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How flexible are travellers under flexible transportation services?

- some insights from real-world observations -

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Contents

1.Background and objective

- Issues in public transport services
  - Shortage of drivers
  - Scattering travel demand
  - Depopulation
- Expectation for flexible transport systems
  - Service variation according to demand
  - Effectiveness in wide and flat areas
- Issues in flexible transport systems
  - Despite reduced service costs, total costs may not decrease due to increased operator and system costs.

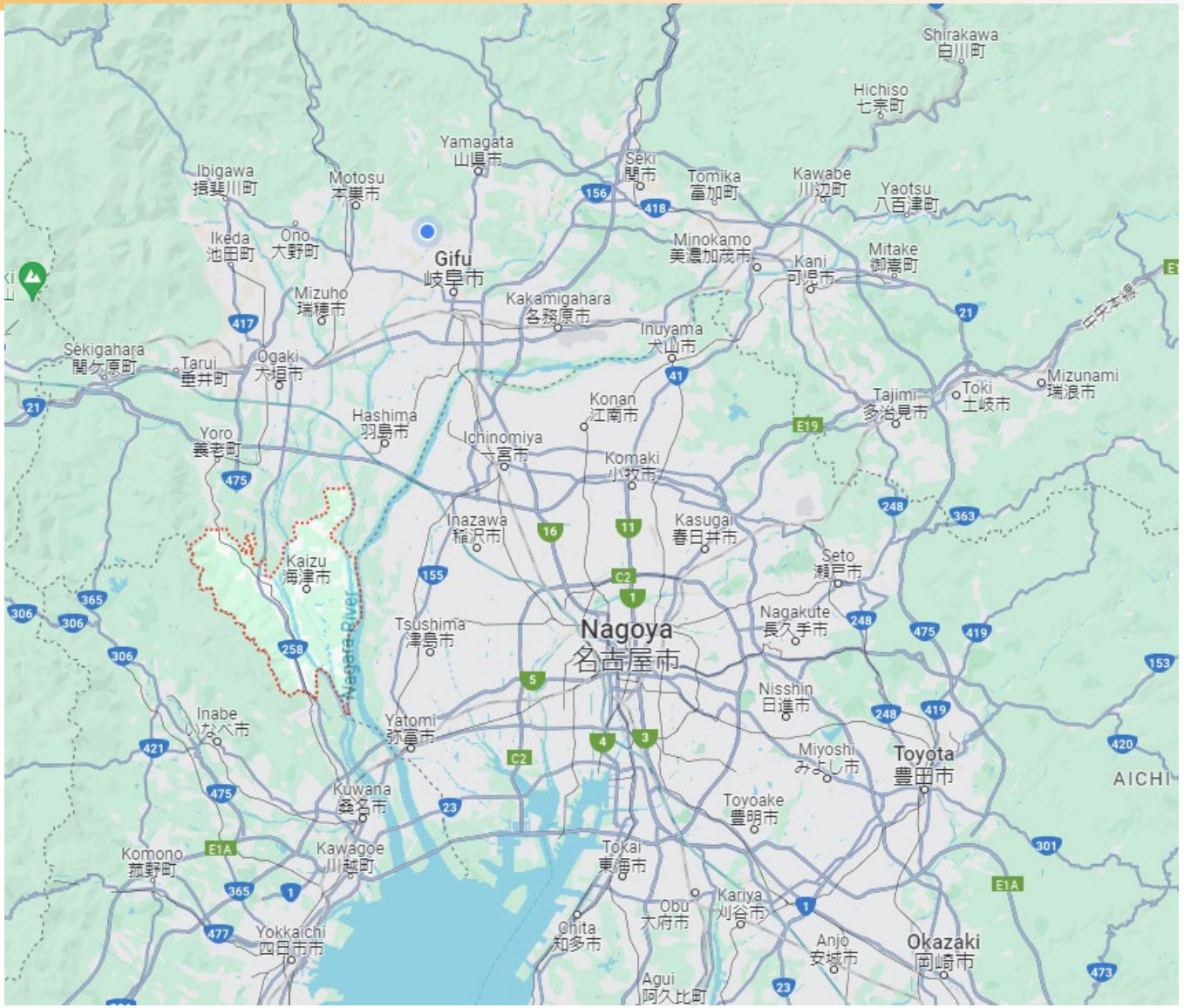
1.Background and objective

- Added values of flexible transport systems
  - Introduction of booking and vehicle assignment system
  - Comprehensive booking data storage
  - Detailed understanding of travel demand
  - Long-term individual tracking
- Objective

The examination of traveler behavior within a flexible transport system is conducted using booking data.
Particular focus is given to understanding and discussing the regularity exhibited in traveller behavior throughout this study.

2.Summary of Kaizu City

- Population: 31,174 (2023/12/1)
- City size: 112.03km^2
- Population density:
  278 persons/km^2
- Yoro mountains on western side, mostly flat areas



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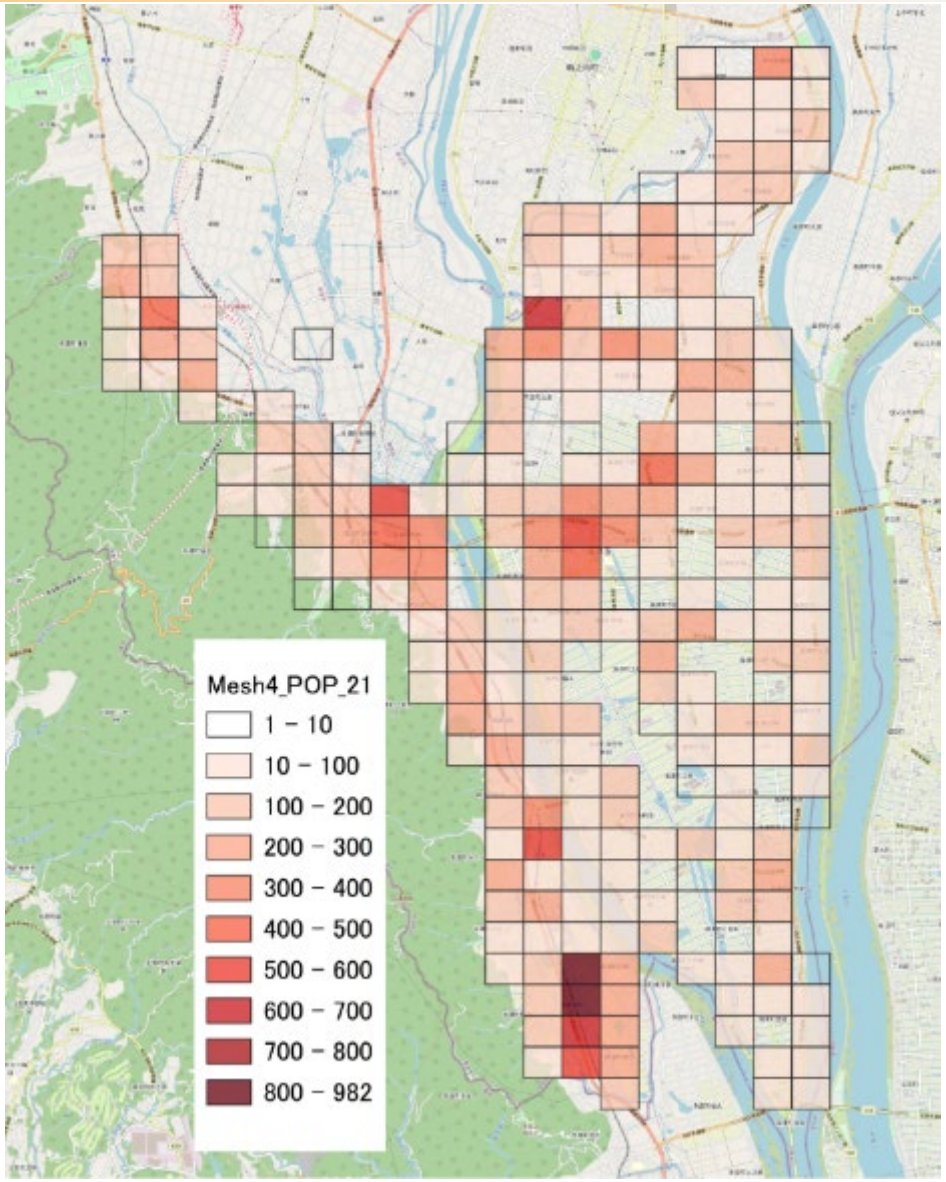
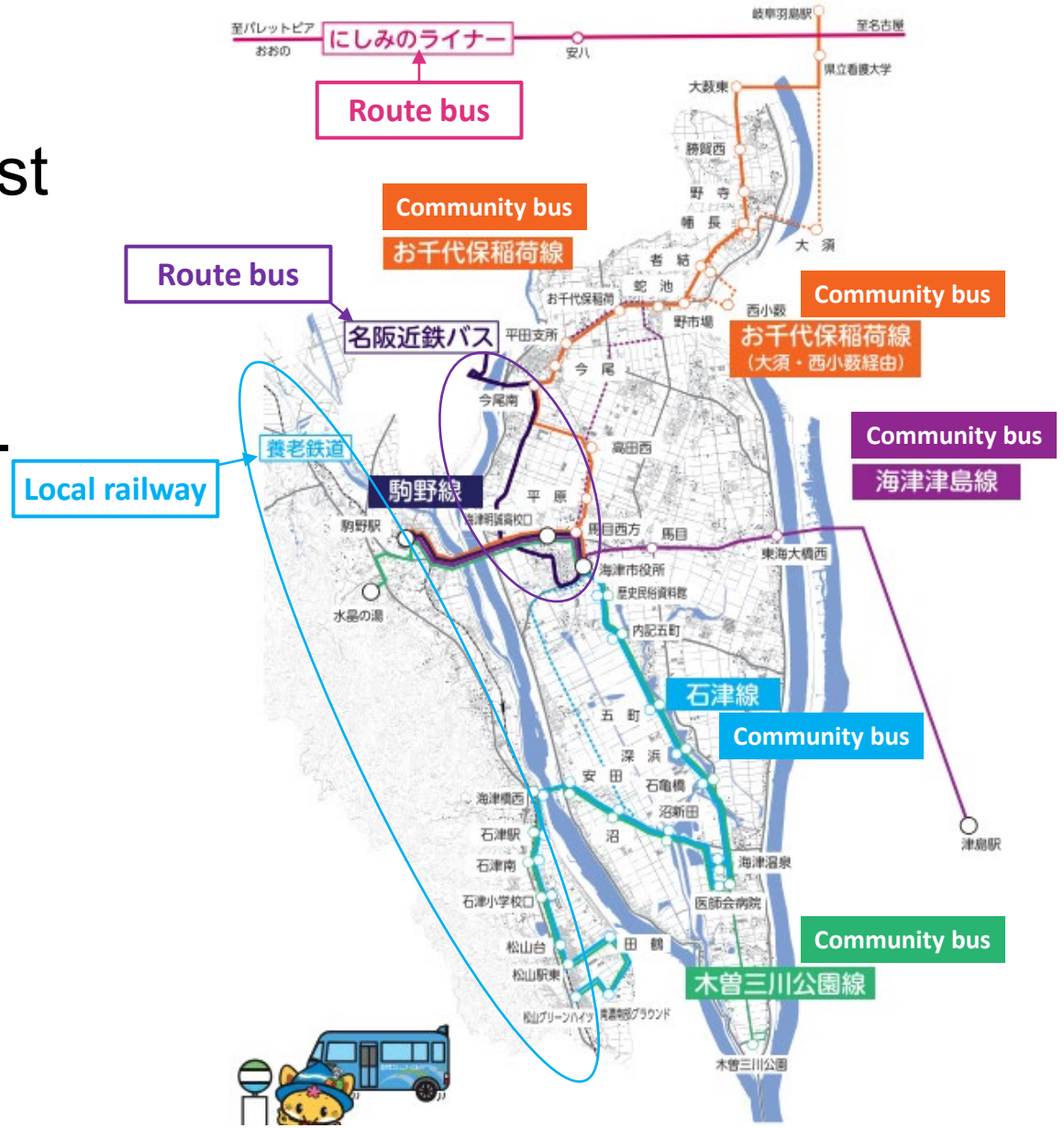


Population Density

2.Summary of Kaizu City

Public transport in Kaizu

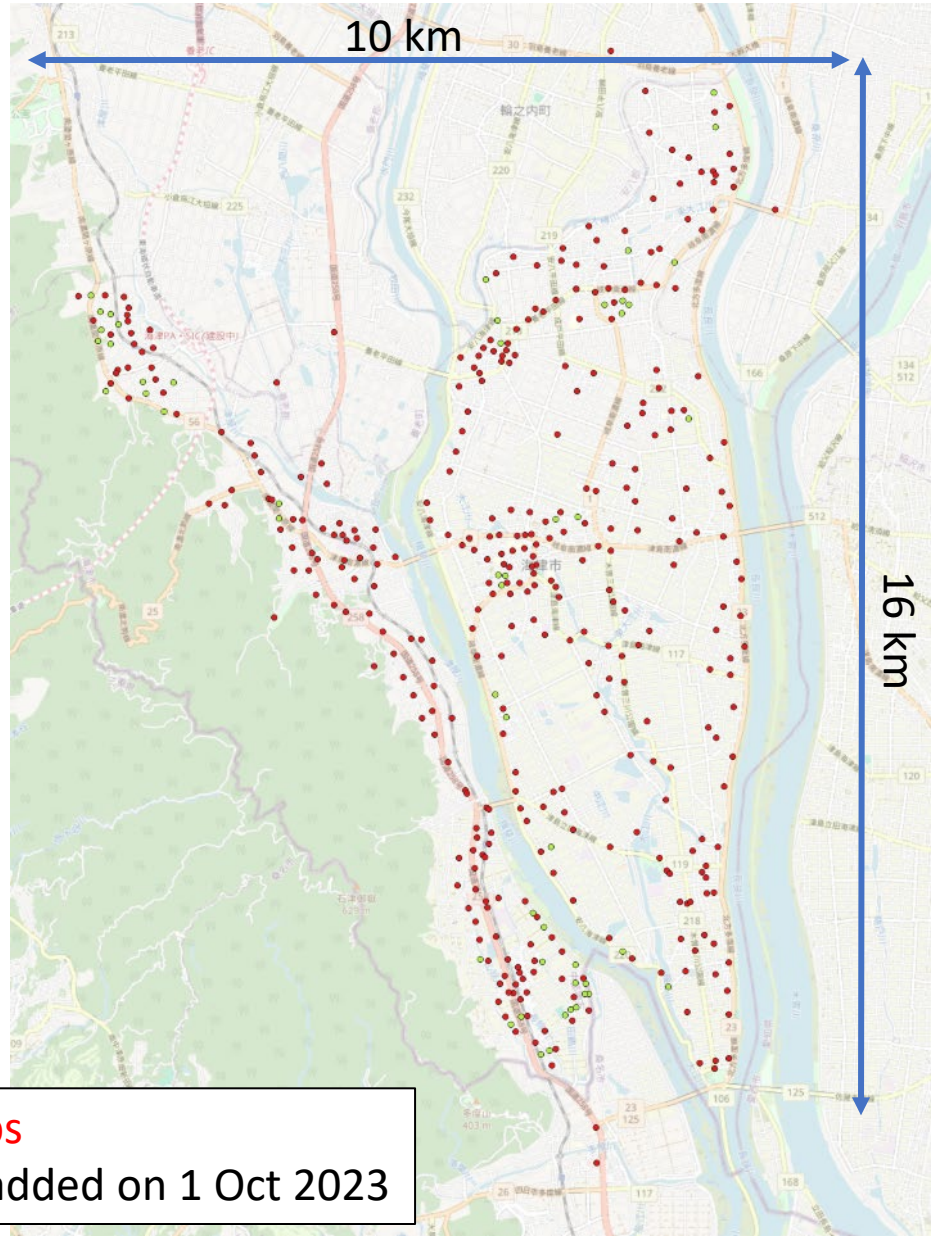
- Local railway (Yoro Tetsudo) on west
- Route bus (Meihan-Kintestu Kaizu line, Nishimino Relay Bus)
- Community bus (Komano, Ochobo-Inari, Kisosansen Park, Ishizu and Kaizu-Tsushima)
- Demand Responsive Transport for whole Kaizu city area



