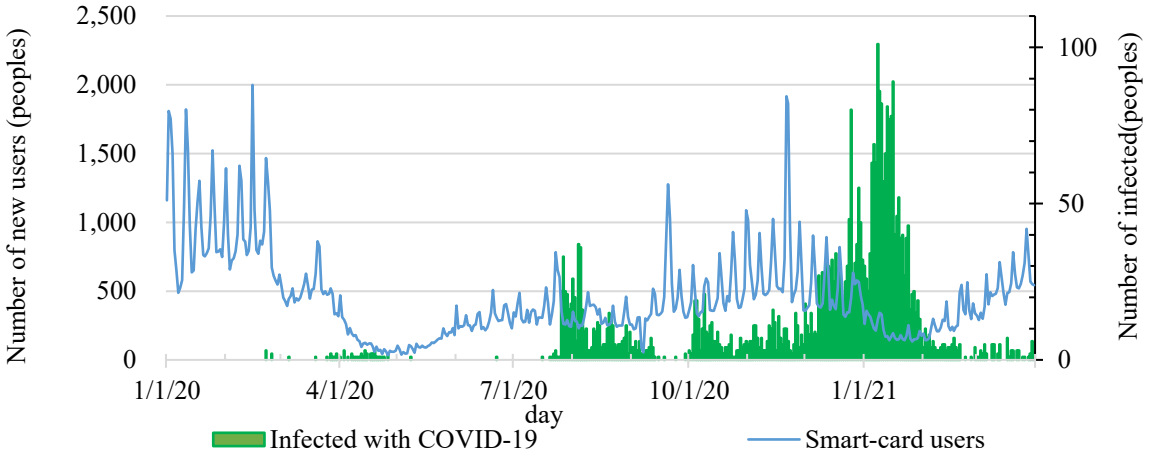


Figure 6 Changes in the number of COVID-19-infected people and the number of new smartcard users

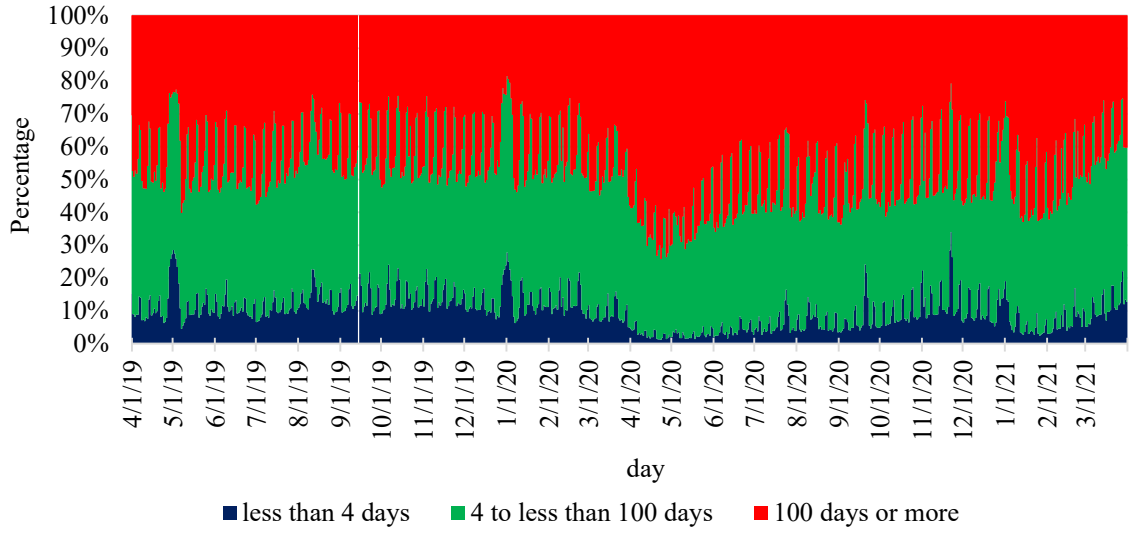


Figure 7 Usage ratio by number of IDs for the National IC pay-as-you-go payments

Figure 7 illustrates the percentage of users based on the number of daily payments over seven years. During the declared state of emergency, the low-frequency users—typically travelers—reduced their usage. However, the number of low-frequency users temporarily increased during the three-holiday period. Note that the government initiated its "Go to Travel" campaign on July 22 to subsidize accommodation and other travel expenses (with certain areas exempted)[8].

