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How flexible transportation services work in reality? - some insights from real-world observations

Joint Workshop with UWA and Japanese Universities
-26/02/05-

Ran DU

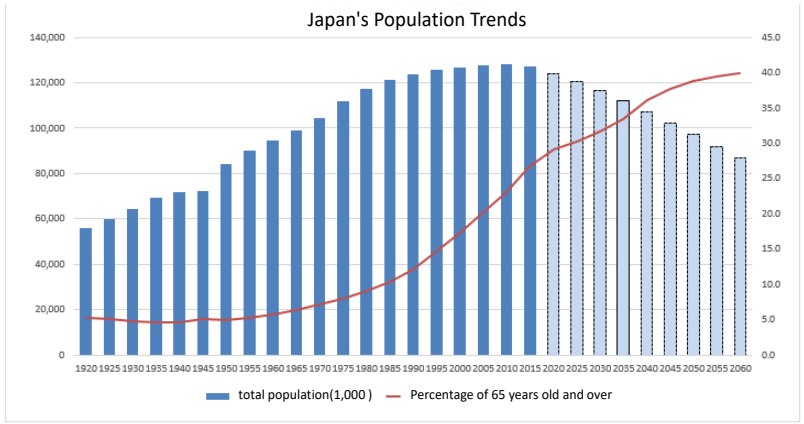
Gifu University

Mobility Analytics Lab

Background

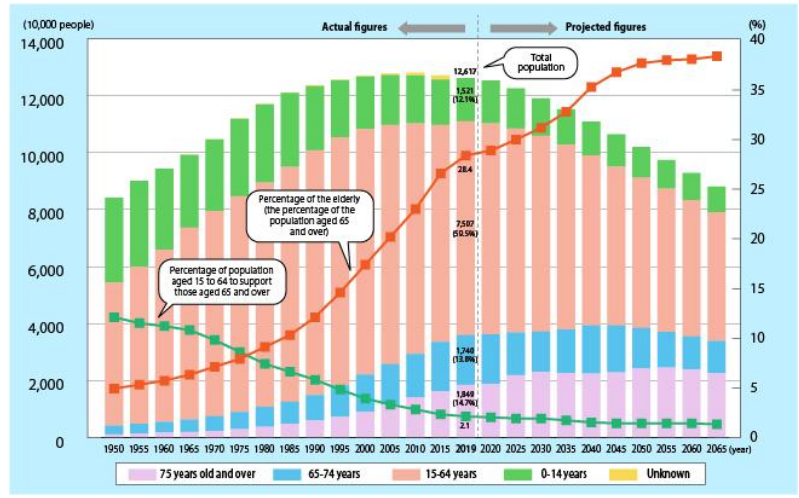
https://wwf.panda.org/wwf_news/?204455/Shanghai-urban-farming

Car Dependence



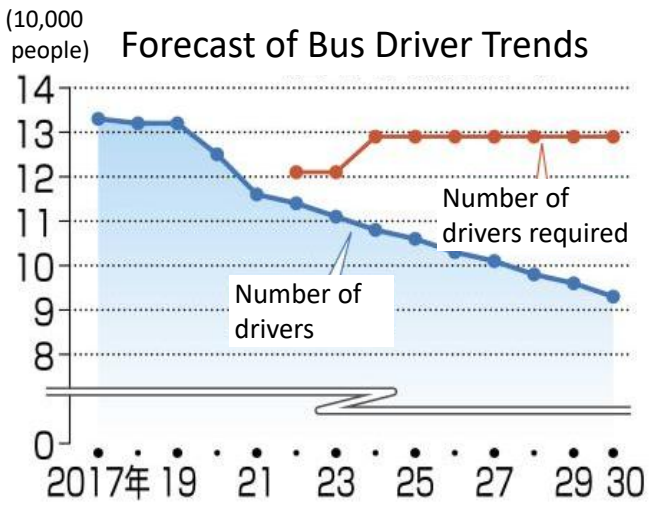
https://www.stat.go.jp/data/nihon/pdf/16nihon.pdf

Population Decline



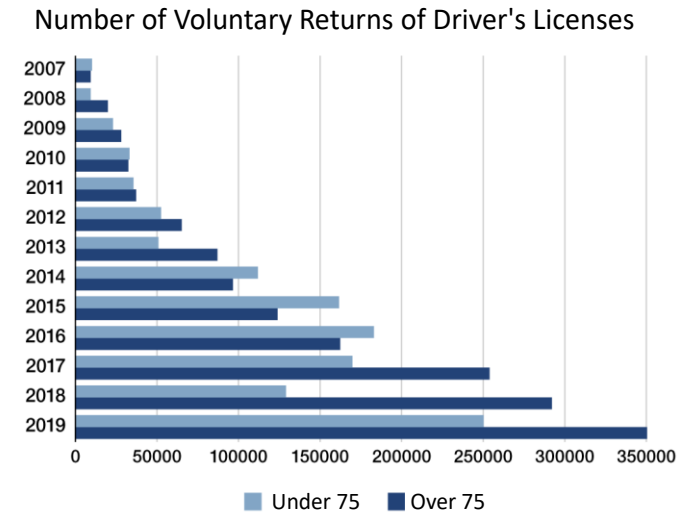
https://www.gov-online.go.jp/eng/publicity/book/hlj/html/202102/202102_09_en.html