3.Overview of DRT in Kaizu

Basic information of DRT

- 8:30-17:00 From Monday to Saturday(Since2023/10)
- Child: 200 yen
- Adult: 400 yen
- Elderly (65+): 200 yen
- Passport (Monthly Travelcard): 3,000 yen
  - terminated on 2020/9/20
- Booking is required at least 30 minutes before the preferred departure time.
  - Booking on the previous day is required if one wish to get a ride by 9:30.
- 422 Bus stops
- Internet booking is available for registered users
  - Available from 2022/7/1 (6:00 to 22:00)



Bus stops
Green: added on 1 Oct 2023

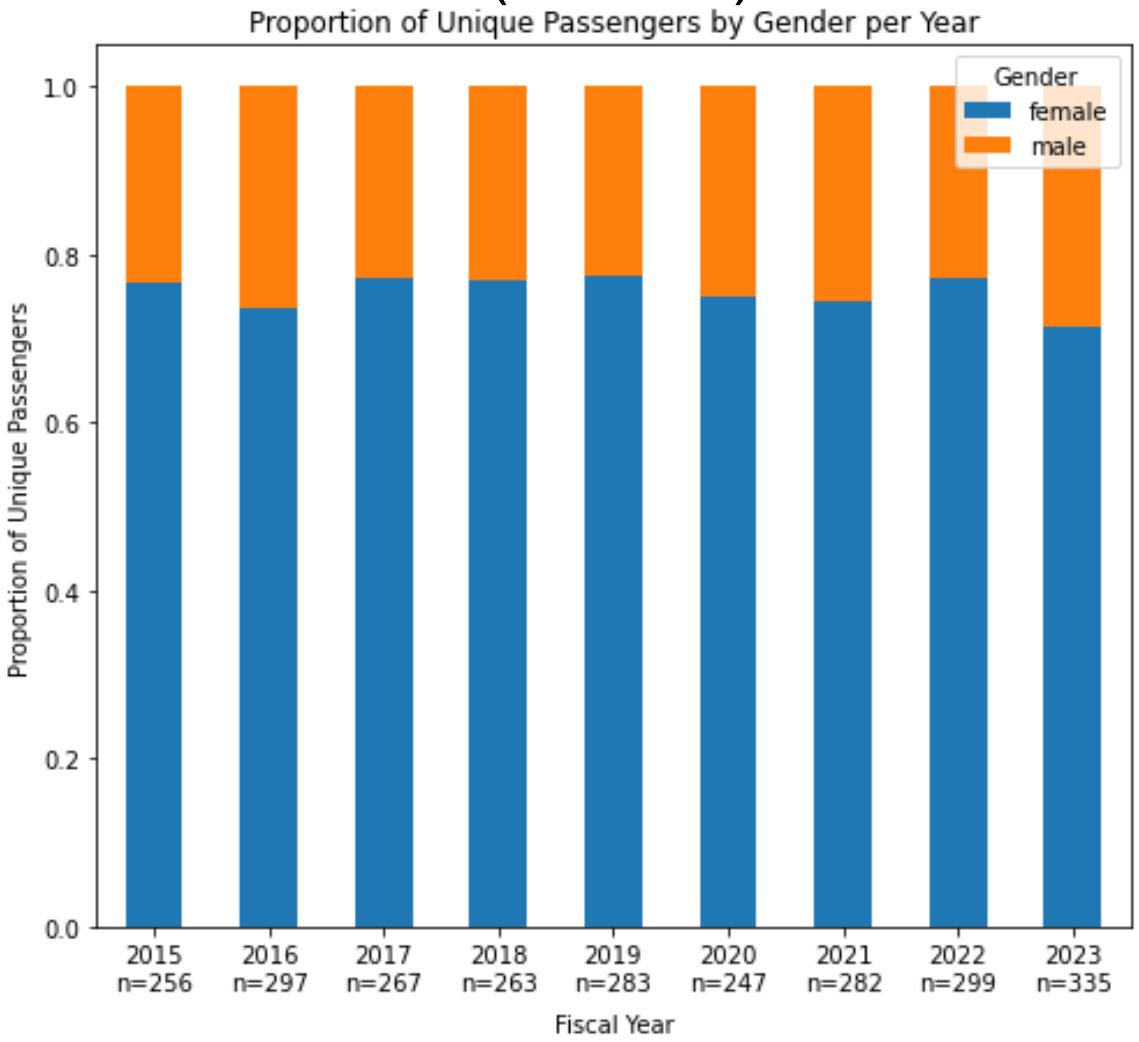
3.Overview of DRT in Kaizu

Booking Data

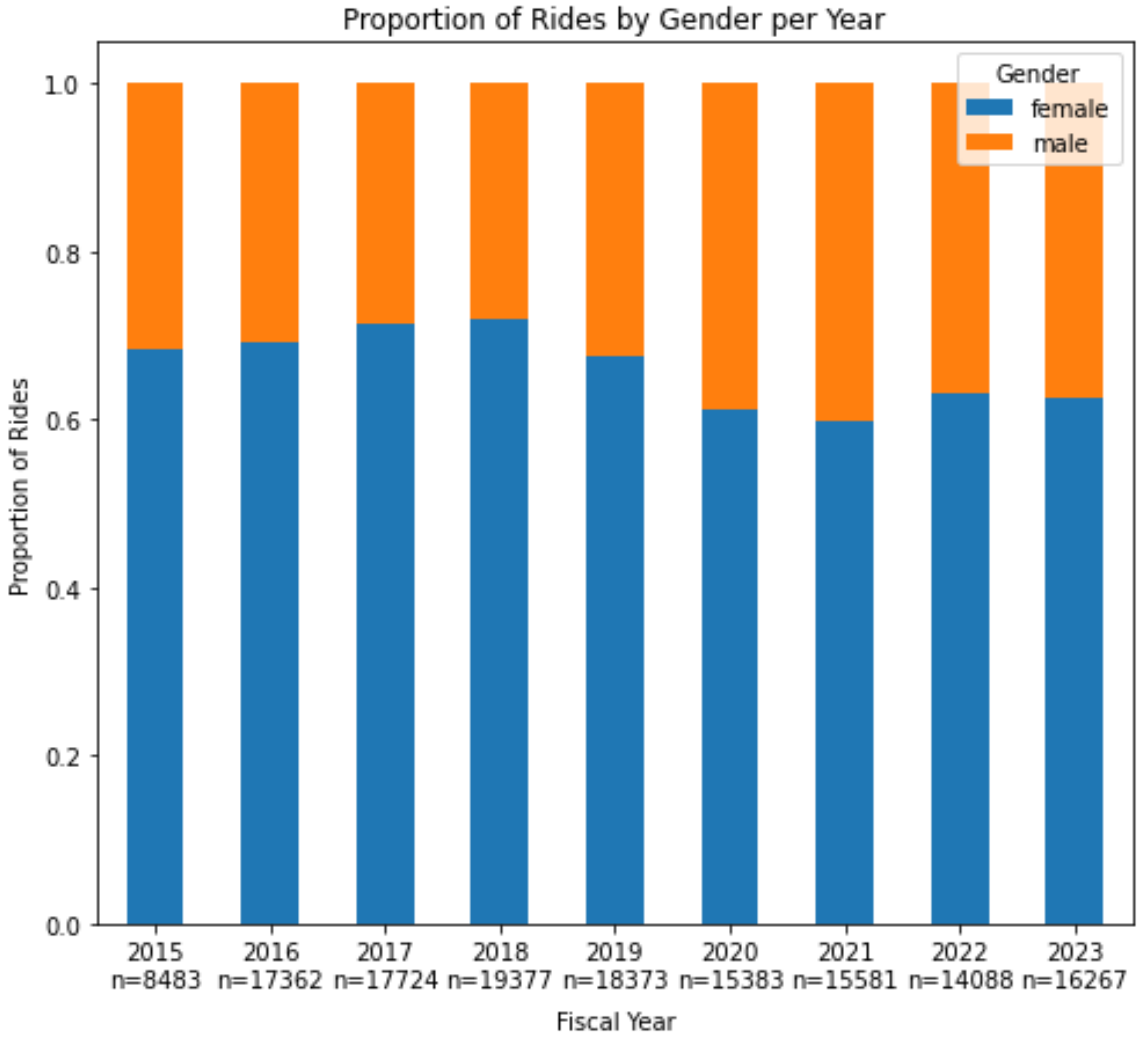
- Periods: 2015/10-2024/4 (about 9 fiscal years)
- Number of records: 142,638
- Number of users: 845
- Number of service days: 2086
- Average number of records /day: 68.4
- Average number of users /day: 36.6
- Data columns
  - Date, Booking #, ID, Gender, Age, Subarea (Home), Subarea (Board), BS(Board), BSName(Board), Subarea (Alight), BS(Alight), BSName(Alight), Time(Board), Time(Alight), Promised time(Board), Promised time (Alight), # of Passengers, Vehicle ID, Fare, Booking date, Booking time, Booking device type, Booking confirmed time, Booking change device type, Booking change time, Cancel device type, Cancel device time, Direct travel time, Planned boarding time, Direct travel distance, Time window type, Dwelling time (Board), Dwelling time (Alight), Difference from preferred time
  - No cancellation data, No passport data

3.Overview of DRT in Kaizu

User attributes (Gender)



By ID

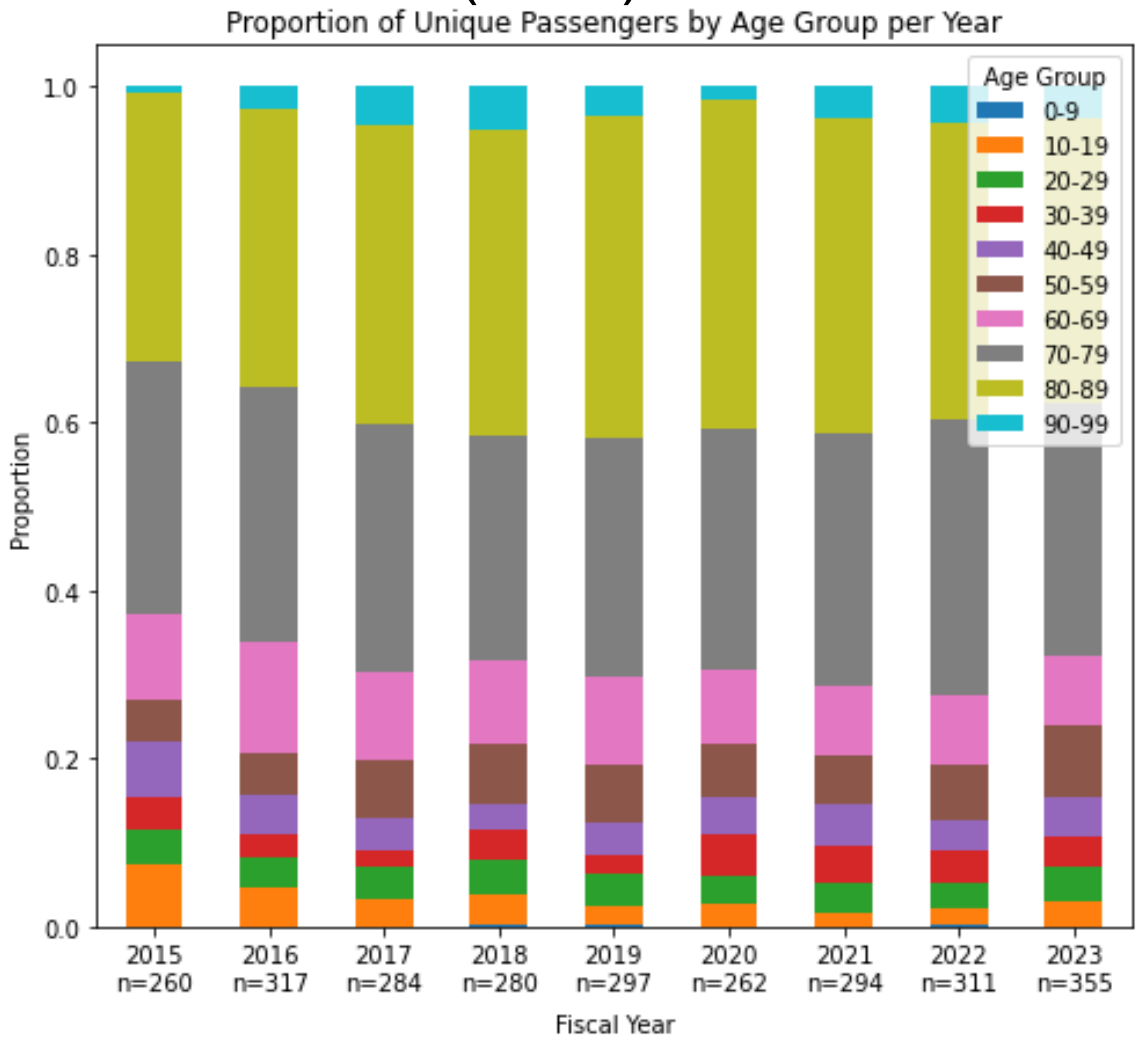


By ride

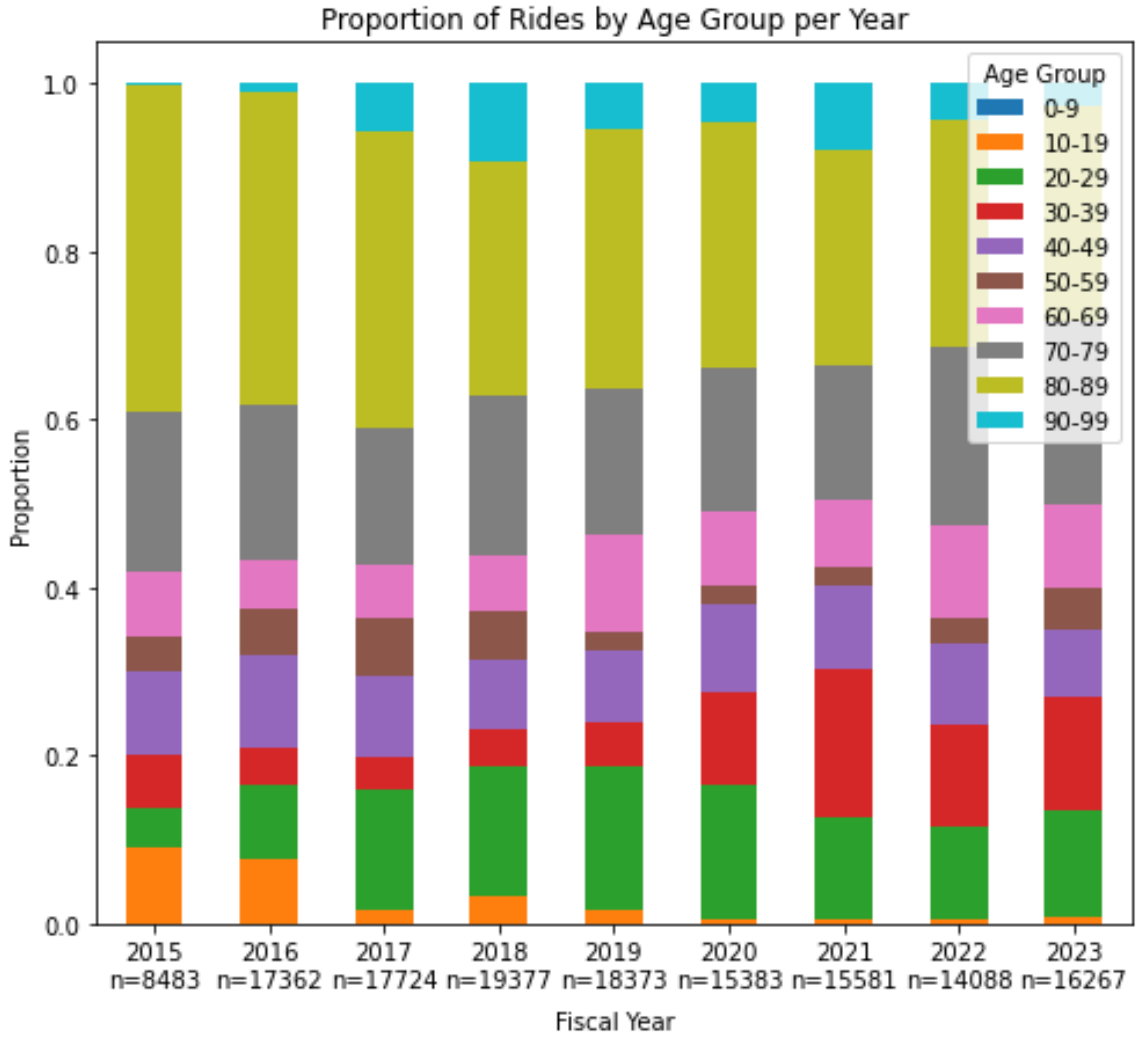
Females are utilising the service more frequently than males.