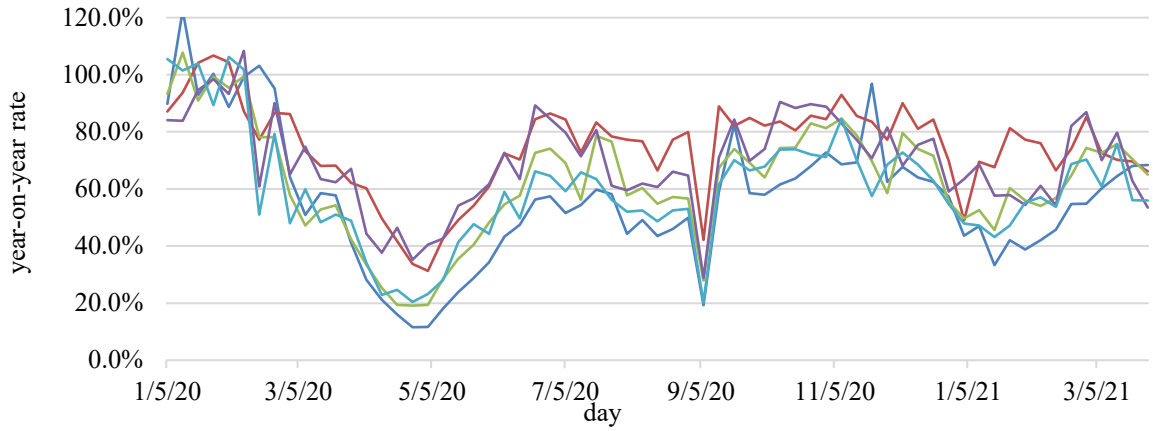
4.2 Differences by Card Type

Following a similar approach to Nakamura and Kanda (2022), we assessed the impact magnitude of each card type. To explore the effects of weekdays and holidays, we compared data from Sundays and Thursdays. The average daily values for Sundays and Thursdays in 2019 were used as a base value (100%). **Figure 8(a)** presents the trend on Sundays. A decline in user count can be observed from mid-February 2022. During the emergency declaration, the number of National IC commuter pass users and SSIC disabled users was approximately 40%, whereas

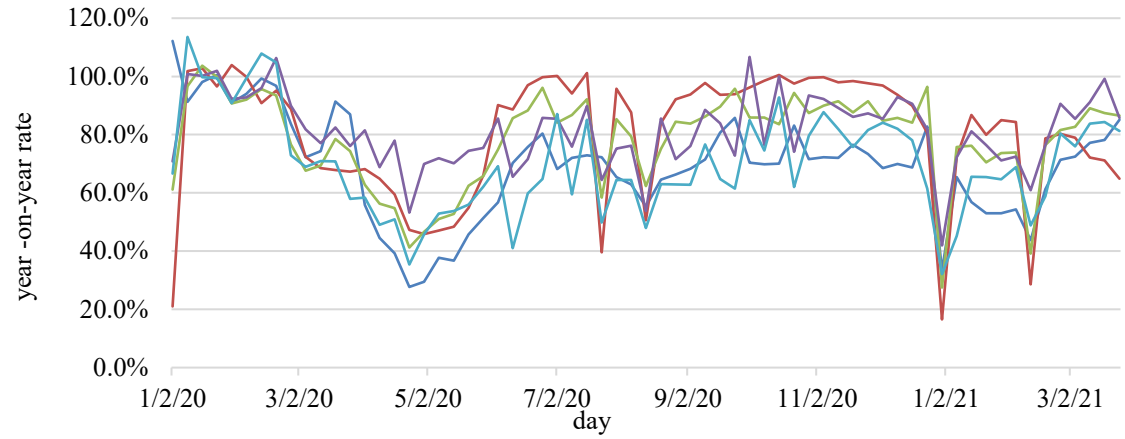
[8] https://www.mlit.go.jp/kankocho/page01_000637.html

the number of Local IC and SSIC users was approximately 20%, and the number of National IC pay-as-you-go users was approximately 10%. Post-emergency declaration, the user count began to recover: National IC commuter pass users reached approximately 80%, SSIC disabled users reached 60–70%, and SSIC elderly and National IC pay-as-you-go users reached 50–60%. However, the number of National IC commuter pass users decreased by 10–20% from the end of the year 2020 to the period when Kumamoto Prefecture declared its state of emergency. Subsequently, the number recovered but remained at approximately 50–80%.