Aging Societies



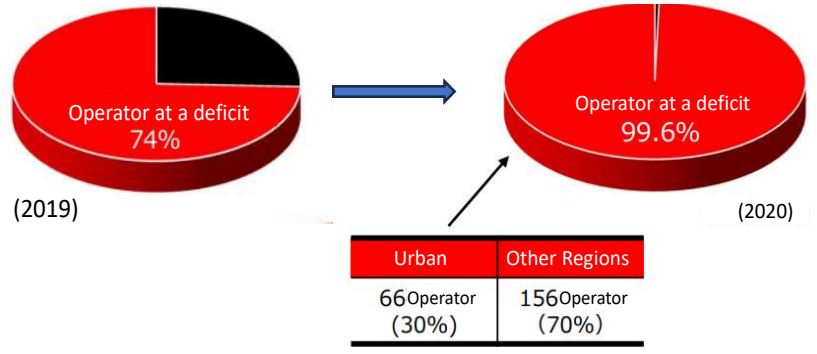
https://news.at-s.com/article/1351759

Driver Shortage



https://www.nippon.com/ja/japan-data/h00689/

Elderly License Returns



https://www.mlit.go.jp/policy/shingikai/content/001612741.pdf

Operational Deficits

Japan's MaaS Project

https://kotsu-kuhaku.jp/adopter_6/kyousou/?s=map

https://wwwtb.mlit.go.jp/tohoku/content/000285728.pdf

Today's Topic:
Kaizu city's DRT
(Close to Nagoya)

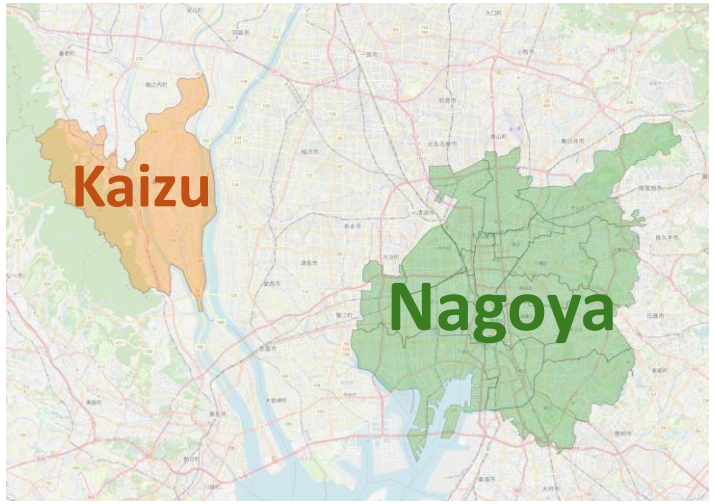
https://www.britannica.com/place/Nagoya

Study Area: Kaizu city

Basic information:

Small city
Population : 30,146 (compared to 2,340,026 in Nagoya)

Weak public transport network
Most residents rely on private cars for daily travel