3.Overview of DRT in Kaizu

User attributes (AGE)



By ID

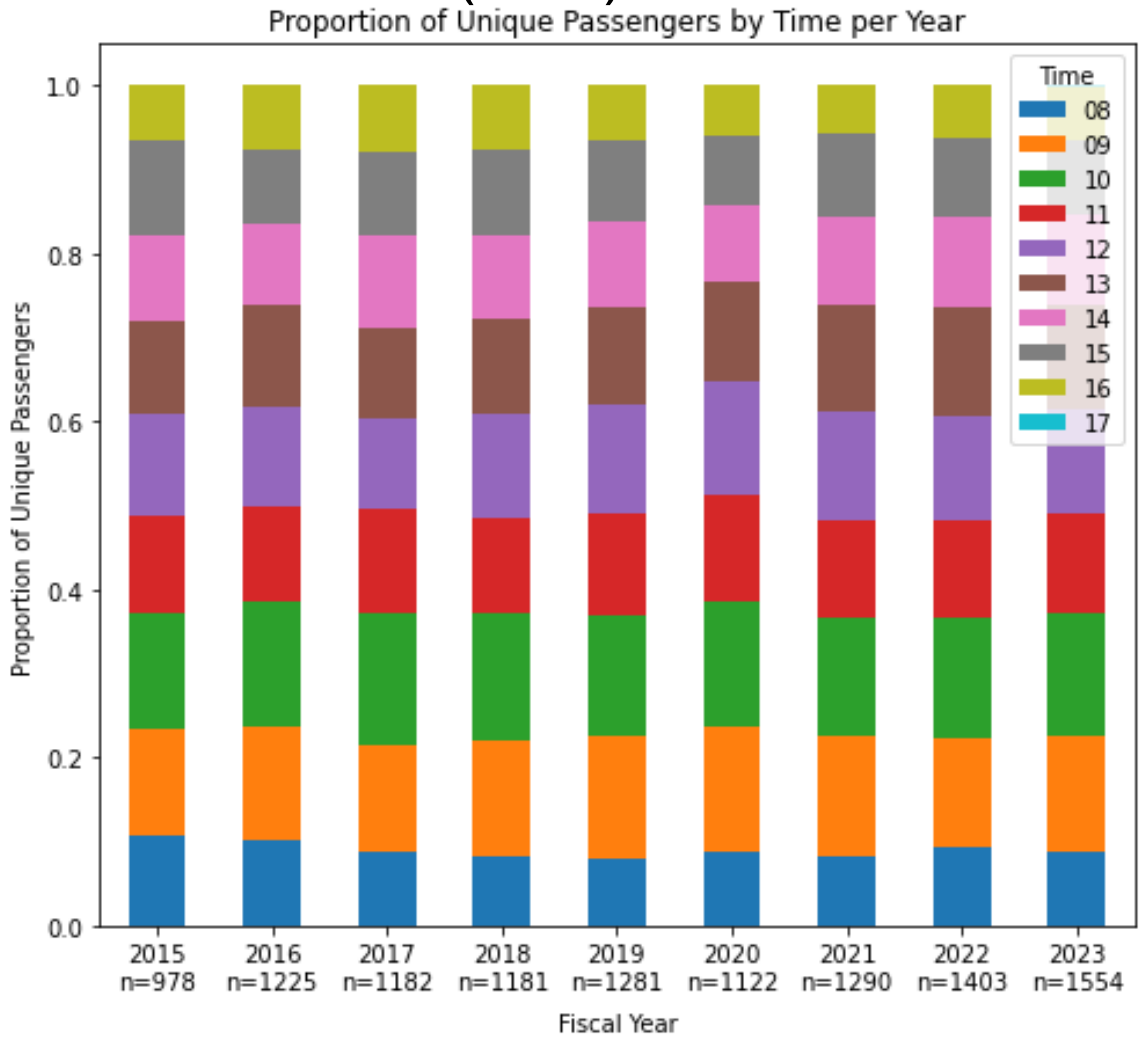


By ride

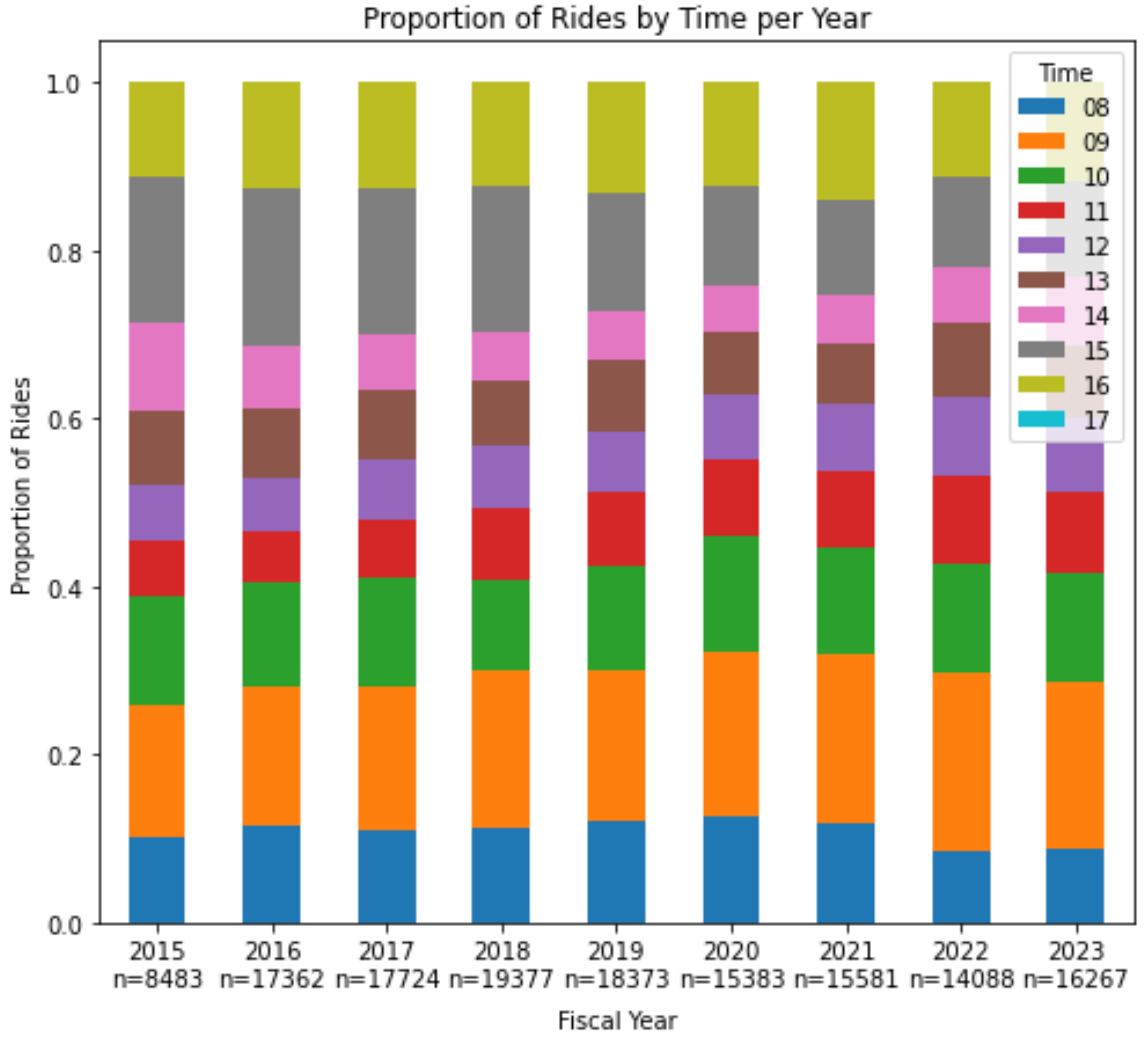
60% of users are over 70 years old. The elderly use the service most frequently.

3.Overview of DRT in Kaizu

User attributes (time)



By ID



By ride

Morning peak(9,10) and early-evening peak(15,16) have been utilising the service frequently.

4.How flexible do travellers move?

- The annual usage per bus stop and per traveller is discussed
- Data for the full period were used for bus stops, while data from the year 2018 were used for travelers.
  - The highest utilization occurred in 2018
- Bus stops were clustered based on the spatial and temporal demands.
- Travellers were clustered based on the day-to-day stability/regularity.

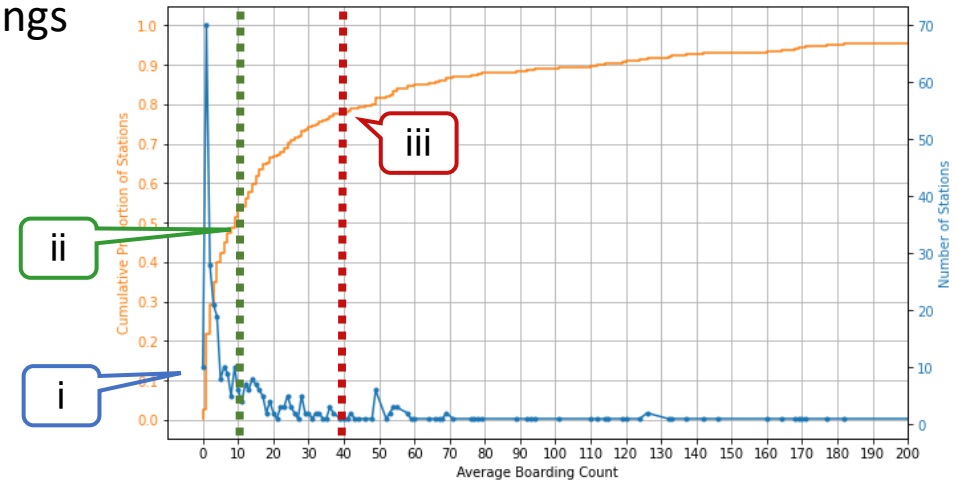
4.1How flexible do travellers move?(bus stop)

- The full data period were used for this study.
  - 2251 bus stops were used from 2015 to 2023
  - Since the characteristics or usage of bus stops change over the years. We consider bus stop in different year to be different
- Spatial and temporal demands analysis using usage patterns and temporal distribution
  - Usage patterns analysis based on the number of boardings and alightings, the number of users, the number of days traveled
  - Temporal distribution analysis based on the proportions of usage across different days of the week and different times of the day
- the movements of vehicles are visualised and discussed

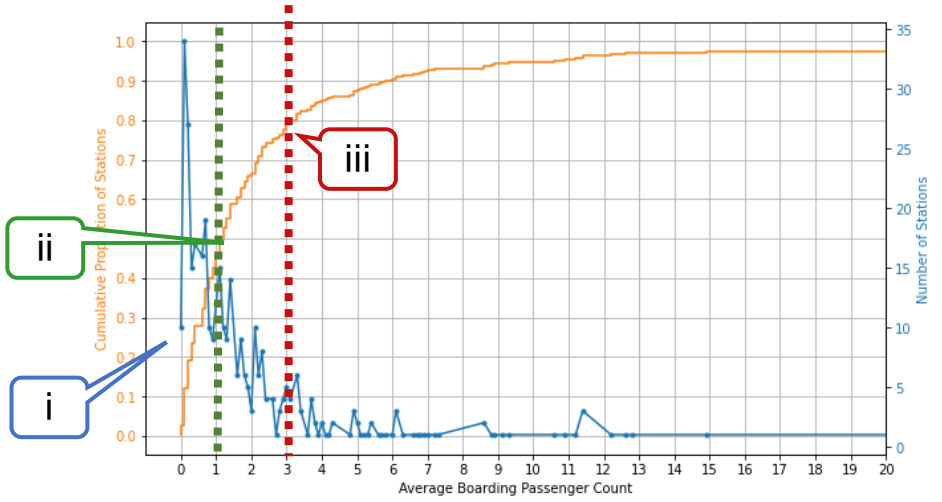
4.1How flexible do travellers move?(bus stop)

Average one-year of Usage

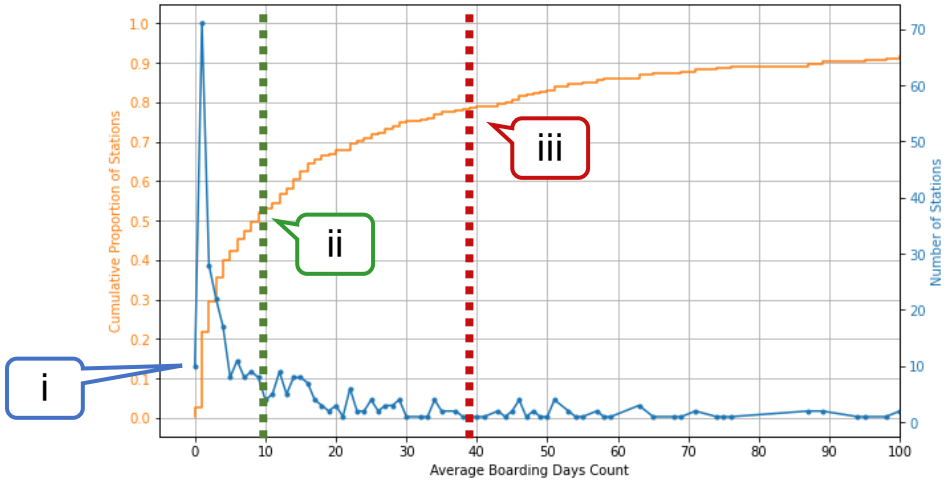
of boardings



# of users



# of days

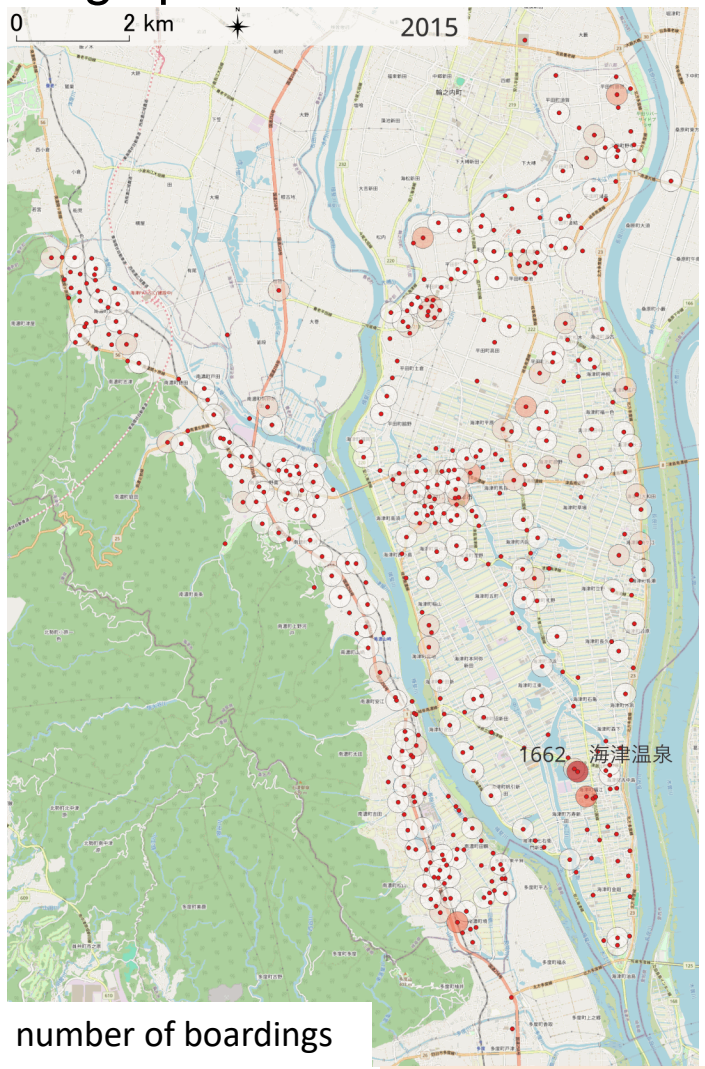


i. about 10 bus stops haven't been used once in 9 years
ii. 50% of the bus stops are used for boarding less than 10 times a year by a single user over no more than 10 days.
iii. 80% of the bus stops are used for boarding less than once a week by 3 users