Figure 8(b) shows the year-on-year change in user count on Thursdays. The percentage of SSIC disabled users is higher than that on Sundays, presenting a declining trend from mid-February 2020. During the emergency declaration, the user count for the disabled was 60–70%, National IC commuter pass users was approximately 50%, Local IC and SSIC elderly users were approximately 40%, and National IC pay-as-you-go users were approximately 30%. Subsequently, the number of National IC commuter pass users recovered to nearly 100%.



a) Sunday



b) Thursday

Figure 8 Year-on-year change in the number of users

The figures for the SSIC disabled and Local IC users were 80%, whereas those for the SSIC elderly and National IC pay-as-you-go users were 60–70%. However, when the Kumamoto Prefecture declared its state of emergency, the total number of users decreased by 20%. Post-emergency declaration, the number of National IC commuter pass users further decreased, whereas the those of other categories returned to their original levels.

These results indicate that commuter pass users and those with disabilities recovered faster, the values for SSIC elderly users being marginally lower than those for the commuter pass users. This is likely because COVID-19 poses a higher risk of severe illnesses in the elderly, thus reducing their propensity to travel. Recovery for National IC pay-as-you-go users was notably slower, which could be attributed to many of them being infrequent users or tourists. Comparing Figure 8 a) and b), the figures were higher on Thursday, thus indicating that the recovery trend varies for each day of the week.

4.3 Changes by Time of Day

To determine the changes in time-of-day usage, we compared 2019—the year before the COVID-19 pandemic—with 2020—the year of the pandemic. **Figure 9** displays the average number of users per day in 2019 and 2020. Days with zero users due to "bus- and train-free days" were excluded.

The overall number of National IC card pay-as-you-go users decreased (**Figure 9 (a)**). In 2019, user count peaked at 18:00, whereas in 2020, it peaked at 08:00 and 18:00 almost equivalently. In 2019, some occasional users of Kumamoto Tram would travel to the city center after work and returned home late at night.