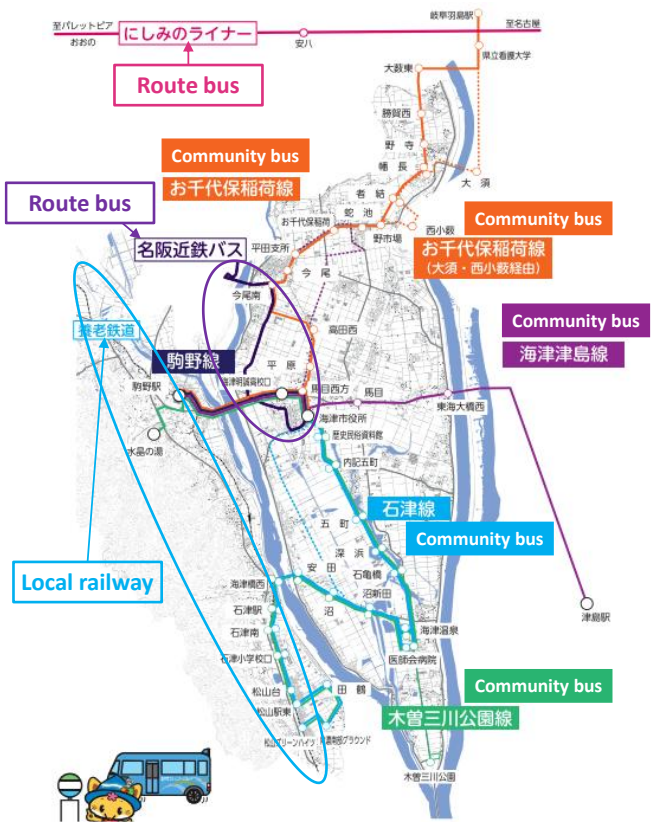


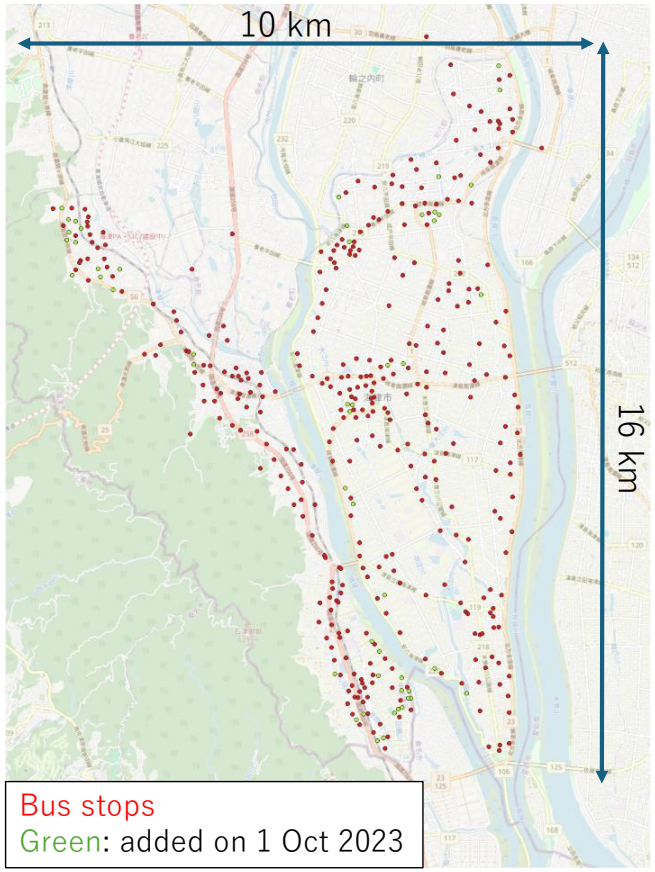
Kaizu City(2024)
Population density : 284 persons/km^2

Nagoya City(2024)
Population density : 7,126 persons/km^2

Problems with the old community bus system
The 8 bus routes covered the whole city, but the long travel times and detours made them inconvenient.

As a result, the city decided to reorganize the 8 routes into 3 in 2015.





New public transport system （2015）
fixed-route buses connects to nearby cities and railway stations for commuting, and DRT for shopping and medical trips within the city.

Basic information of DRT

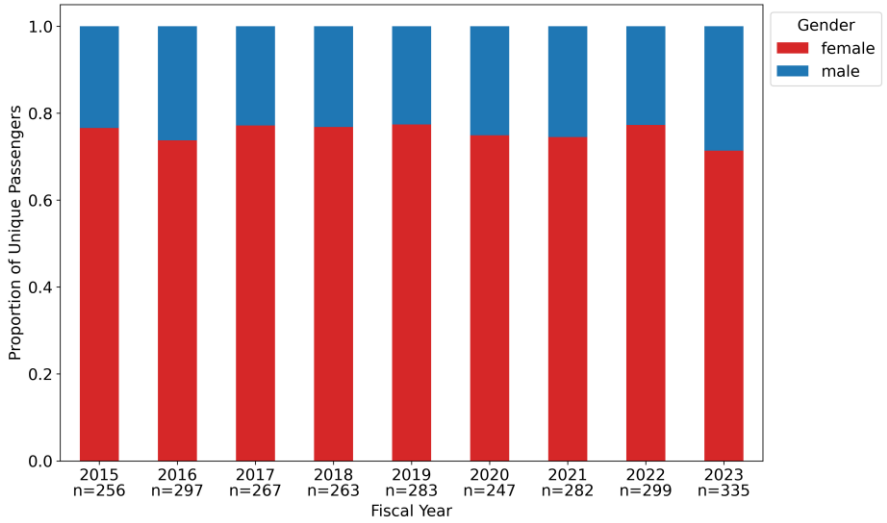
- 8:00-17:00 From Mon to Fri (Since2023/10， to Sat)
- Child: 200 yen
- Adult: 400 yen
- Elderly (65+): 200 yen
- Passport (Monthly Travelcard): 3,000 yen
  - Terminated on 2020/9/20
- Booking is required at least 30 minutes before the preferred departure time.
  - Booking on the previous day is required 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)

Booking data

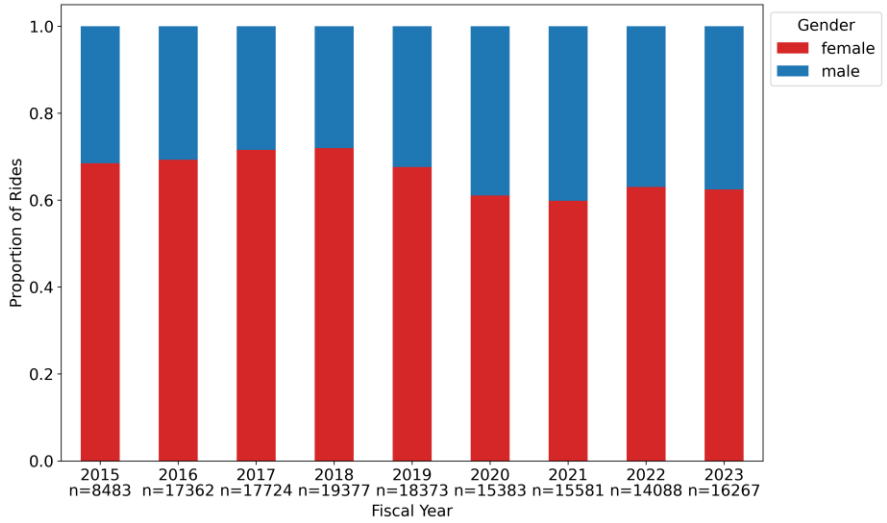
- Periods: 2015/10-2024/4 (about 9 fiscal years)
- Number of records: 142,638
- Number of users: 845
- Number of service days: 2086
- Average number of records /day: 68.4
- Average number of users /day: 36.6
- Data columns
  - Date, Booking #, ID, Gender, Age, Subarea (Home), Subarea (Board), BS(Board), 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