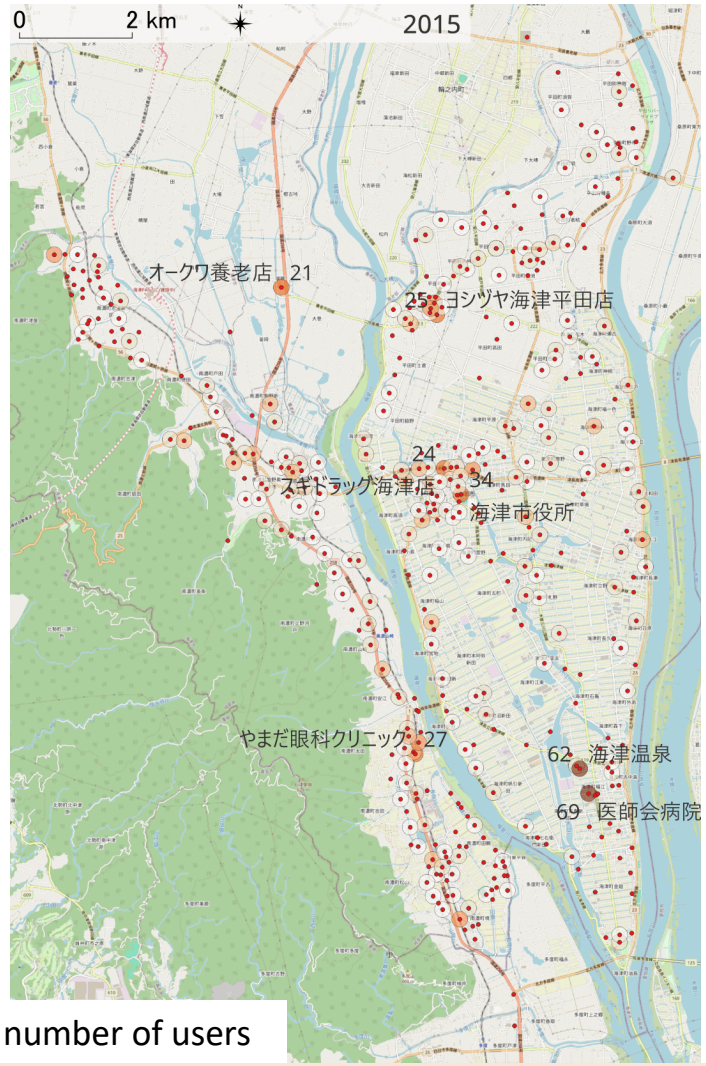
Most bus stop are not used regularly

4.1How flexible do travellers move?(bus stop)

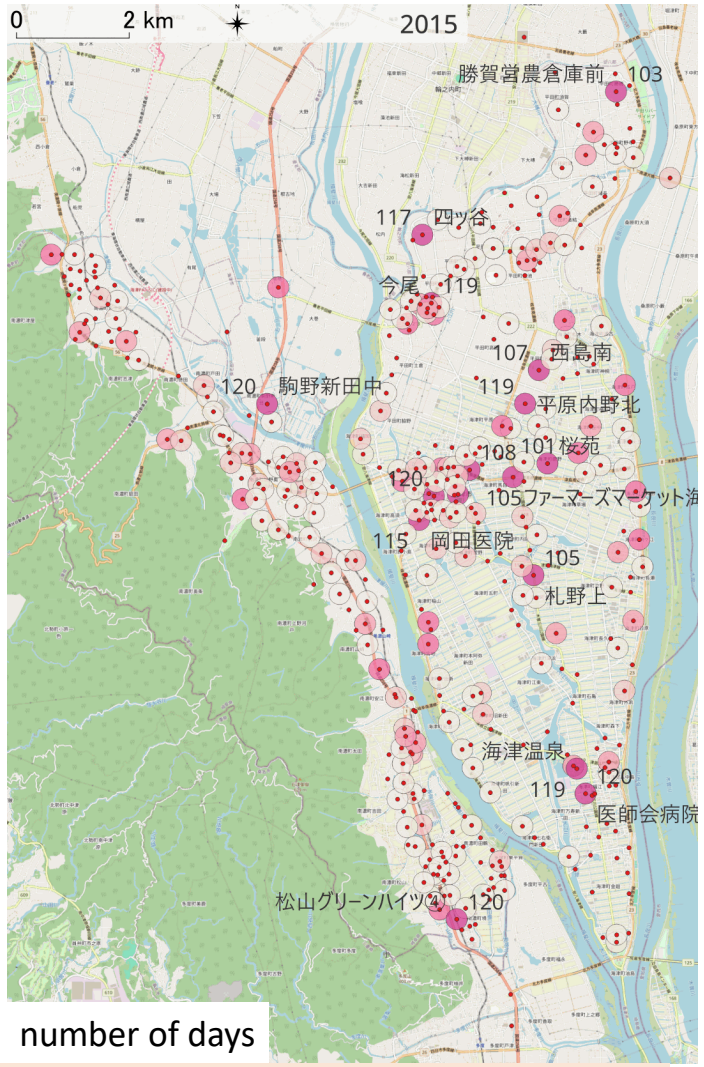
Usage patterns of each bus stop



number of boardings



number of users



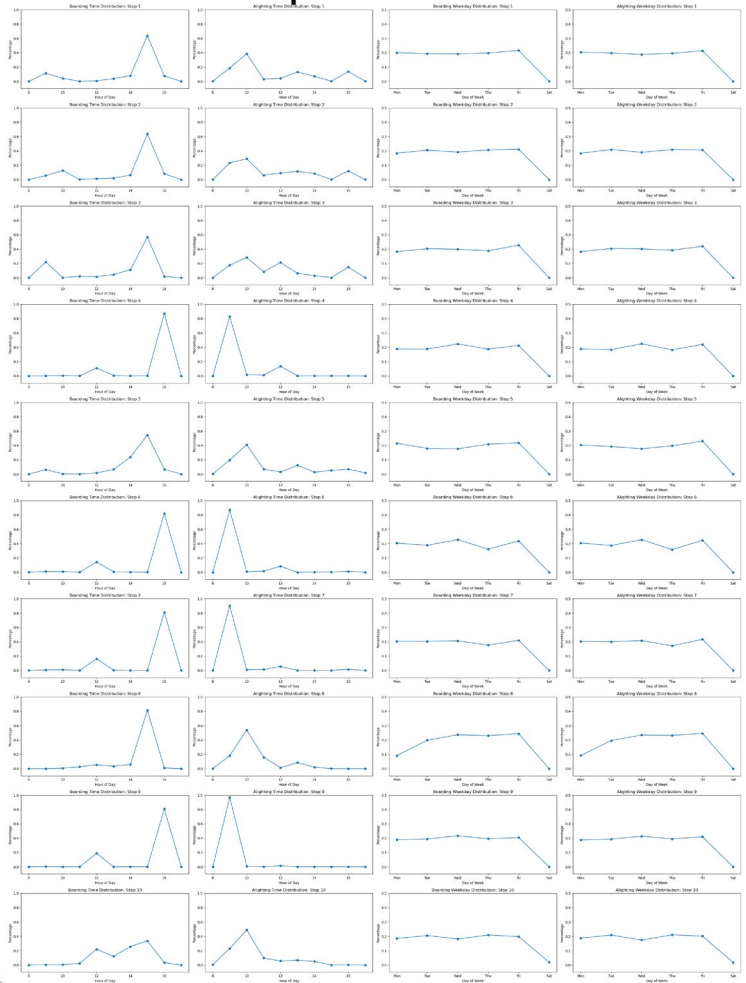
number of days

some stops with many boarding days don’t have many boardings or users, indicating they are likely used habitually by specific users

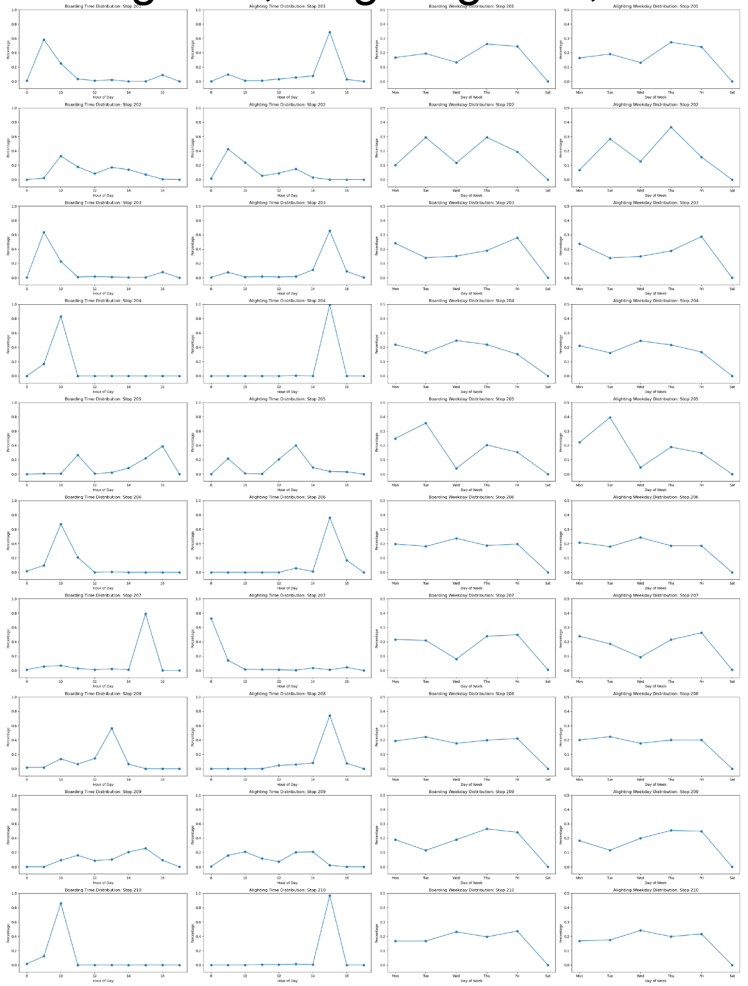
4.1How flexible do travellers move?(bus stop)

Temporal distribution of each bus stop

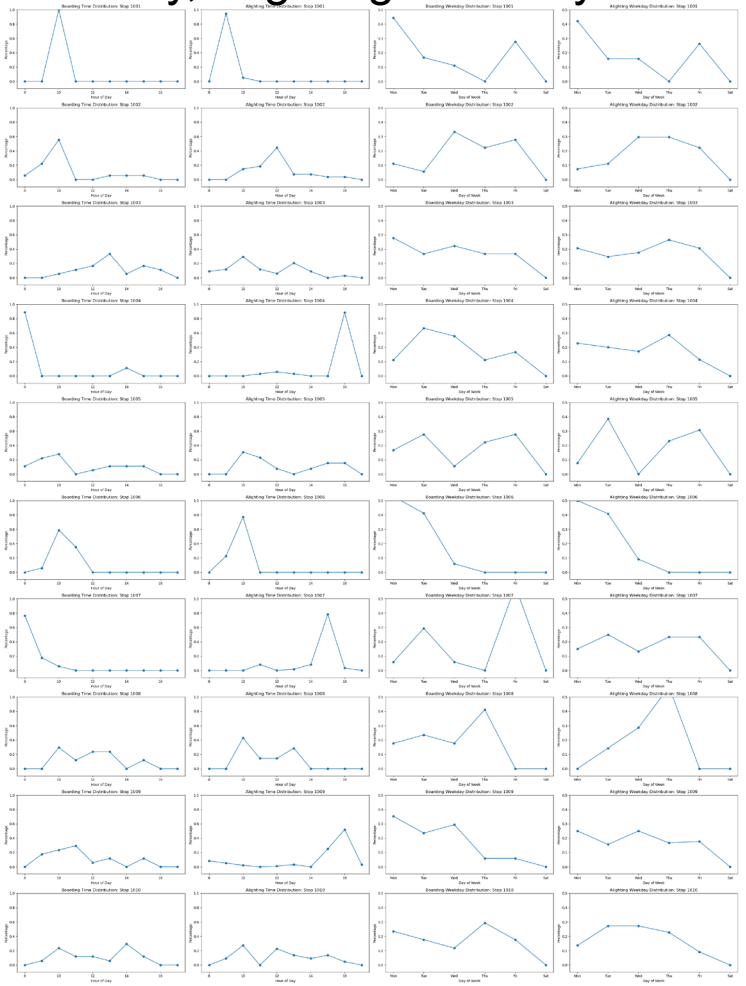
- Ordered by the number of boardings of each bus stop
- Each bus stop's rider distribution of Boarding time, Alighting time, Boarding weekday, Alighting weekday



Top 1-10



Top 200-210



Top 1000-1010

4.1How flexible do travellers move?(bus stop)

Result of clustering analysis using Usage patterns and temporal distribution

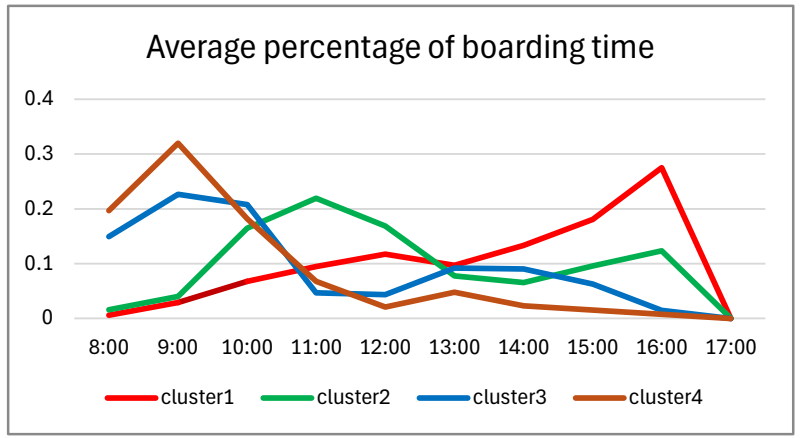
Cluster ID	# of IDs		sum of rides		average per stop	Average users per stop	Average days per stop	Interpretation
1	60	2.7%	46,079	32.3%	768.0	39.7	195.2	High-frequent bus stop
2	511	22.7%	25,853	18.1%	50.6	6.5	38.3	Low-frequent bus stop
3	1479	65.7%	34,333	24.1%	23.2	2.2	21.8	Low-frequent bus stop
4	201	8.9%	36,373	25.5%	181.0	2.7	146.5	High-frequent bus stop
Total	2251		142,638					

- 58% of trips are travel from only 12% bus stop
- 88% of bus stops are used ‘randomly’.