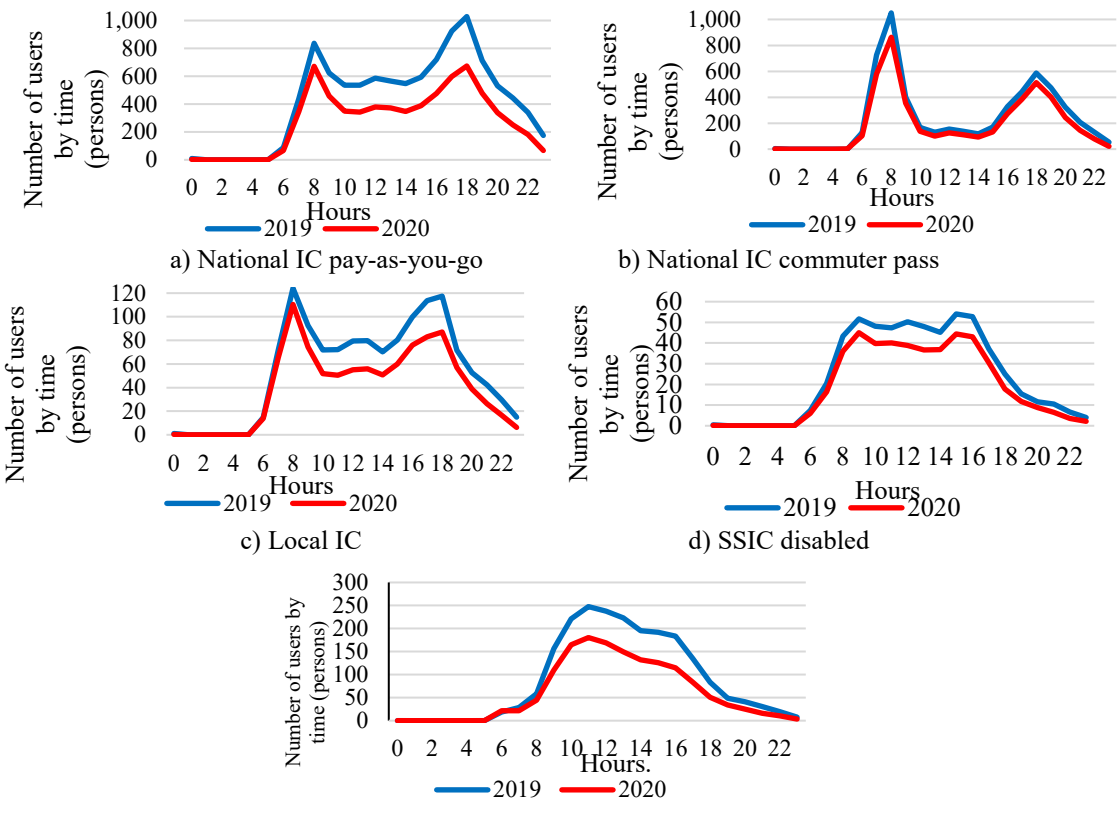


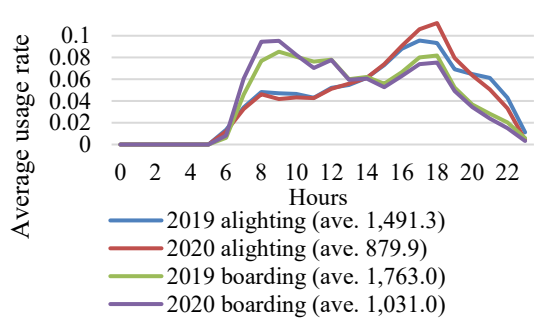
Figure 9 Time distribution of users by type

As shown in **Figure 9(b)**, the overall count of National IC commuter pass users decreased, with no discernible difference in time-of-day usage. Despite the recommendation of staggered work hours, commuting behavior remained consistent. The number of National IC commuter pass users was low during the daytime. **Figure 9(c)** shows that the decrease in the number of Local IC users from 06:00 to 08:00 was minimal, whereas the reduction from noon to evening was substantial. The small decrease in the morning can be attributed to that some local IC users were commuters using both bus and tram.

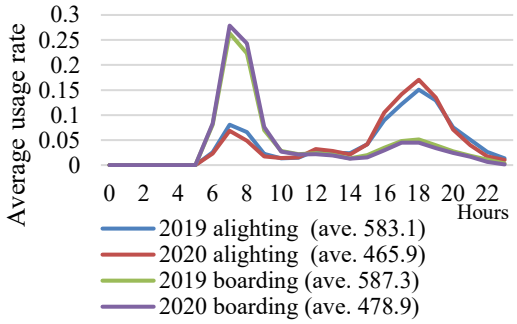
As depicted in **Figure 9(d)**, the overall count of SSIC-disabled users decreased. Users with disabilities are characterized by peak usage at 09:00 and between 15:00 to 16:00. Similarly, as illustrated in **Figure 9(e)**, the count of SSIC elderly users also declined, exhibiting a mountain-shaped usage pattern peaking around 11:00.

4.4 Differences in Stops

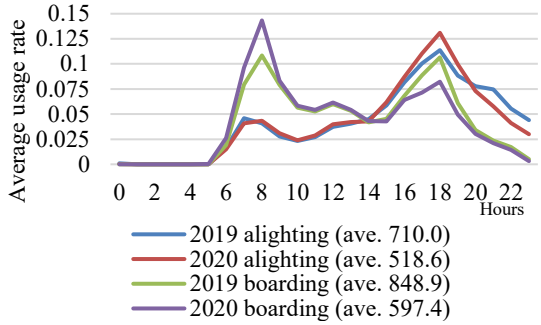
The targeted tram stops include Kumamoto Station (populated largely by National IC pay-as-you-go users), Shinsuizenji Station (frequented by numerous National IC commuter pass users), and Torichosuji located in the central area.



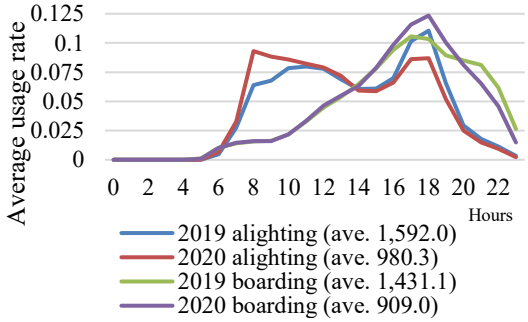
a) National IC pay-as-you-go users at Kumamoto Station



b) National IC commuter pass users at Shinsuizenji Station



c) National IC pay-as-you-go users at Shinsuizenji Station



d) National IC pay-as-you-go users at Torichosuji

Figure 10 Time-of-day usage of stops

Figure 10(a) depicts the time-of-day usage of National IC pay-as-you-go users at Kumamoto Station. The average annual number of paying users (notated next to the legend) revealed a decrease in both boarding and alighting users in 2020 compared with in 2019. At Kumamoto Station, a terminal station, usage was observed throughout the day for both boarding and alighting. The proportion of morning boarders and passengers alighting during 16:00–20:00 decreases gradually, whereas the proportion of both those boarding and alighting post-21:00 decreased significantly.