Demographic trends of DRT

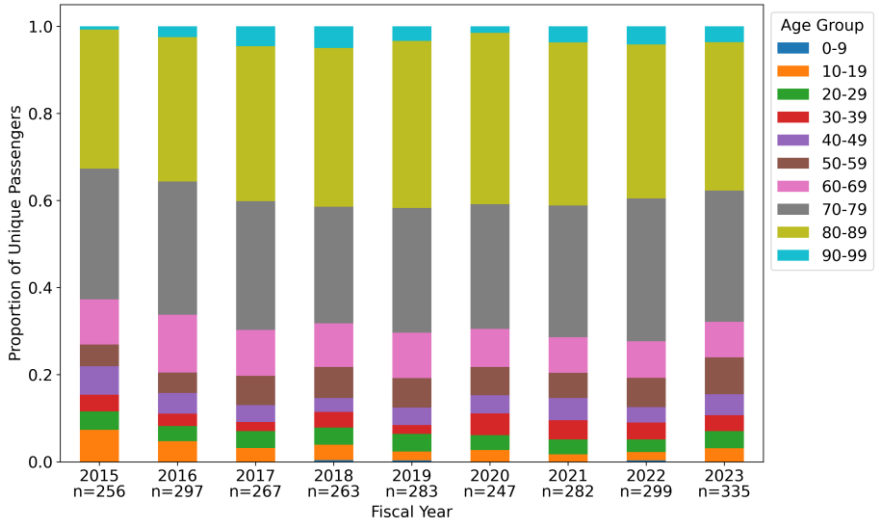
(a) Proportion of Unique Passengers by Gender per Year



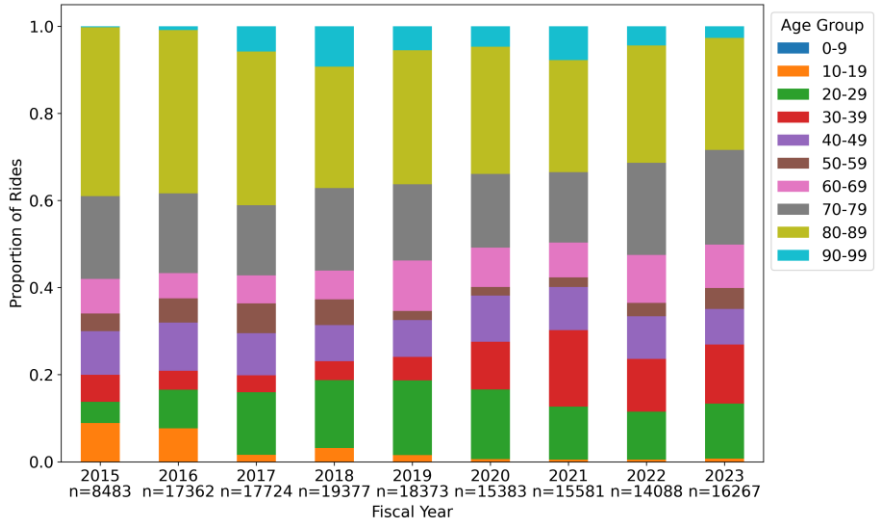
(b) Proportion of Rides by Gender per Year



(c) Proportion of Unique Passengers by Age Group per Year



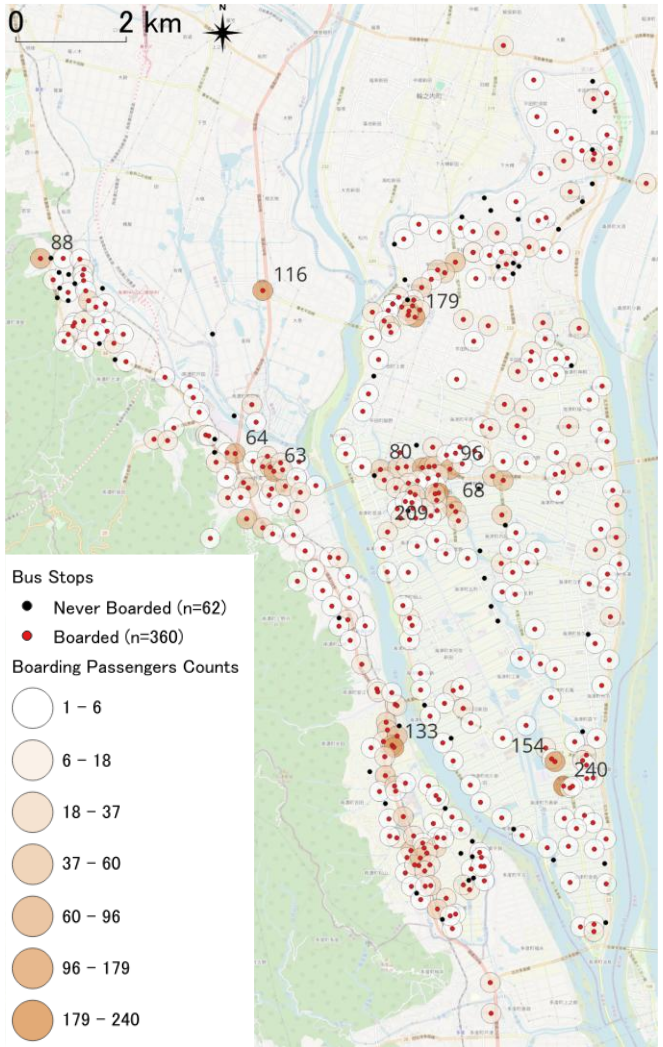
(d) Proportion of Rides by Age Group per Year