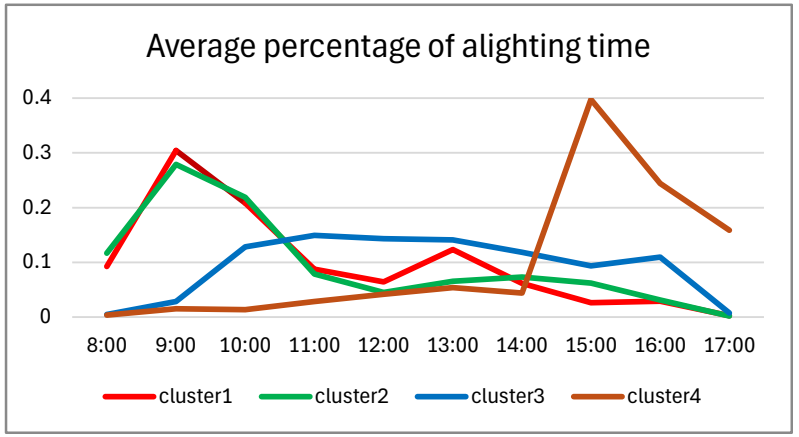
4.1How flexible do travellers move?(bus stop)

Average percentage of boarding time alighting time boarding weekday alighting weekday

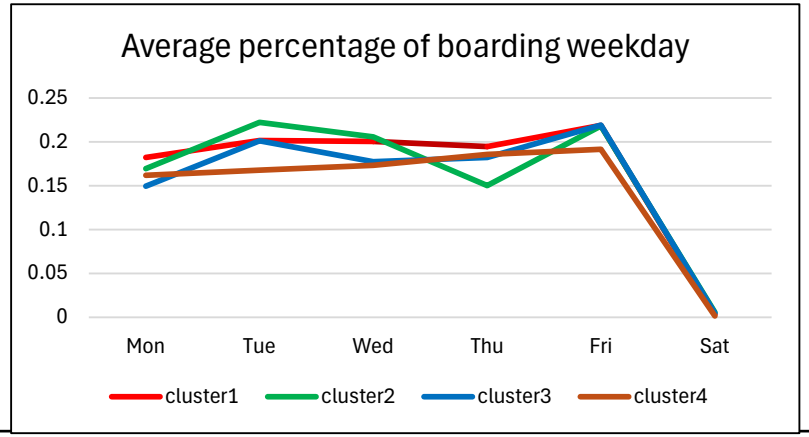
Boarding time



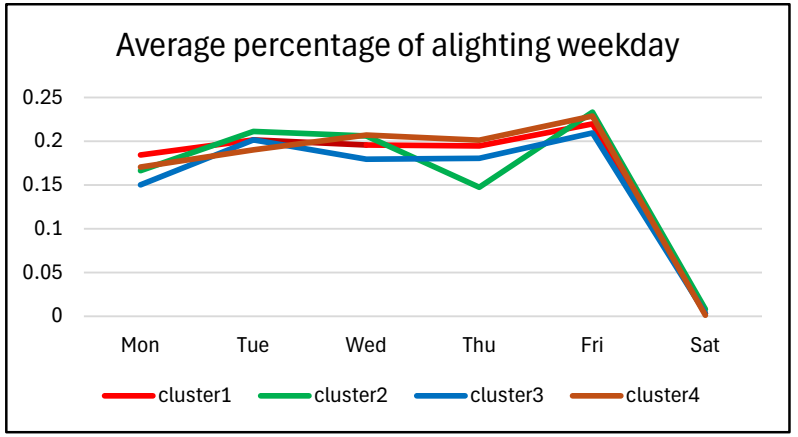
Alighting time



Boarding weekday



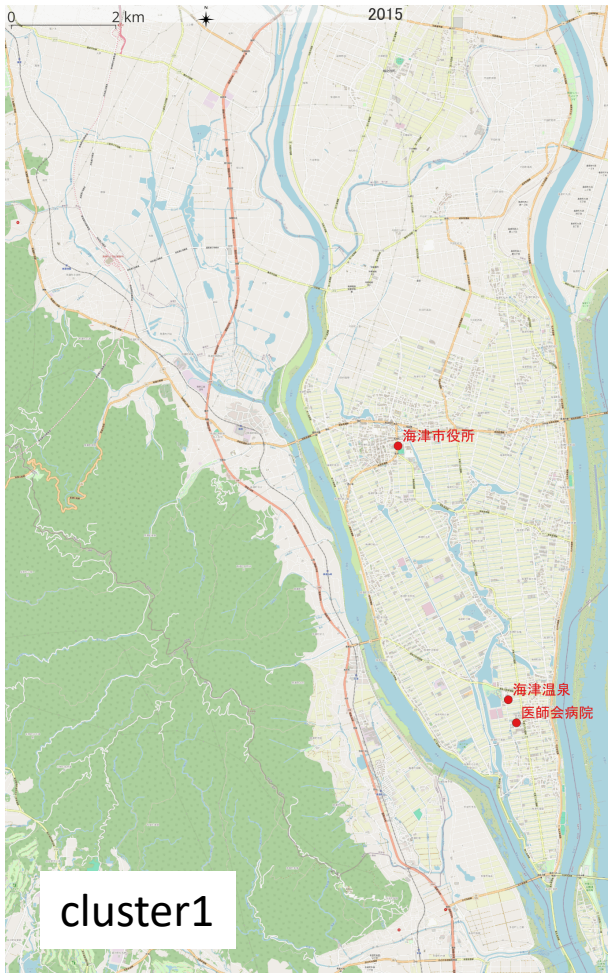
Alighting weekday



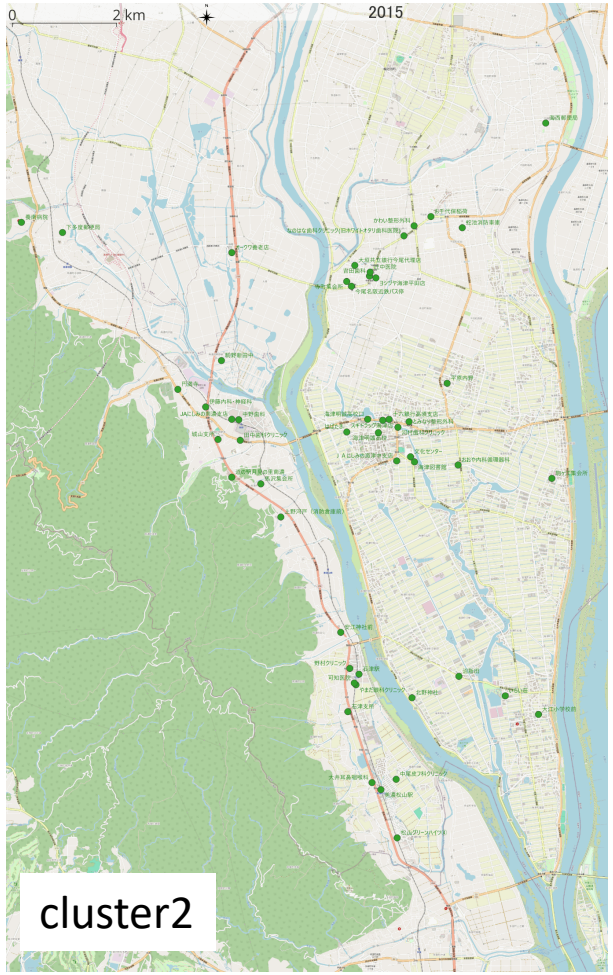
cluster1: High percentage of evening boardings and morning alighting, possible bus stops near work area
cluster2: High percentage of morning alighting, low usage on Thursdays, possibly a bus stop near a clinic
cluster3: Randomly used bus stops
cluster4: High percentage of morning boardings and evening alighting, possibly bus stops near residential area

4.1How flexible do travellers move?(bus stop)

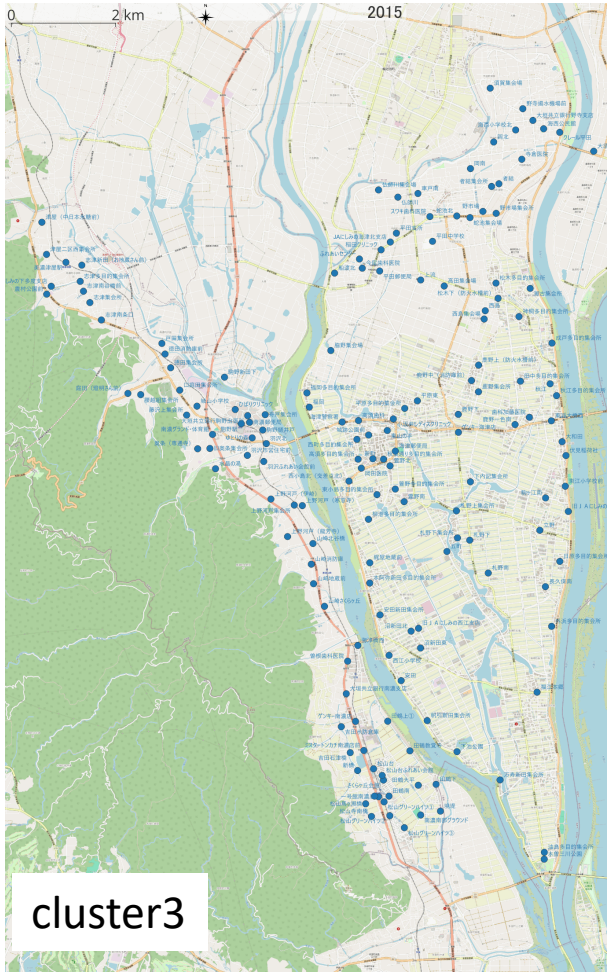
Distribution of each cluster



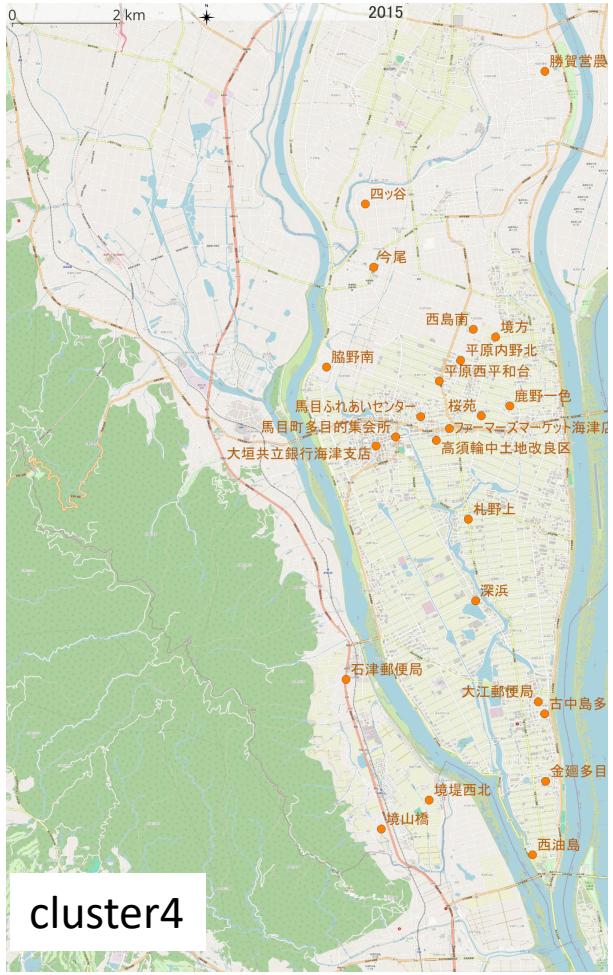
cluster1



cluster2



cluster3



cluster4

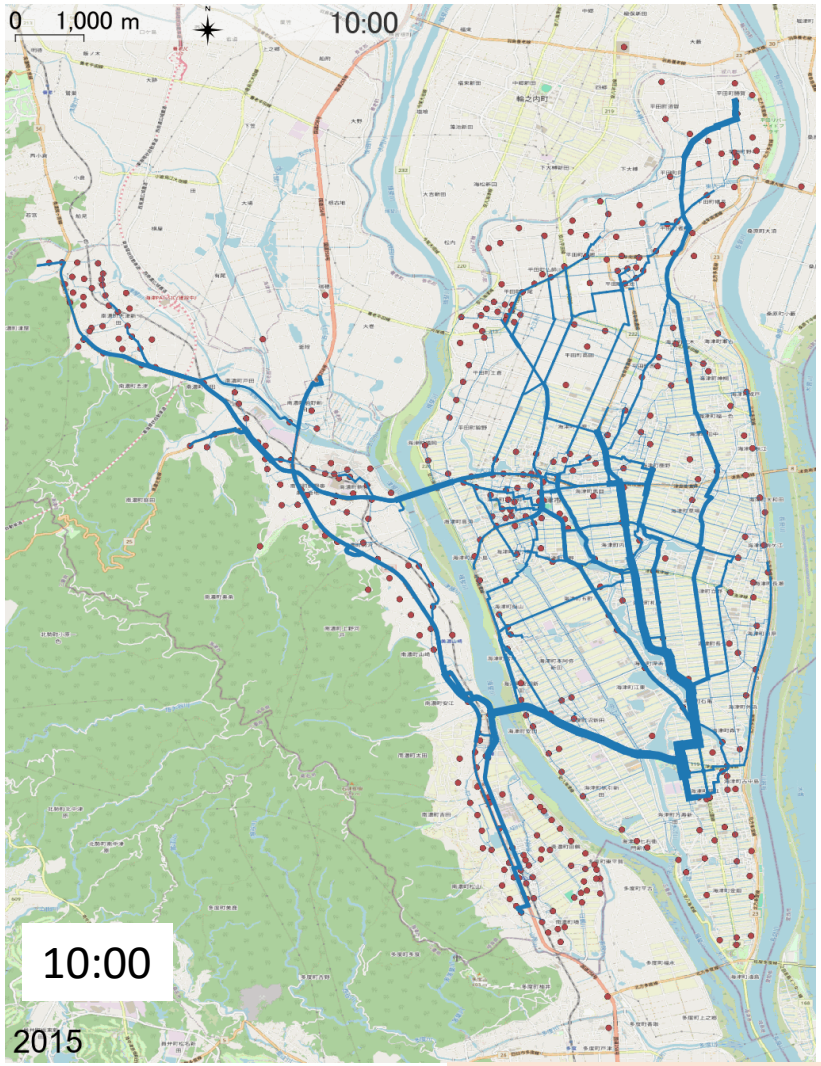
Based on the spatial and temporal characteristics of bus stops being utilized, we can consider increasing the supply of public transport near these stops at specific time.

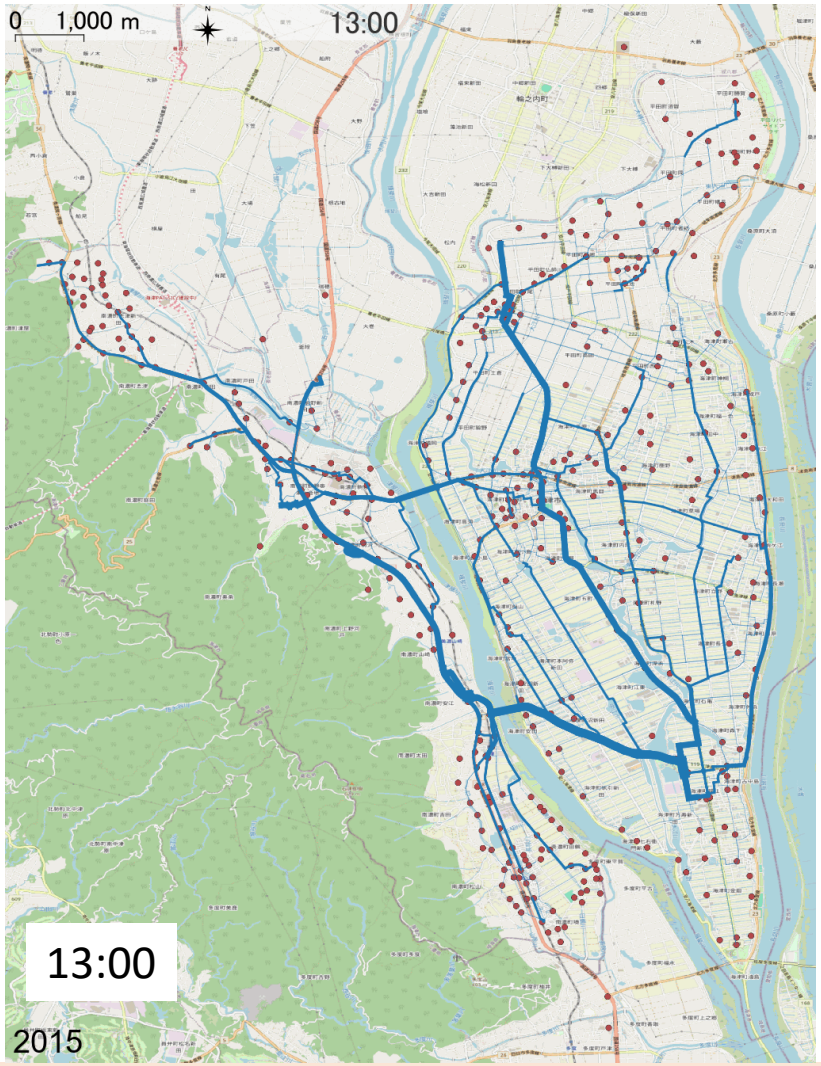
4.1How flexible do travellers move?(bus stop)