Figure 10(b) and **(c)** display the time-of-day usage by National IC commuter pass users and National IC pay-as-you-go users, respectively, at Shinsuizenji Station. In 2020, the proportion of commuting passengers increased during commute hours, whereas it slightly

decreased during non-commute hours. It is important to note that the increase is relative and the absolute number of users for each time period in 2020 does not exceed that of 2019. The distribution of National IC pay-as-you-go users was higher in the morning and evening, whereas the daytime user ratio surpassed that of the National IC commuter pass users. The average daily user count during the 8:00 period exhibited a decline of only 11.4 users. Consequently, the behavior during the evening and late-night periods changes considerably. The high proportion of evening boardings and late-night alighting in 2019 could be attributed to round-trip journeys associated with social gatherings in the city center and other areas. However, given the constraints of the COVID-19 pandemic, these activities were no longer viable, thus altering the late-night usage pattern.

Finally, we examined Torichosuji in the city center, situated between two urban arcades, Kamitori and Shimotori Streets. This location is ideal for understanding the real-world usage of downtown areas. **Figure 10(d)** shows the percentage of pay-as-you-go users segmented by the time of day. Given that this is a downtown area, morning boarding is minimal, whereas evening boarding is substantial. Morning and daytime boarding as well as alighting can likely be attributed to recreational activities, such as travel.

Evening alighting is potentially linked to social events, which may have decreased owing to the difficulties in organizing them amidst the COVID-19 pandemic.

5. CLUSTER ANALYSIS OF CHANGES IN THE USE OF STOPS IN COVID-19

5.1 Cluster Analysis and Data Overview

The findings confirmed a decrease in user numbers due to the impact of the COVID-19 pandemic and a relative increase in the use of stops during commuting hours. Changes in the actual usage of stops are related to the diverse purposes for which these stops are utilized. However, as highlighted in **Section 4.4**, visualizing all stops and card characteristics is not easy. Therefore, we can minimize the number of visualizations by grouping similar features to understand the stop characteristics. Moreover, data with similar values can be collected using hierarchical cluster analysis.

By understanding the characteristics of each data group collected, we can clarify the attributes of stops. If a shift in group characteristics or in the group breakdown before and after the COVID-19 pandemic is noted, we can consider COVID-19 to have had a significant impact on the stops. The data are presented in **Table 2**.

Table 2 Cluster analysis variables

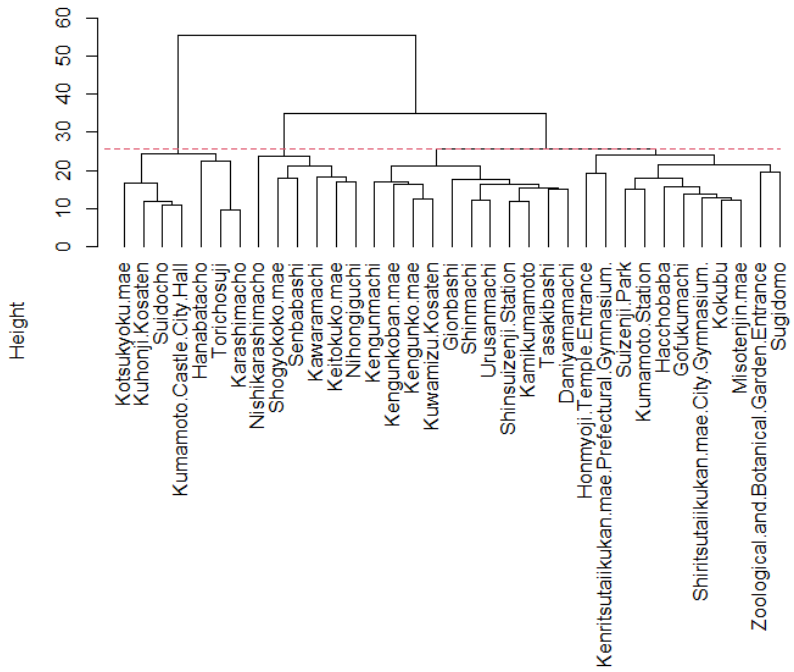
Variable	Type
Stop	35
Smartcard type	5
Ride-on record	1
Get-off record	1
Average number of uses per day (ride stop/ get-off stop)	1
Daily average hourly usage rate (excluding 01:00–04:59)	20