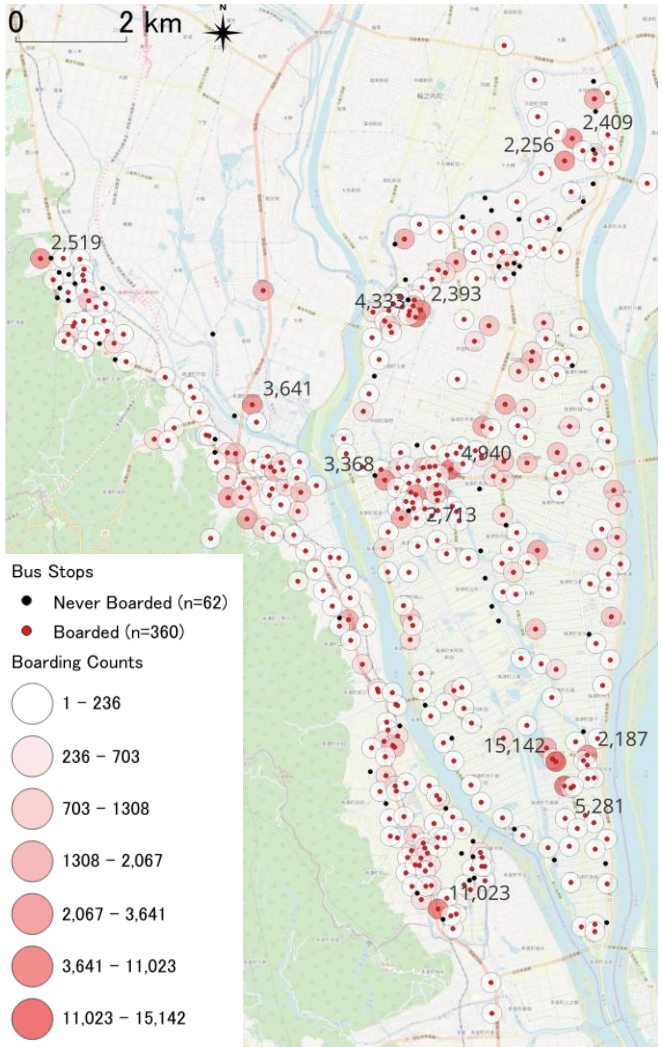
Females, elderly (over 75) use the service more frequently

Spatial patterns of DRT

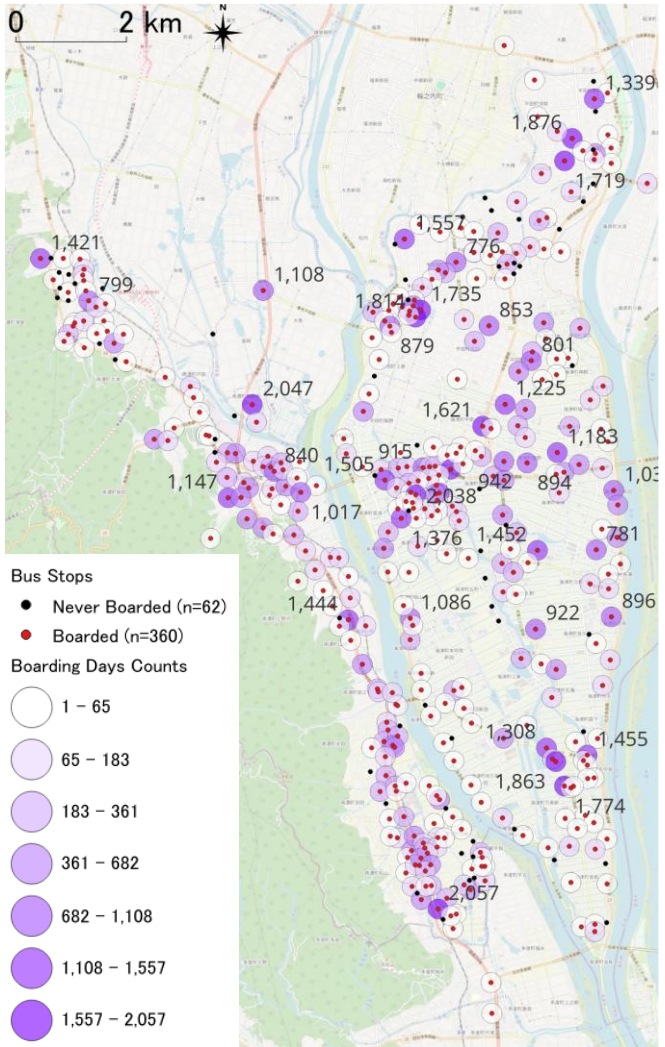
Some bus stops have high value of boarding days counts but few boarding counts and passenger counts → These stops are frequently used by a small group of passengers



(a) Boarding Passenger Counts



(b) Boarding Counts



(c) Boarding Days Counts

Methodology

Passengers were clustered based on the **day-to-day stability/regularity**.

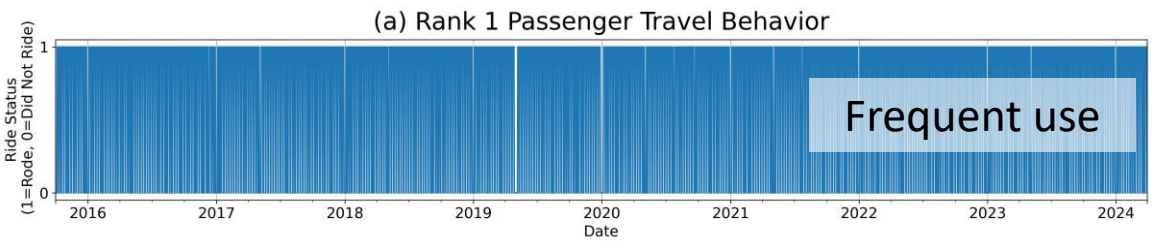
- Day-to-day regularity analysis using **auto-correlation coefficients(ACC)**
  - ➢whether travelers used the service each day is coded as 1 if used, 0 if not.
  - ➢Annual patterns are visualised, and clustering analysis was applied to the annual pattern of daily usages for each traveller.