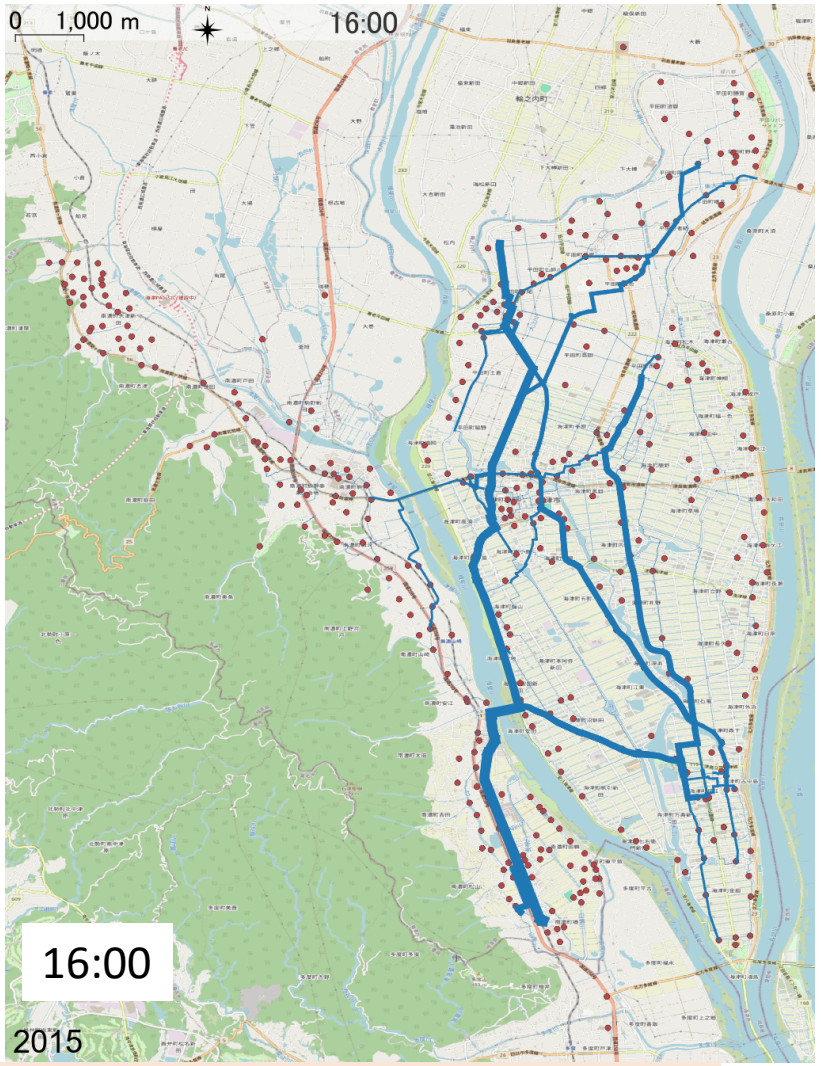
Visualising vehicle movement

- Vehicle movement is reproduced and visualised by booking data.
  - Visited order of bus stops are identified by sequencing the bus stop by the ascending order of arrival time
  - The route between bus stops was identified by shortest distance path search

4.1Vehicle locations by time(10:00, 13:00, 16:00)







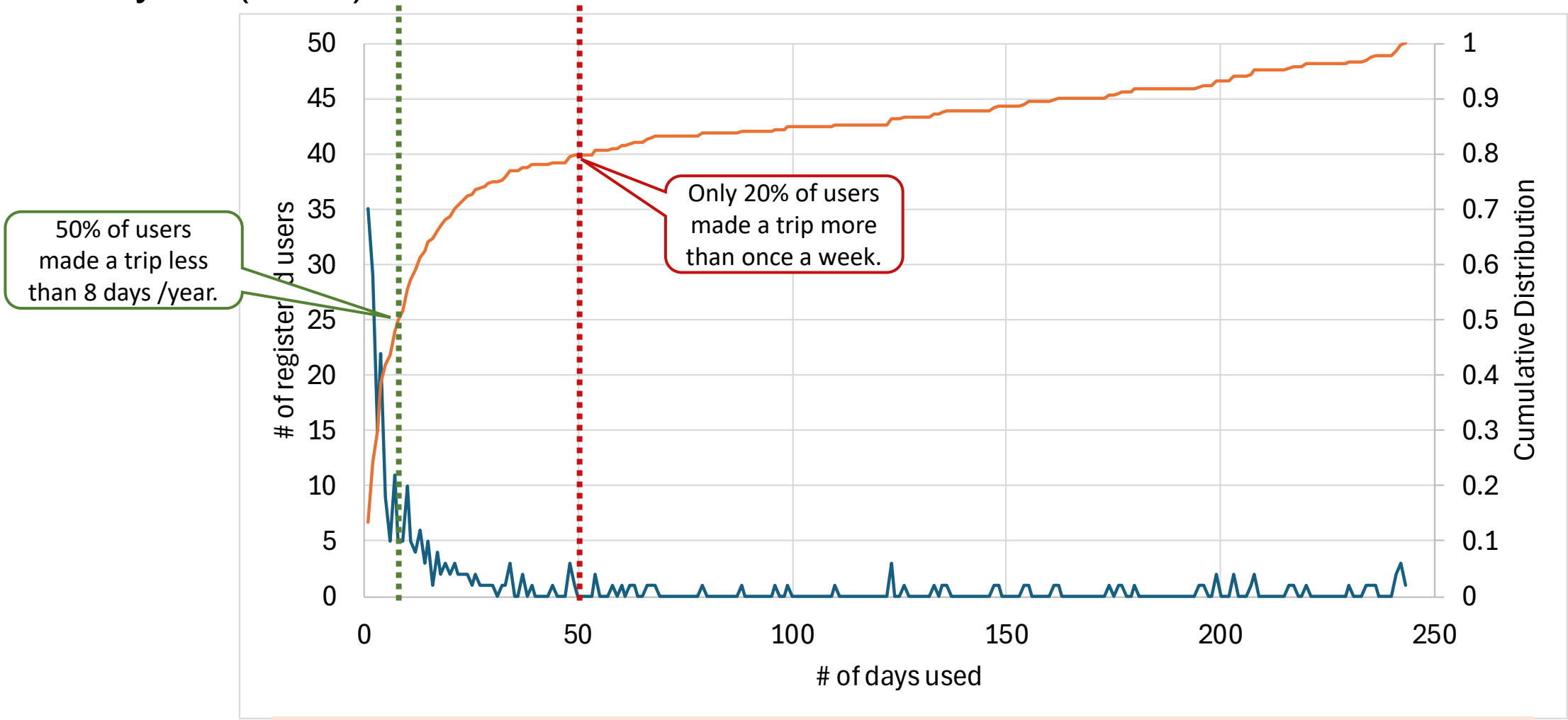
The vehicle trajectories in busy time interval is more or less stable, meaning that same persons are continually using the service on these periods.
Some passengers usually head to Kaizu Hot Springs at 10 o'clock, in 2019 Kaizu Hot Springs is temporarily closed so they head to another Hot Springs at the same time .

4.2How flexible do travellers move?(travellers)

- Data from year 2018 were used for this study.
  - 263 travellers used the service in 2018.
- Day-to-day regularity analysis using auto-correlation coefficients(ACC)
  - We determined whether travelers used the service each day (coded as 1 if used, 0 if not).
  - Annual patterns are visualised, and clustering analysis was applied to the annual pattern of daily usages for each traveller.
- Especially, the movements by high-frequent regular travellers are visualised and discussed.

4.2How flexible do travellers move?(travellers)

Usage for 1 year (2018)



Specific groups of people may utilise demand-responsive transport?

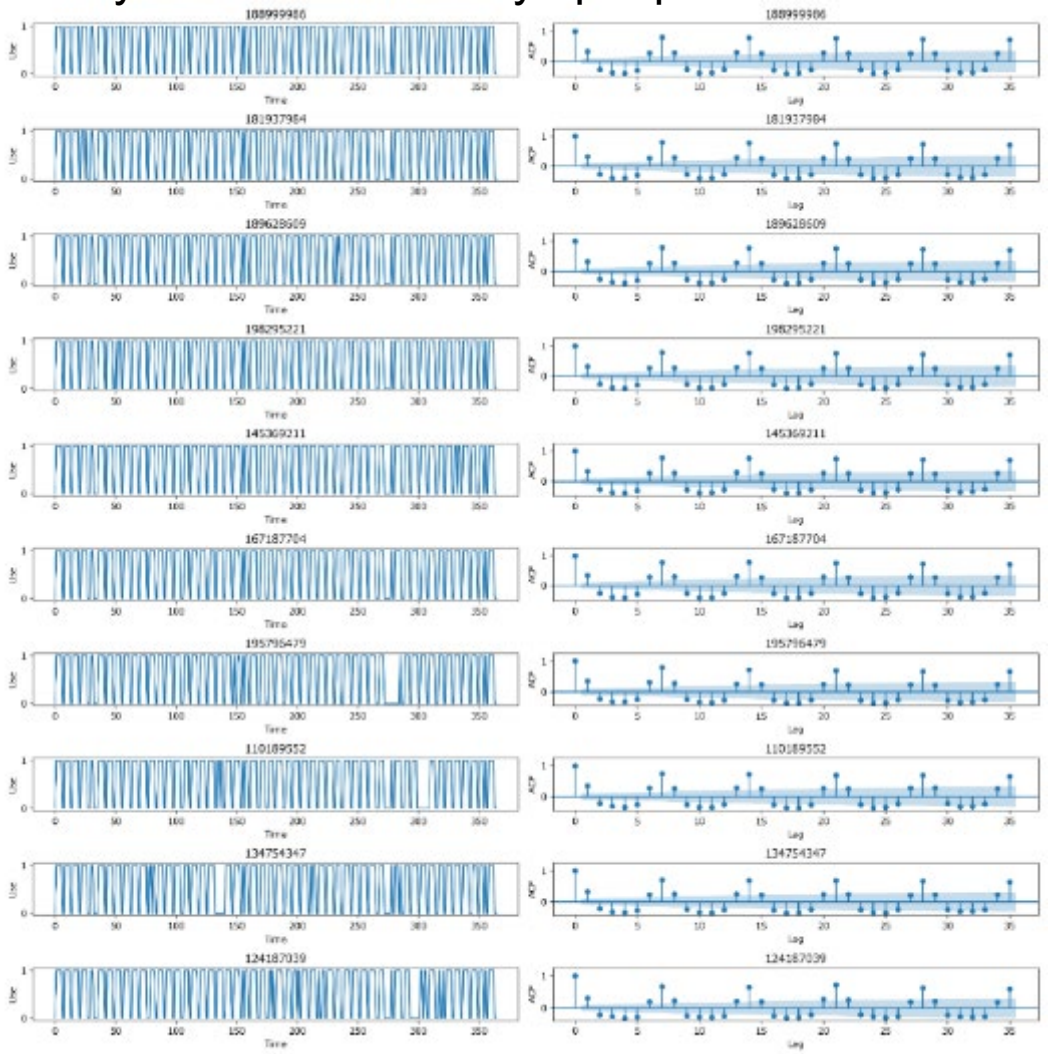
but this could also be true for fixed-route services..

4.2How flexible do travellers move?(travellers)

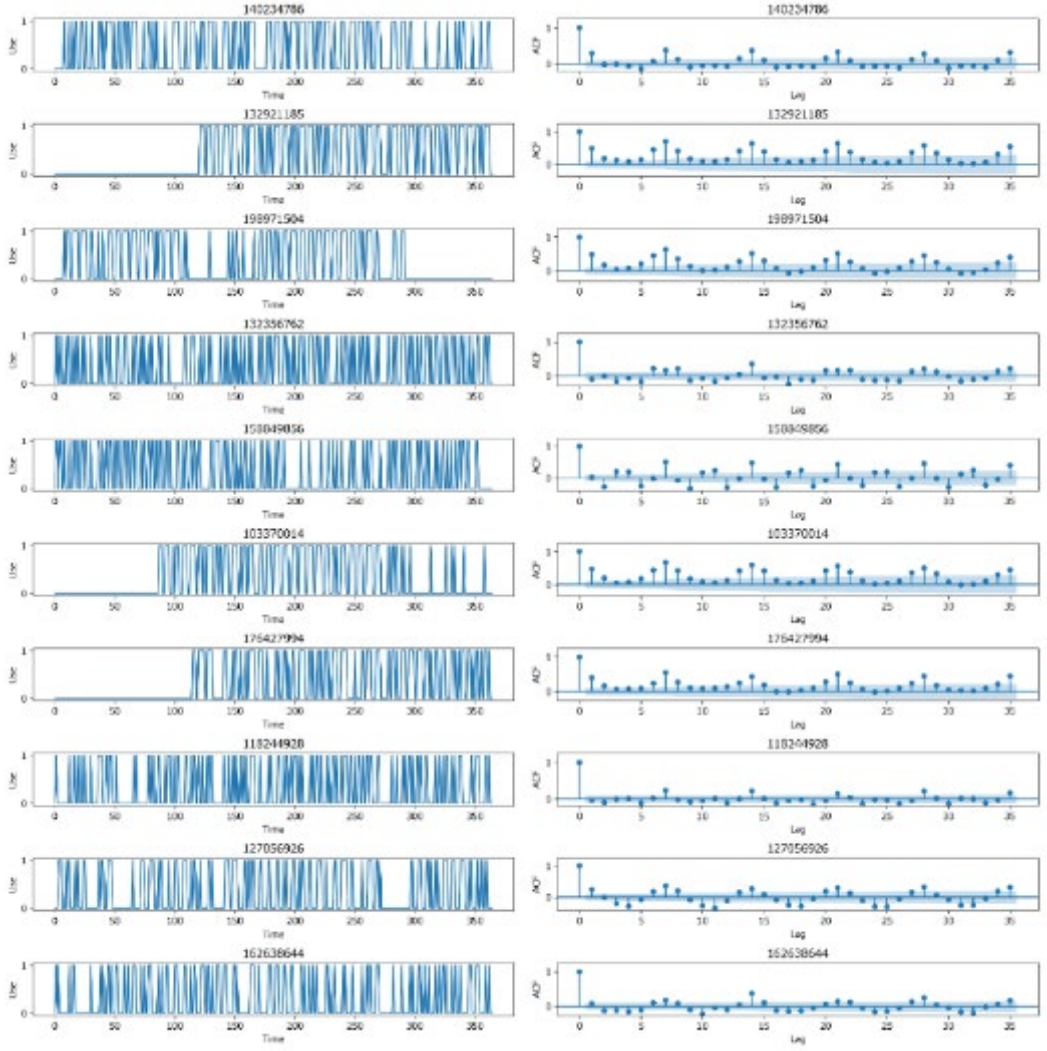
Day-to-day auto-correlation (2018)

263 registered users

- Ordered by the number of days people used the service



Top 1-10



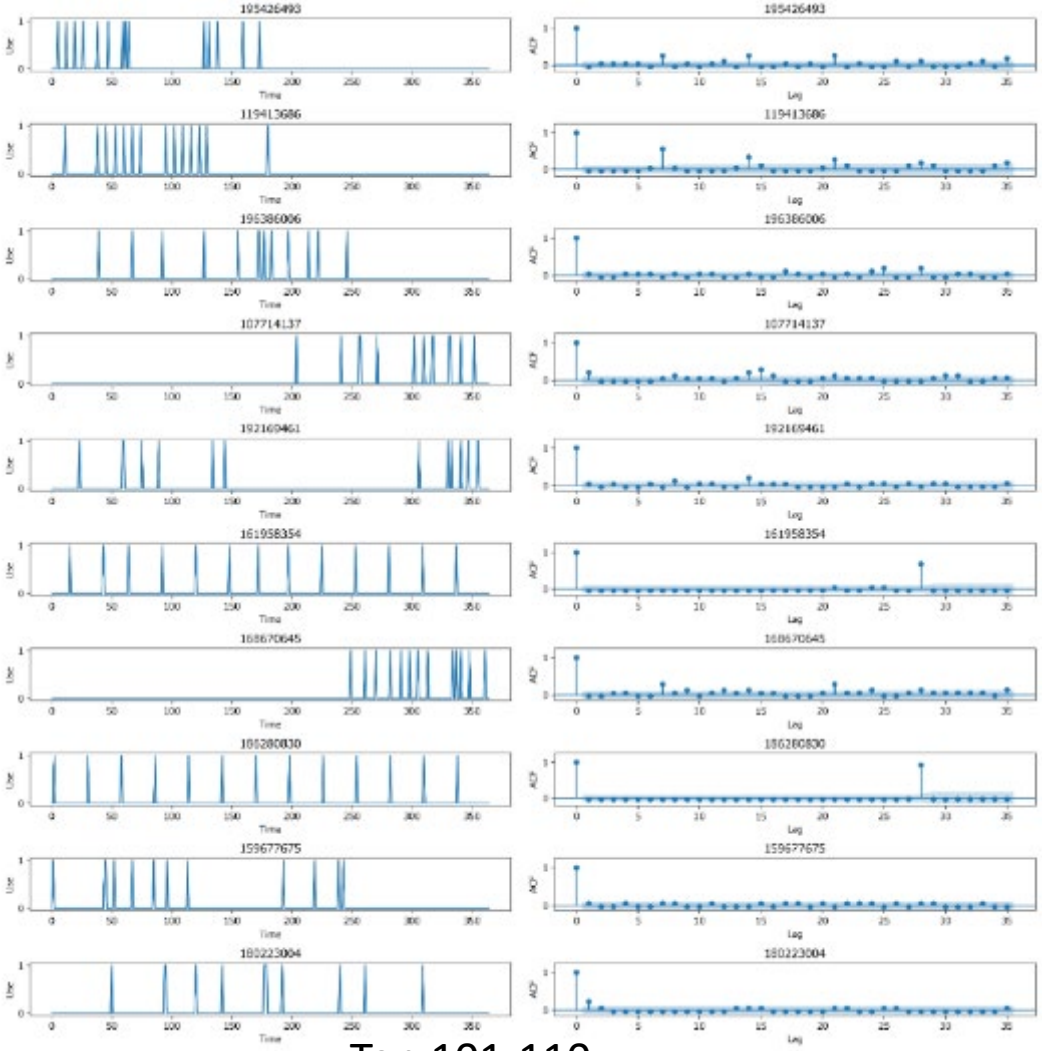
Top 31-40

4.2How flexible do travellers move?(travellers)