For each type of smartcard and each boarding and alighting record for each stop, we compiled 21 variables for the average daily passenger count and the average hourly passenger percentage from 05:00 to 24:59—excluding 01:00–04:59, when service is unavailable. Because

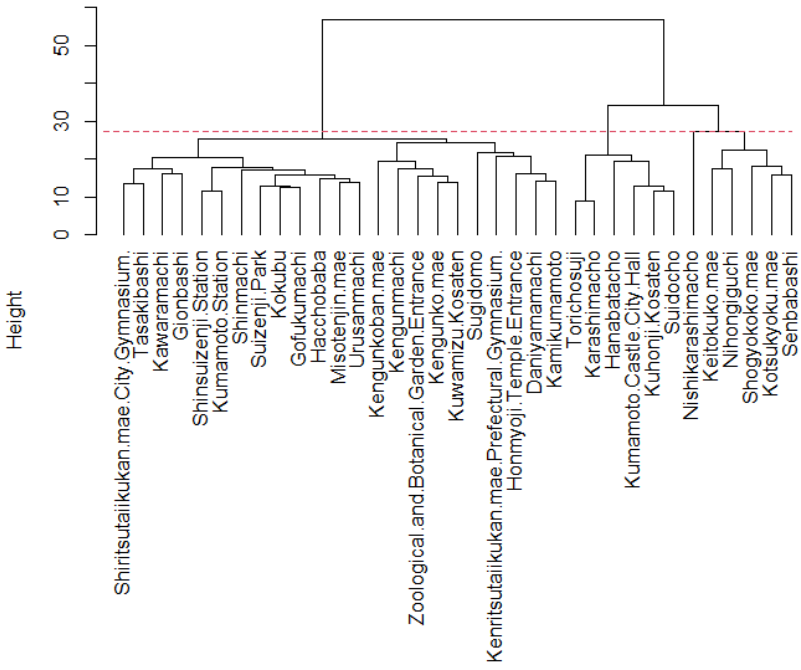
of the differing scales of the average daily ridership and the average hourly ridership percentage, each variable was normalized. The cluster analysis used the Ward method with Euclidean distance.

5.2 Results of Cluster Analysis

The dendrograms for 2019 and 2020, before and after the COVID-19 pandemic, are depicted in **Figure 11**. The total of 35 stops could be categorized into three groups—namely, groups A, B, and C (from left to right) in 2019, and groups C, A, and B (from left) in 2020. **Table 3** presents the group averages of the daily user count for 2019 and 2020.



a) Dendrogram of stops in 2019



b) Dendrogram of stops in 2020

Figure 11 Dendrograms for 2019 and 2020 before and after the COVID-19 pandemic

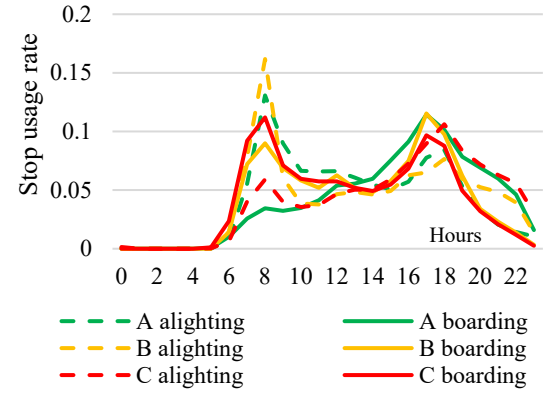
Table 3 Group average of the average number of daily users

	Year	Group	National IC pay-as-you-go	National IC commuter pass	Local IC	SSIC disabled	SSIC elderly
Alighting	2019	A	676.9	299.3	83.5	33.6	129.3
		B	82.6	66.9	12.5	4.3	18.1
		C	226.0	146.2	29.0	14.4	50.4
	2020	A	489.1	265.3	68.0	29.1	95.7
		B	67.0	73.7	12.3	5.5	15.2
		C	150.1	114.5	21.6	11.1	34.5
Boarding	2019	A	556.0	284.8	73.5	31.3	117.9
		B	90.8	63.5	12.8	4.8	19.9
		C	262.2	151.7	32.1	15.0	53.5
	2020	A	409.9	256.4	60.6	27.6	87.7
		B	69.6	70.0	12.3	5.1	15.8
		C	170.1	117.8	23.6	11.7	36.4