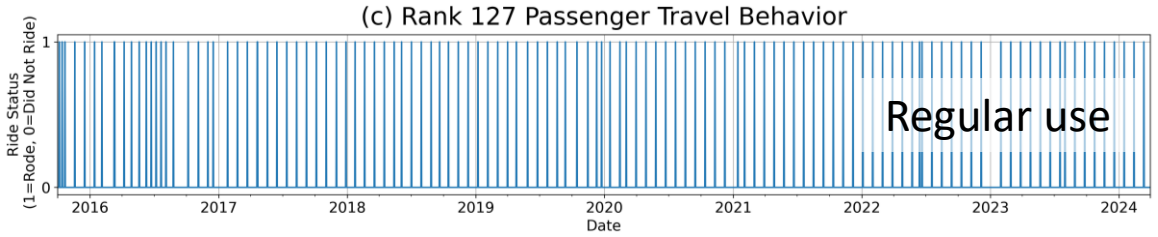
Bus stops were clustered based on the **spatial and temporal demands**.

- 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

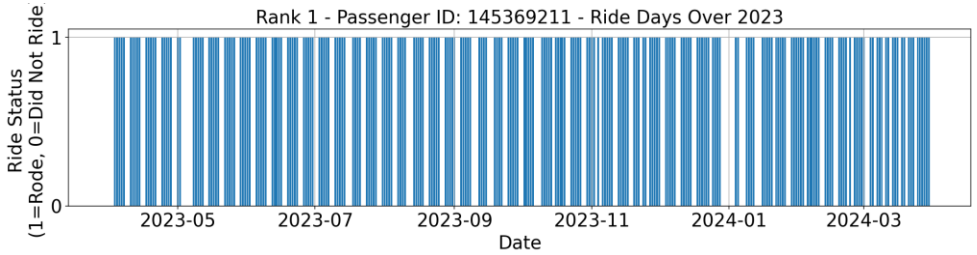
Example of annual travel pattern and ACC analysis

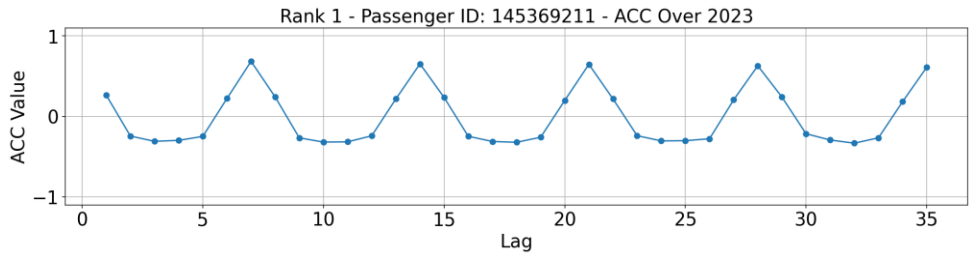
Each day‘s usage: taking a trip (1) or not taking a trip (0)



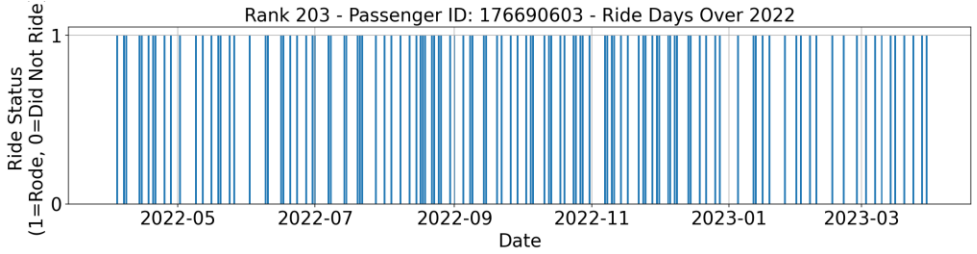


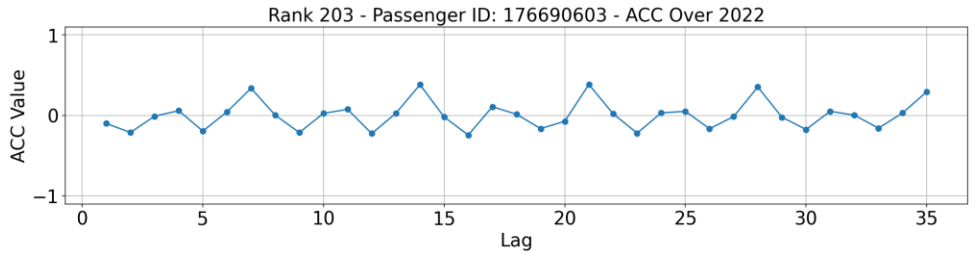
ACC quantifies the similarity between a passenger’s current travel behavior and their past behavior at different time lags