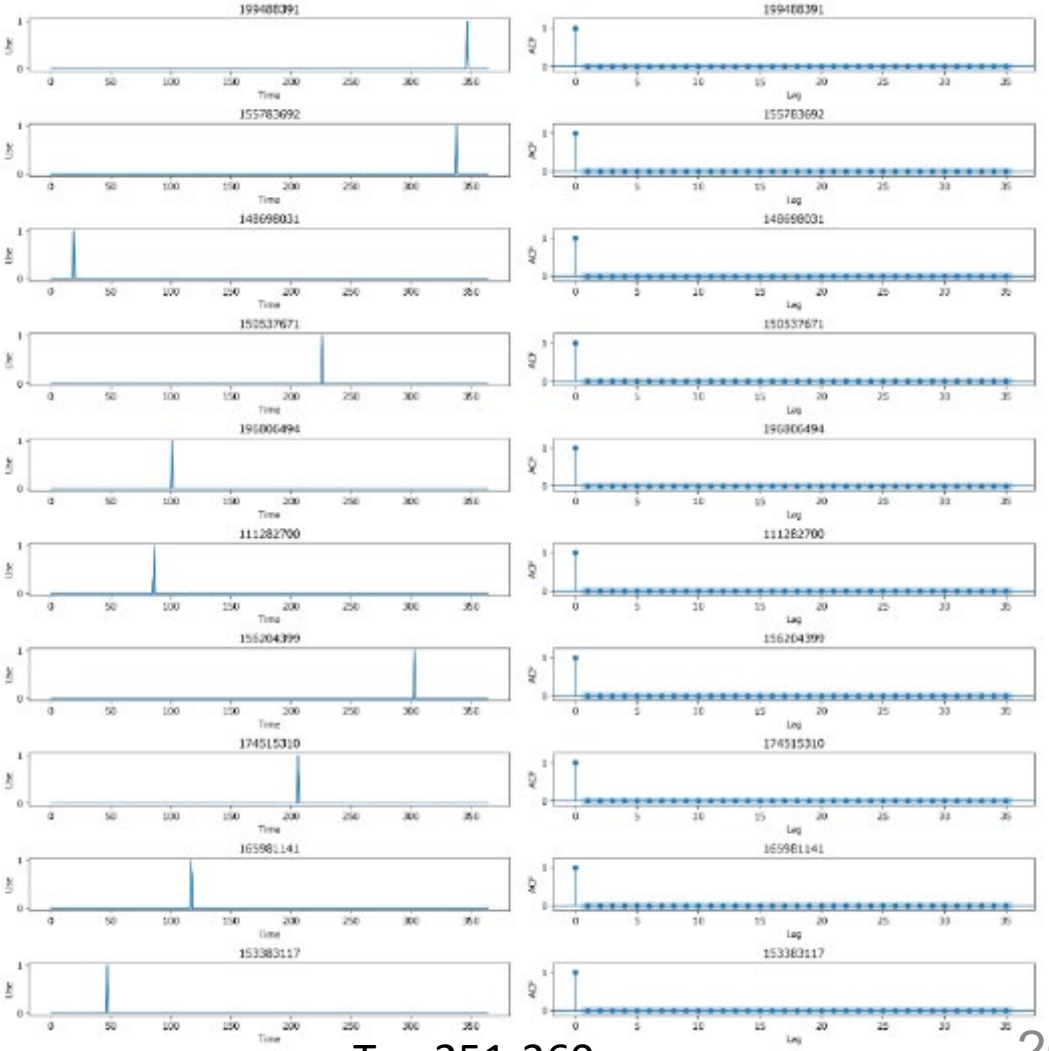
Day-to-day autocorrelation (2018)

263 registered users

- Ordered by the number of days people used the service



Top 101-110

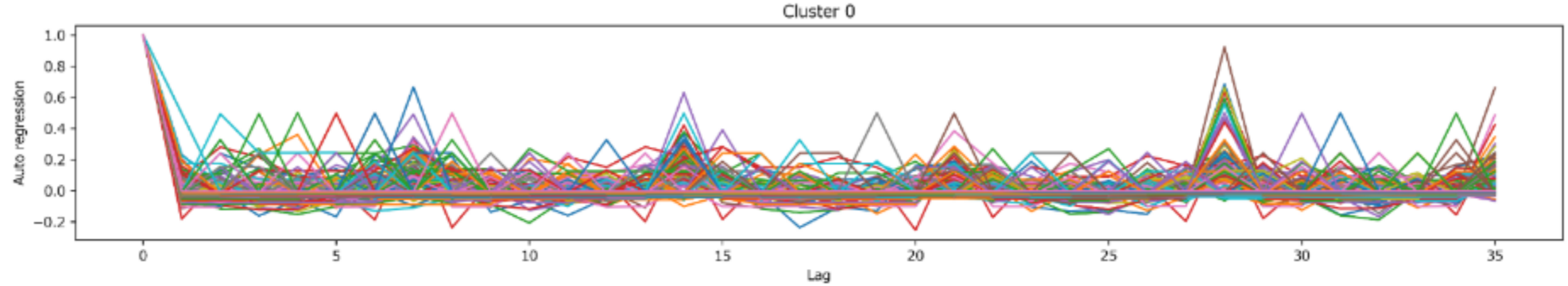


Top 251-260

4.2How flexible do travellers move?(travellers)

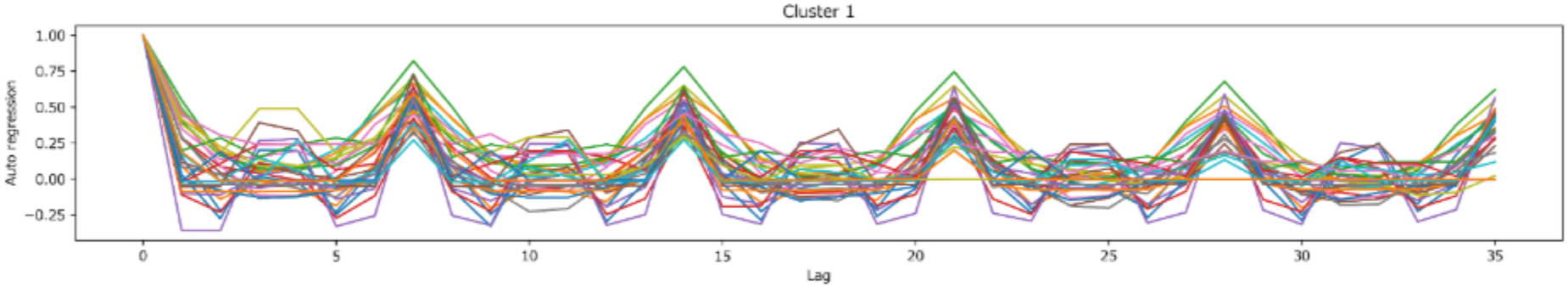
Result of clustering analysis using auto-correlation coefficients(ACC)

Cluster 0

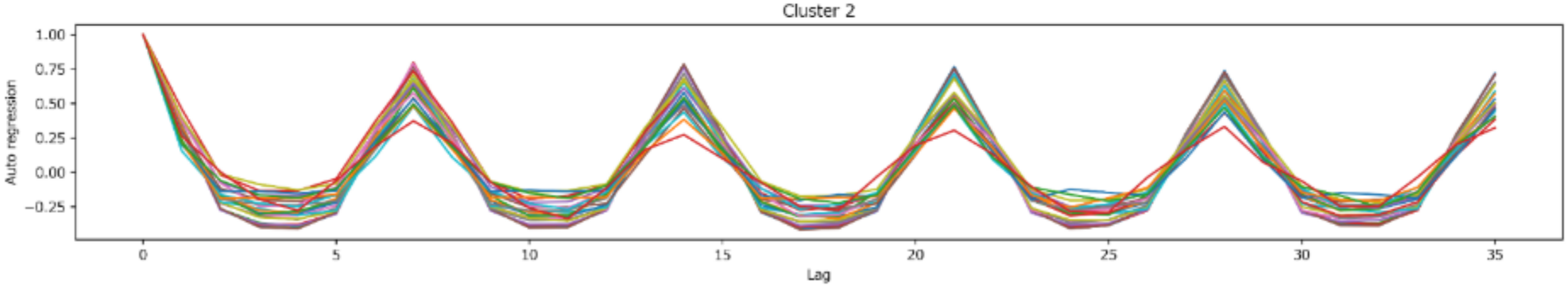


Random?

Cluster 1



Cluster 2



Regular / Routine?

Cluster 2 has very stable/regular behaviour.

4.2How flexible do travellers move?(travellers)

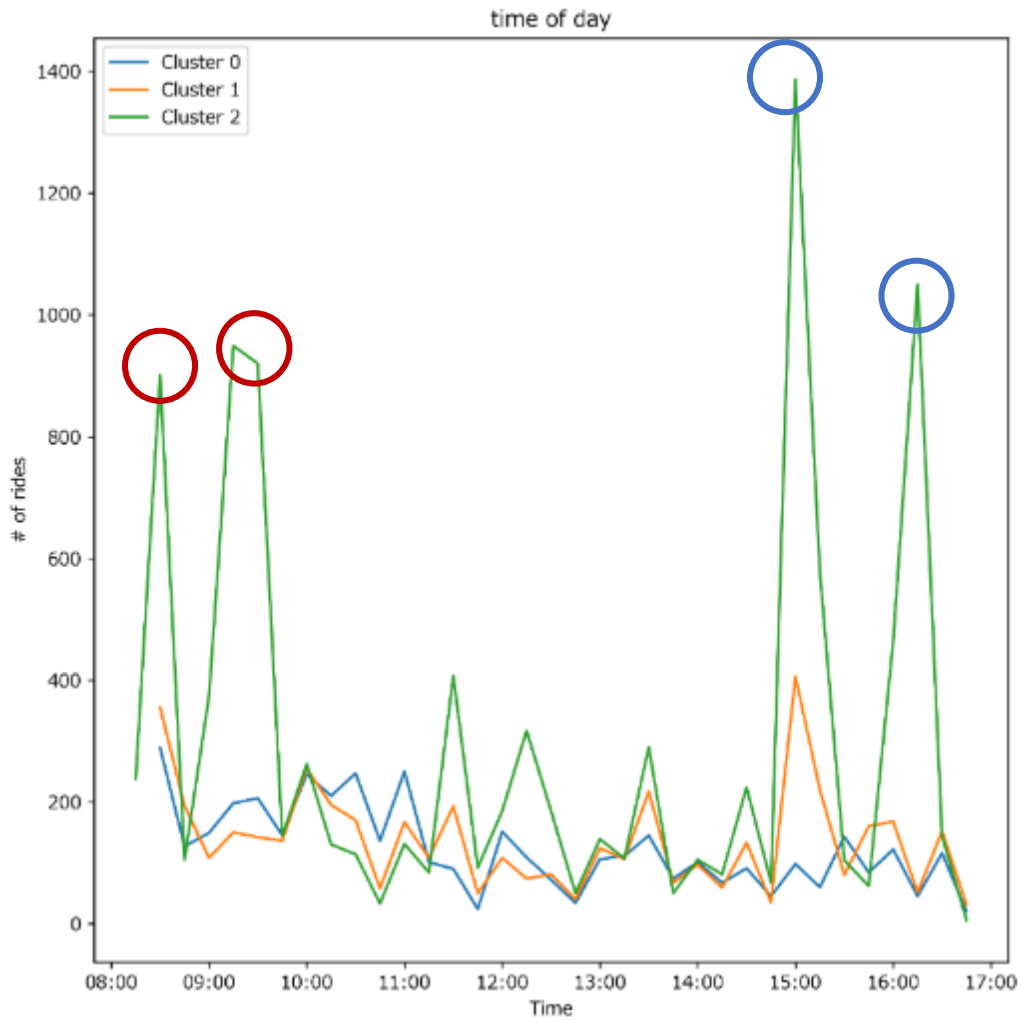
Result of clustering analysis using autocorrelation coefficients

Cluster ID	# of IDs		sum of rides		average per person	sum of days (243 service days)		average per person	Interpretation
0	207	78.7%	4,211	21.7%	20.34	2,518	24.2%	12.16	Low-frequent tourists/trial users
1	32	12.2%	4,690	24.2%	146.56	2,727	26.2%	85.22	Frequent rather regular users
2	24	9.1%	10,476	54.1%	436.50	5,156	49.6%	214.83	High-frequent regular users
Total	263		19,377			10,401			

- Only 10% of people (24) make 54% of trips
  - ➢ Is it really a ‘public’ transport?
- Only 21.7% of trips are made rather ‘randomly’.

4.2How flexible do travellers move?(travellers)

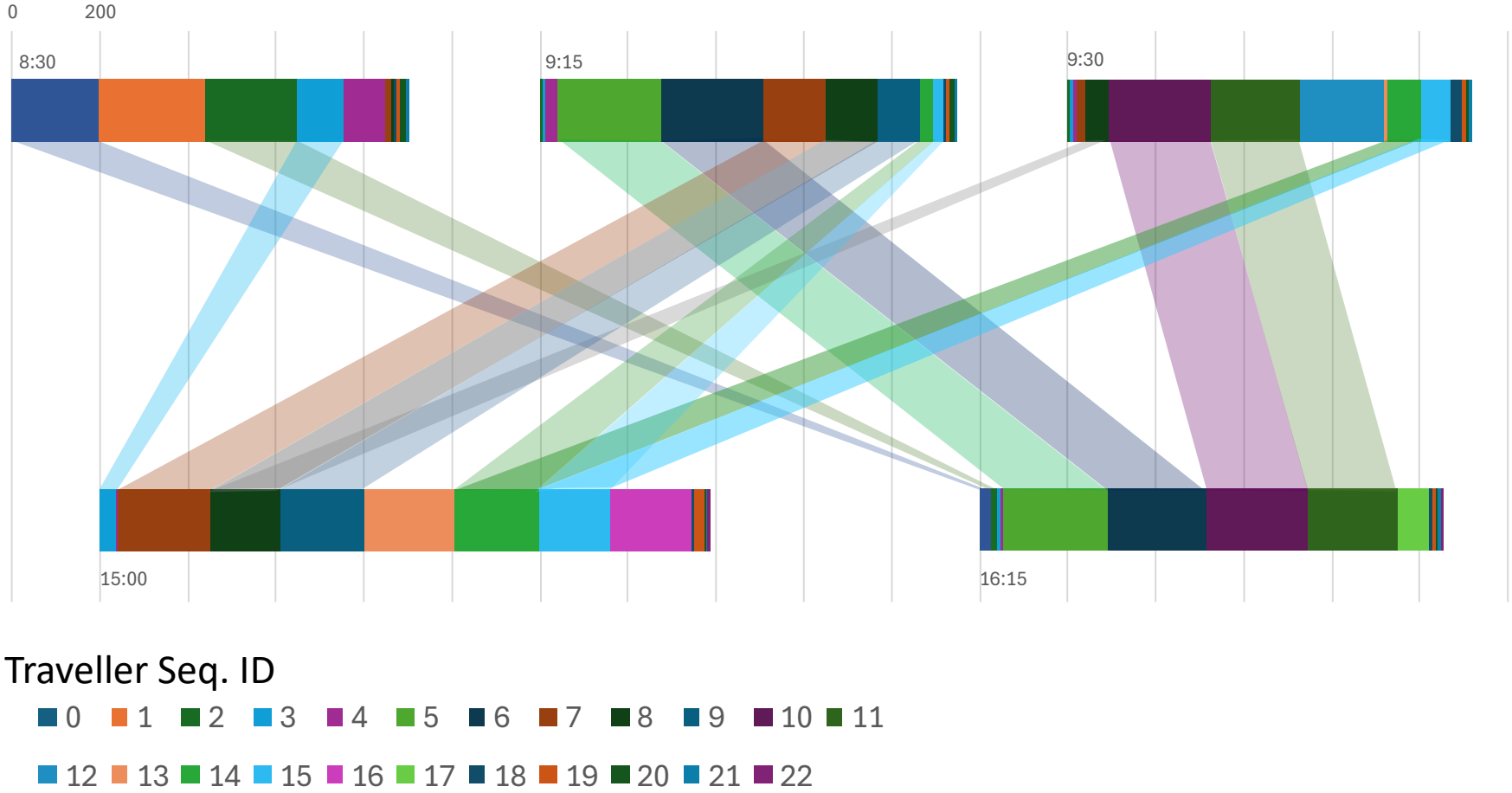
Within-day distribution of usage by clusters



- Cluster 2 users' trips concentrate either in the morning or early-evening peaks.
- Their trips are 4 to 5 times larger than members in other clusters.
- Let us look at following time of day for Cluster 2
  - 8:30, 9:15,9:30 (morning peak)
  - 15:00, 16:15 (early-evening peak)

4.2How flexible do travellers move?(travellers)

Temporal movement of Cluster 2 travellers



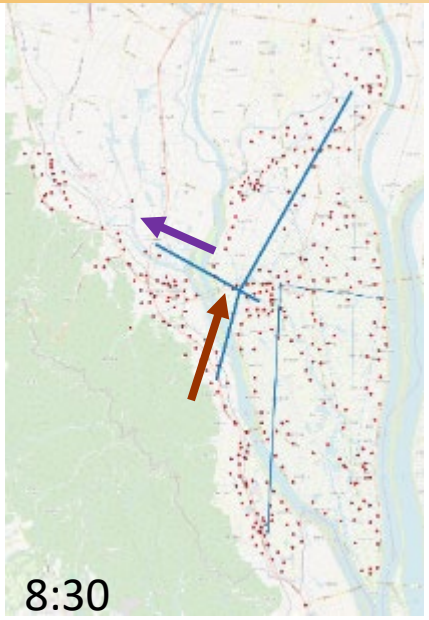
- At busiest time intervals, rides are dominated by only 4 to 7 travellers, most of whom maintain a fixed departure time both in the morning and the evening.