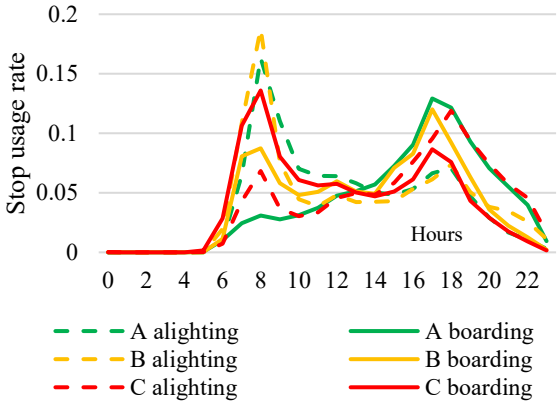
Table 4 Annual comparison of affiliation groups

Stop number	Stop	'17	'18	'19	'20
1	Tasakibashi	C	C	C	C
2	Nihongiguchi	B	B	B	B
3	Kumamoto Station	C	C	C	C
4	Gionbashi	C	C	C	C
5	Gofukumachi	C	C	C	C
6	Kawaramachi	C	C	B	C
7	Keitokuko-mae	C	B	B	B
8	Karashimacho	A	A	A	A
9	Hanabatacho	A	A	A	A
10	Kumamoto Castle/City Hall	A	A	A	A
11	Torichosuji	A	A	A	A
12	Suidocho	A	A	A	A
13	Kuhonji Kosaten	B	A	A	A
14	Kotsukyoku-mae	B	A	A	B
15	Misotenjin-mae	C	C	C	C
16	Shinsuizenji Station	C	C	C	C
17	Kokubu	C	C	C	C
18	Suizenji Park	C	C	C	C
19	Shiritsutaiikukan-mae (City Gymnasium)	C	C	C	C
20	Shogyokoko-mae	B	B	B	B
21	Hacchobaba	C	C	C	C
22	Kuwamizu Kosaten	C	C	C	C
23	Kengunko-mae	C	C	C	C
24	Zoological and Botanical Garden Entrance	C	C	C	C
25	Kengunkoban-mae	C	C	C	C
26	Kengunmachi	C	C	C	C
B1	Kamikumamoto	C	C	C	C
B2	Kenritsutaiikukan-mae (Prefectural Gymnasium)	C	C	C	C
B3	Honmyoji Temple Entrance	C	C	C	C
B4	Sugidomo	C	C	C	C
B5	Daniyamamachi	C	C	C	C
B6	Urusanmachi	C	C	C	C
B7	Shinmachi	C	C	C	C
B8	Senbabashi	C	B	B	B
B9	Nishikarashimacho	B	B	B	B

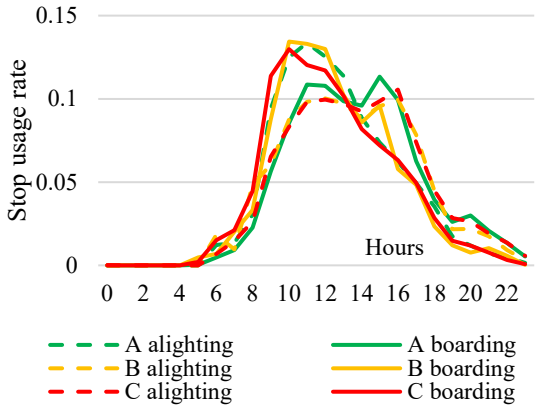
Table 4 depicts the group transitions from 2017 to 2020. Group A comprises stops near the city center, whereas Group B includes stops near the city center, schools, and joint government buildings. Group C consists of many stops located in residential areas and at JR-Kyushu nodes. **Figure 12(a)** (2019) and **Figure 12(b)** (2020) illustrate the characteristics of each group by showing the average usage ratio by time of day for each group of National IC pay-as-you-go users. **Figure 12(c)** and **12(d)** display the average usage percentages by time of day for 2019 and 2020, respectively, for each group of SSIC users.