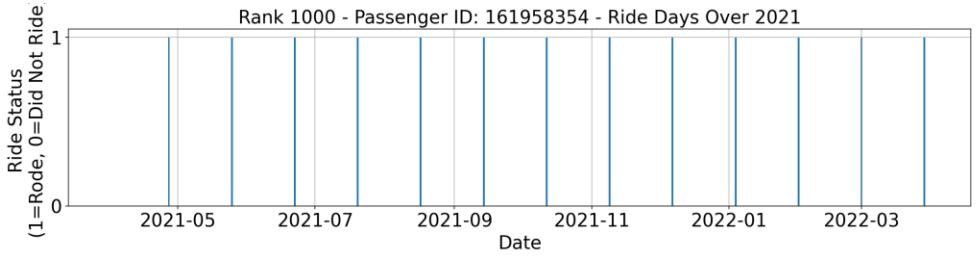


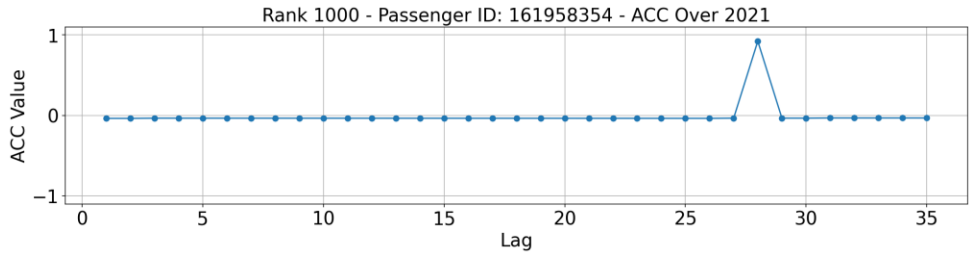
Frequent users
a stable trend of ACC





Random users
ACC close to 0



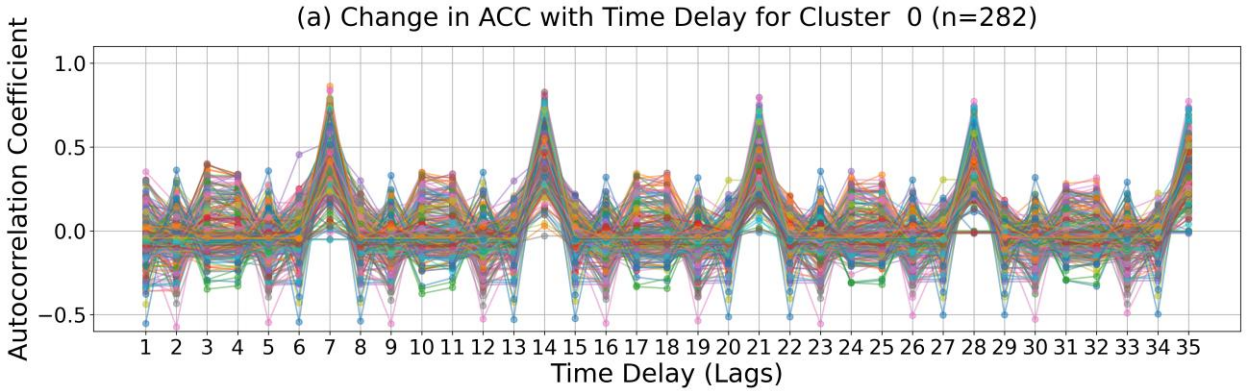


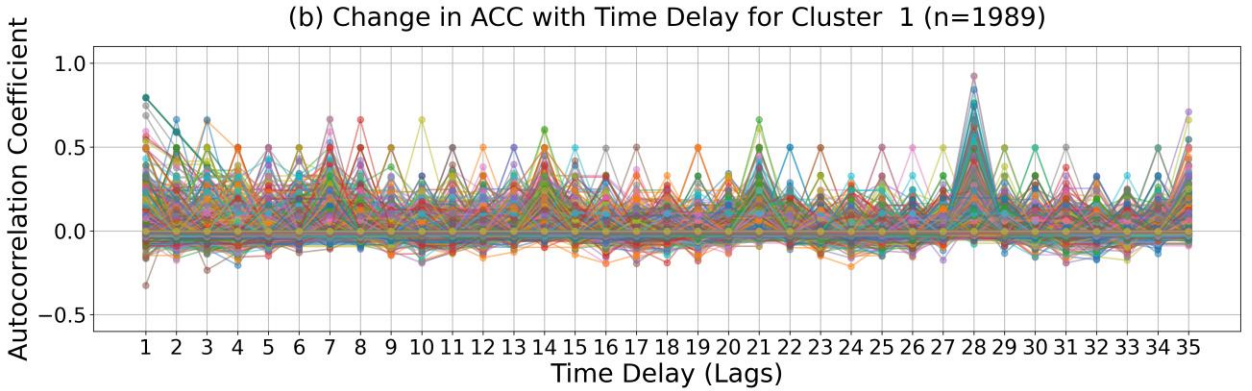
Regular travel with
specific interval
a notable peak