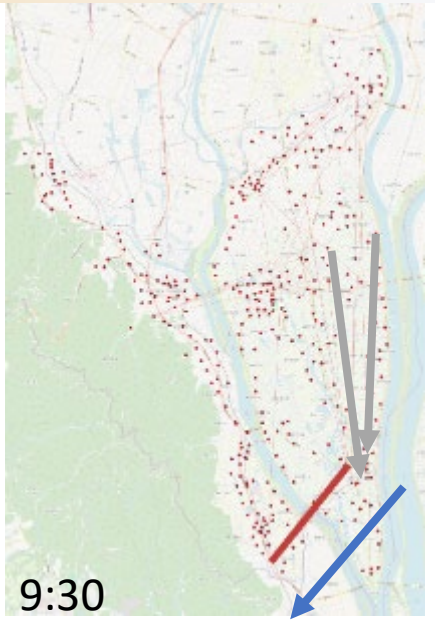
From where to where are they moving?

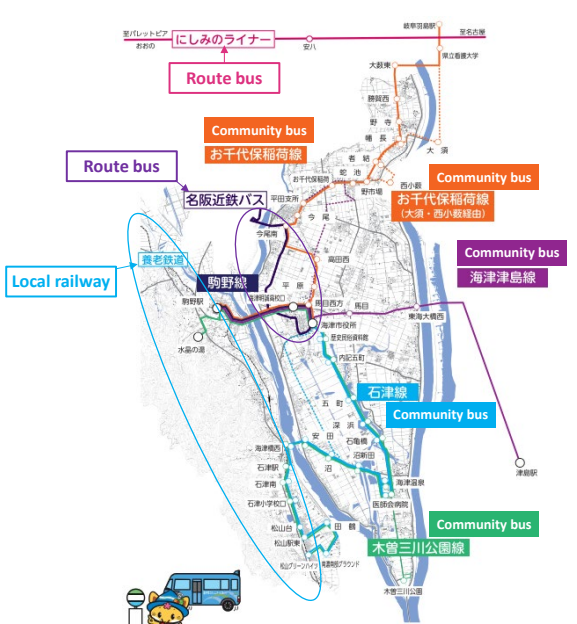
4.2How flexible do travellers move?(travellers)

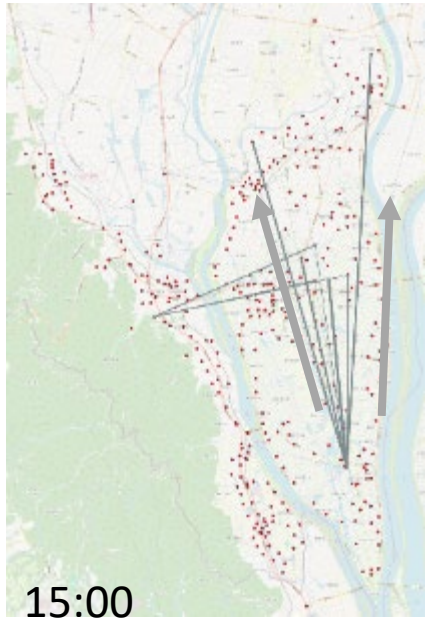
OD distributions
for each time interval (Cluster 2)

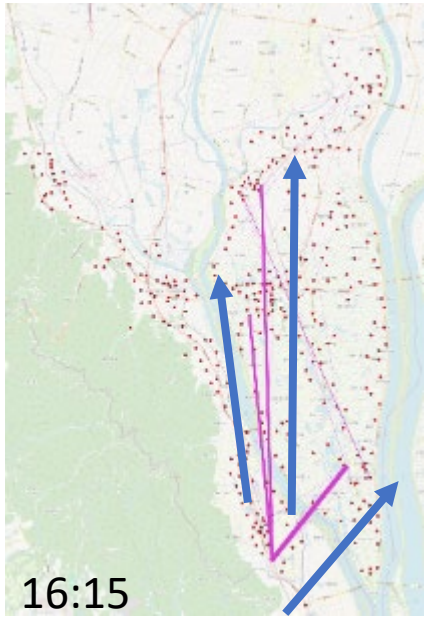
- The movement patterns of high-frequency regular travelers appear to be highly stable.
- However, if these users switch to fixed-route buses, they will face transfer challenges.











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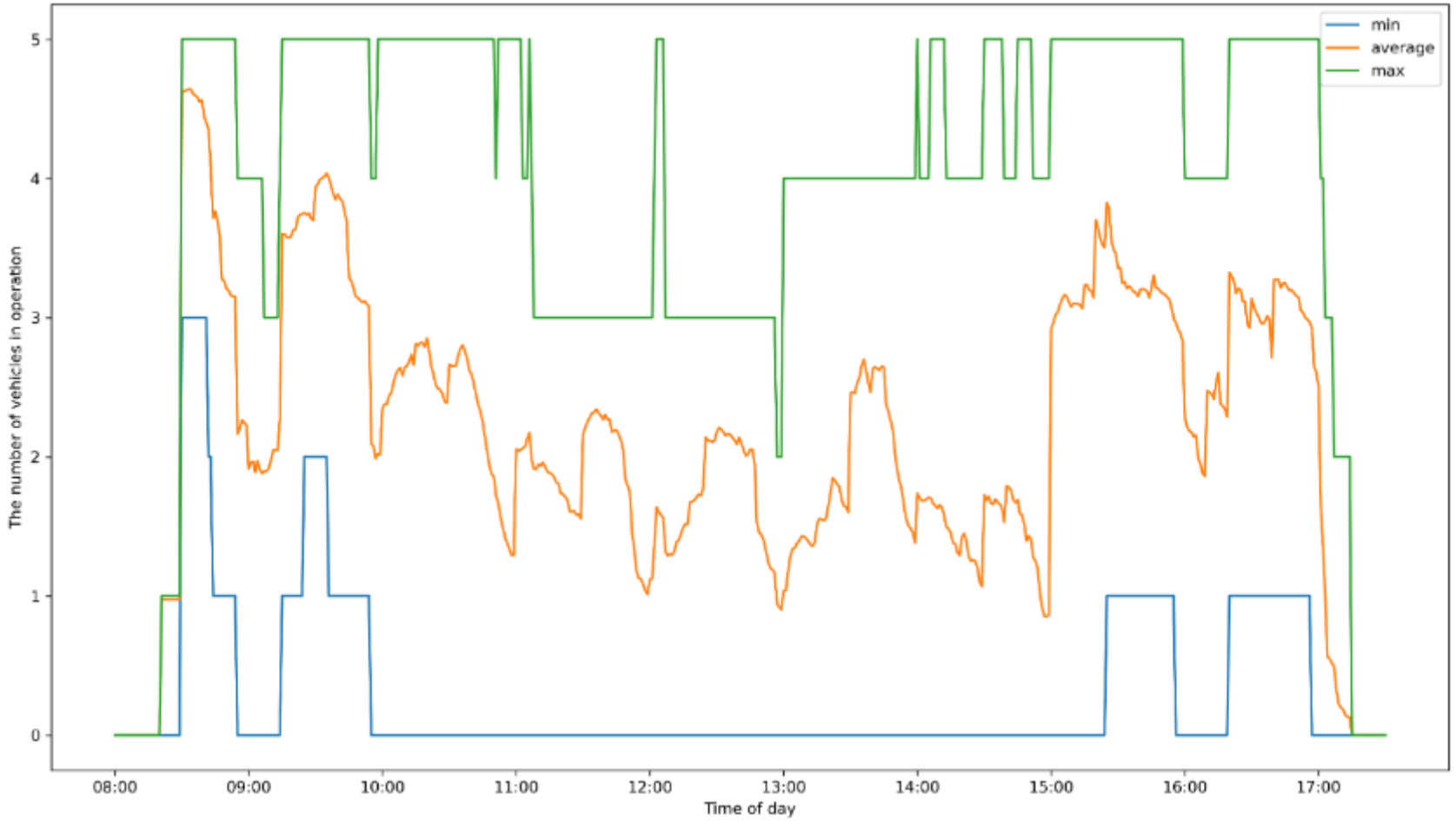
4.2How flexible do travellers move?(travellers)

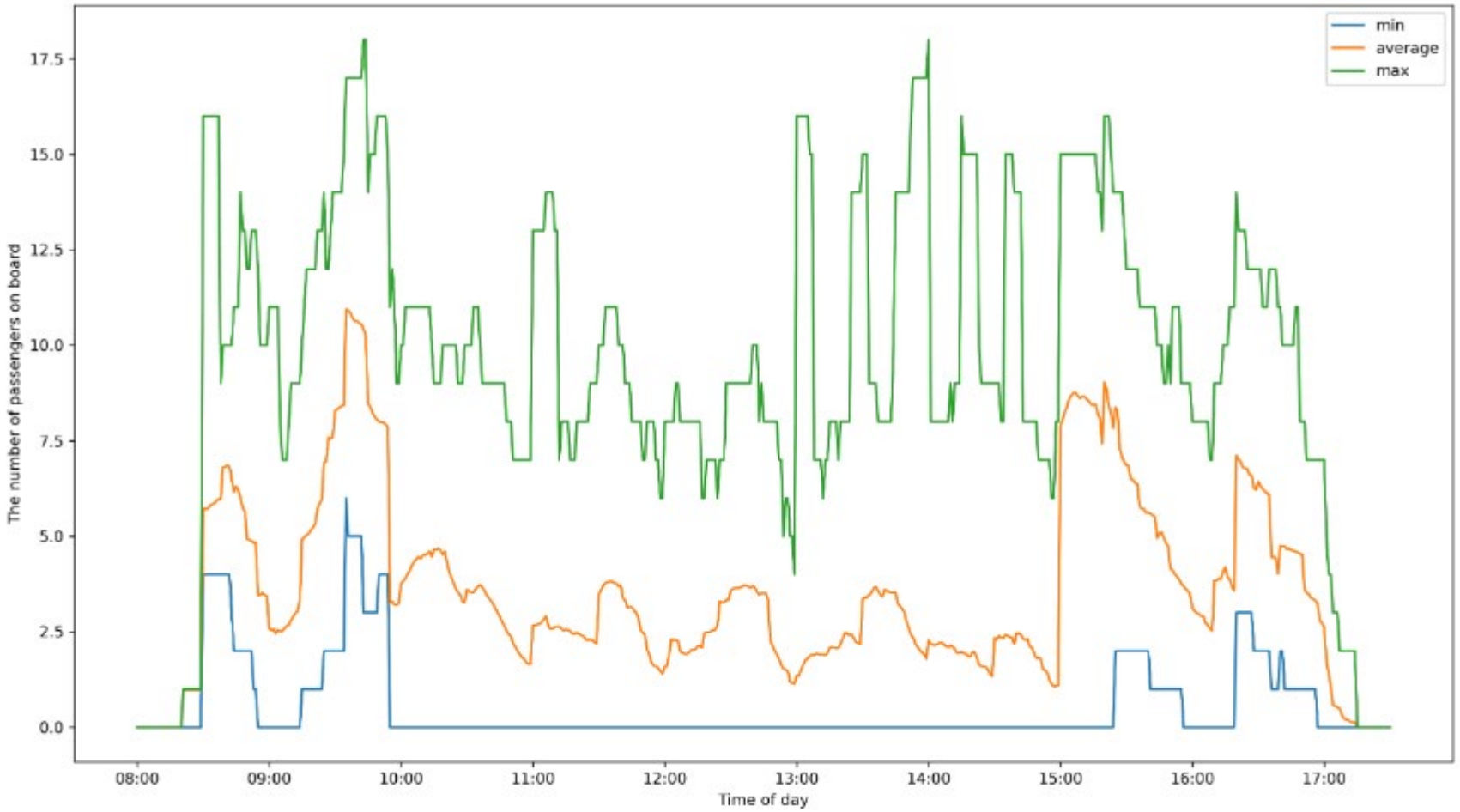
The number of vehicles in operation



- Vehicles are efficiently utilised during the times when cluster 2 travellers are making a significant number of trips (8:30, 9:15 - 9:30, 15:00 and 16:15)
- During the daytime, only three vehicles are in operation.

4.2How flexible do travellers move?(travellers)

The number of passengers on board



- More passengers are on board during the mentioned times.
- Efficient service observed around 9:30 and 15:00-15:30.
- The services are most efficient during periods when cluster 2 travellers are making a significant number of trips.

Vehicles are efficiently used when there are many ‘regular’ travellers.

5.Findings

- The movements of vehicles are **predominantly shaped by a small group of high-frequency regular travellers**, and the annual variations of these travellers are relatively minor.
- Some of these frequent travellers, who commute to 'Employment Support' facilities on weekdays, may have disabilities, while others visit the hot spring daily.
- Travel **distance may often become beyond 15km**; the vehicle may be occupied up to 1 hour.
- The consistent patterns of these regular movements significantly influence vehicle movements, particularly during busy periods.
- Such **consistent patterns are only observed during busy periods**, and flexible movement has been observed during other periods. However, the use of vehicles are rather low.
- This predominant use, however, **poses a limitation on access for other citizens, while contributing to improve service efficiency**.
- Certain high-frequency regular travellers persist in using the service even in the absence of a monthly travel pass.

6.Discussions

- Unified services among different user types may be **predominantly used by individuals who get benefits more**
  - Introducing another transport service (STS) might be necessary if we impose restrictions on the use by disabled people.
- The spatial and temporal dimensions of services should also be taken into account.
  - The size of the service area determines the efficiency of services, but reducing areas may require many travellers to make transfers.
- It may be worthwhile to discuss the reform of route bus services during peak periods.
  - Some vehicles operate with empty seats during the daytime, while consistent movement occurs during peak times.
- We must consider the role of public transport in community settings and determine appropriate evaluation metrics.
  - Cost efficiency may not be a primal concern.
  - Better indicators needed.

Further studies

- Understanding rather ‘random’ behaviour
  - Can we reduce uncertainty in passenger movement?
- Understanding long-term behaviour of travellers
  - Analysis of habitual behaviour
- Exploring the relationship between clustered bus stops and passengers
  - how specific passenger behaviors correlate with the frequency and timing of bus stop usage
- Evaluation indices (or objective functions) of flexible transport services
  - Maybe multi-objective?
- How can we predict such predominant risks?
  - Can we make a good forecast of people movement using other data sources, like big data?
  - Can we develop some simulation models to check the possible consequence before implementing flexible transport services?

Thank you for your attention!

Contact: du.ran.d4@s.gifu-u.ac.jp

Aknowledgment to…
Kaizu City and Teikoku Co. Ltd.