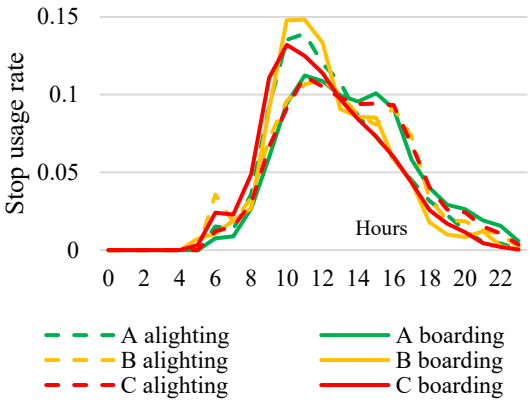
a) National IC pay-as-you-go users in 2019



b) National IC pay-as-you-go users in 2020



c) SSIC elderly users in 2019



d) SSIC elderly users in 2020

Figure 12 Usage ratio by time period of average value for each group

5.3 Characteristics of Each Group and the Impact of the COVID-19 Pandemic

When comparing 2019 and 2020, the average daily user count for each group decreased (**Table 3**). However, the trend of the average number, $A > C > B$, remained unchanged. The group classification altered only at two stops (Kawaramachi and Kotsukyoku-mae). Consequently, the passenger usage pattern of the stops remained largely unaffected during the COVID-19 pandemic.

Table 5 summarizes the characteristics of the three groups. Group A is located in the city center, with a high volume of tram users during commuting hours and the evening. Group B has characteristics indicative of commuting destinations—morning alighting and evening boarding are high. Evidently, passengers use trams for their evening commute home. Group C serves as the starting point for commuting to work and school, with morning boarding and

evening disembarking being the most frequent. Additionally, passengers use trams to commute home in the evening.

Table 5 Group characteristics

Group	Name	Special characteristic
A	High usage areas	• High average number of users • Morning ride usage is low • Morning and evening drop-off use is high
B	Commuting destinations	• Low average number of users • Morning ride usage is low • High use of drop-offs in the morning • There is use later in the evening
C	Commuting starting points	• Average number of users is equal to the average • Morning ride use is high • High use of drop-offs in the evening and later

COVID-19 resulted in a considerable decrease in the number of users, reduction in evening and nighttime usage, and relative increase during commuting and schooling hours. However, changes in the usage characteristics of stops could not be conclusively linked to the COVID-19 pandemic.

6. CONCLUSIONS

In this study, we evaluated the impact of the COVID-19 pandemic on the usage patterns of the Kumamoto City Tram through the analysis of smartcard data. The significant findings of our investigation are summarized as follows.

1) Smartcard utilization varied according to the type of card, with National IC commuter pass users and SSIC users exhibiting increased frequency of use.
2) The volume of users fluctuated depending on the day of the week. During the recovery phase from the COVID-19 pandemic, we noted a more pronounced trend on Thursdays as compared with Sundays. The usage distribution of National IC commuter pass users remained fairly consistent throughout the year.
3) Overall user volume has been on the decline owing to COVID-19; as of 2021, the user count was 60–80% of the 2019 level. However, the usage of the National IC commuter pass recovered quickly to the 2019 level.
4) The characteristics of tram stop usage could be categorized into three primary groups: central high usage areas, commuting destinations, and commuting starting points.
5) The COVID-19 pandemic did not change the usage characteristics of the stops, although overall usage declined.

The future course of action and potential research avenues can be outlined as follows:

1) This analysis was conducted from a macro perspective. Moving forward, we encourage the use of the system by conducting a microanalysis. The current examination served as an exploratory inquiry, and no explicit policies have been proposed to promote public transport based on our findings. However, a more detailed analysis using individual data could yield viable recommendations for such policies.
2) Our analysis was limited to hourly and annual timeframes. A detailed analysis of the minute

and monthly levels could allow for tracking more subtle shifts in usage.

3) This study categorized users as either National IC pay-as-you-go visitors or National IC commuter pass users commuting to work or school. However, detailed attributes of individual users remain unknown. Therefore, a more accurate segmentation approach leveraging ride frequency or timing patterns is desirable.
4) Individual attributes remain unidentified in smartcard data. A questionnaire survey could provide more detailed analysis, thus enabling us to examine the changes in smartcard usage during the COVID-19 pandemic by understanding factors such as demographics, land use type, and work attributes.
5) We utilized annual averages in our cluster analysis. However, cluster analysis could be applied to reveal the characteristics of shorter periods (such as during the declaration of a state of emergency) and to group time-series data according to time. Although our cluster analysis focused on usage characteristics, the population distribution and industries surrounding tram stops should be characterized.

ACKNOWLEDGMENTS

We would like to express our deepest appreciation to the Kumamoto City Transportation Bureau for providing the data.

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