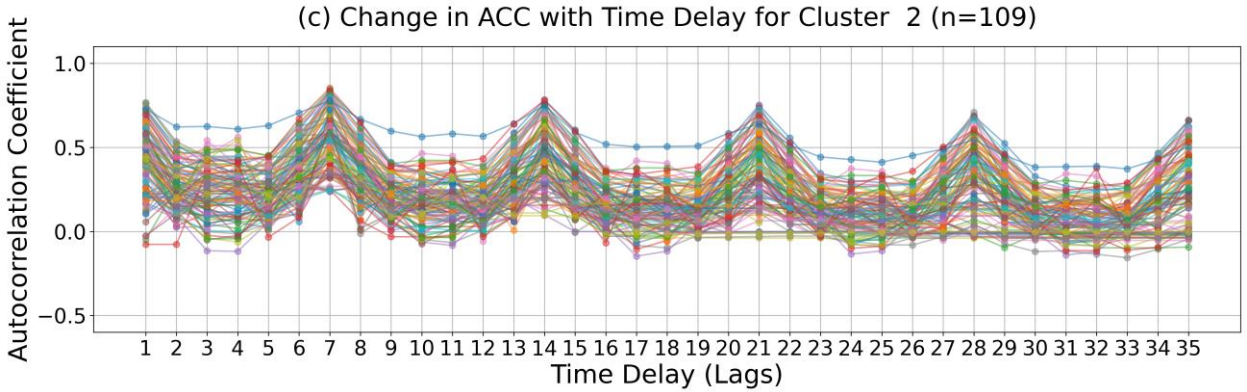
ACC for different passenger clusters

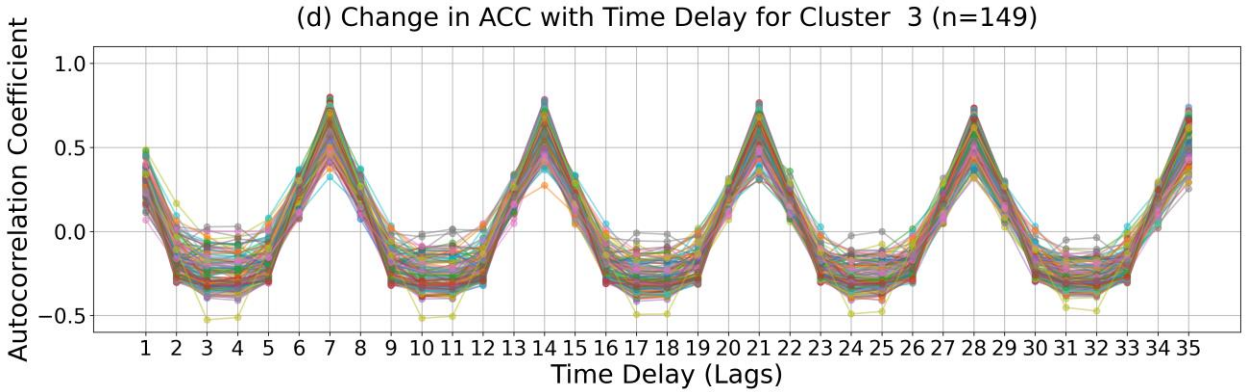
Result of clustering analysis using auto-correlation coefficients(ACC)

- Cluster 1: Random passenger
- Cluster 3: Regular passenger
- Cluster 0,2: Frequent rather regular









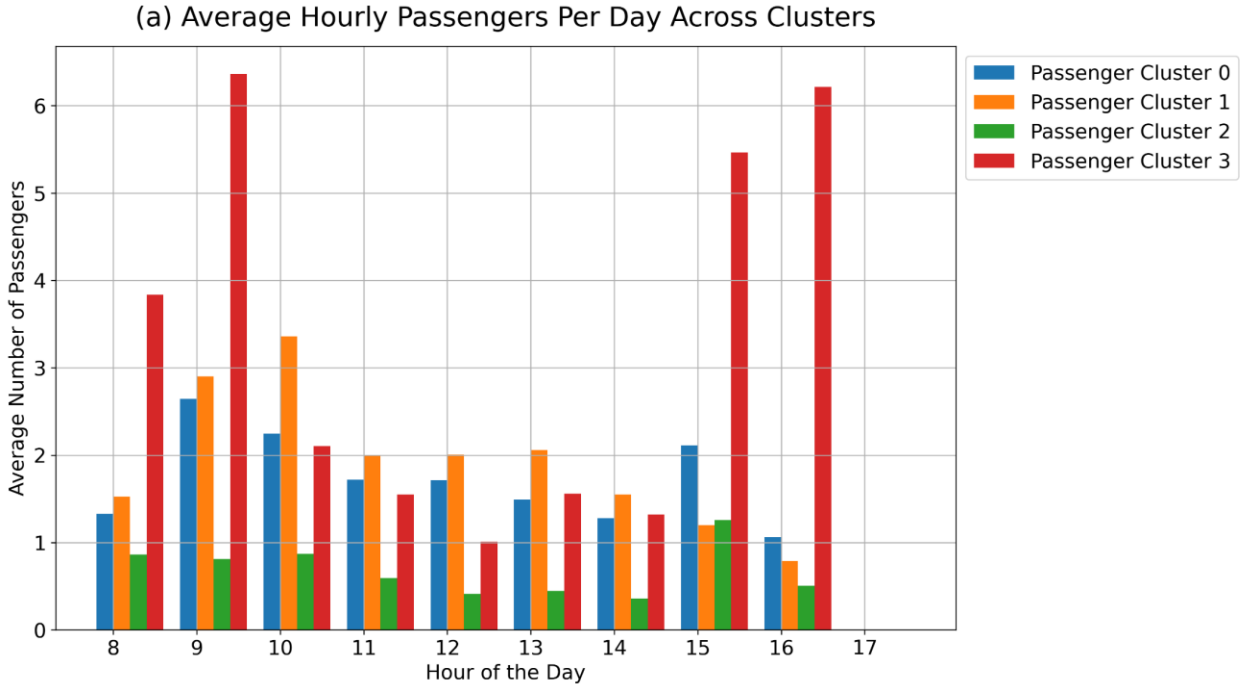
Average hourly and daily passenger for different passenger clusters

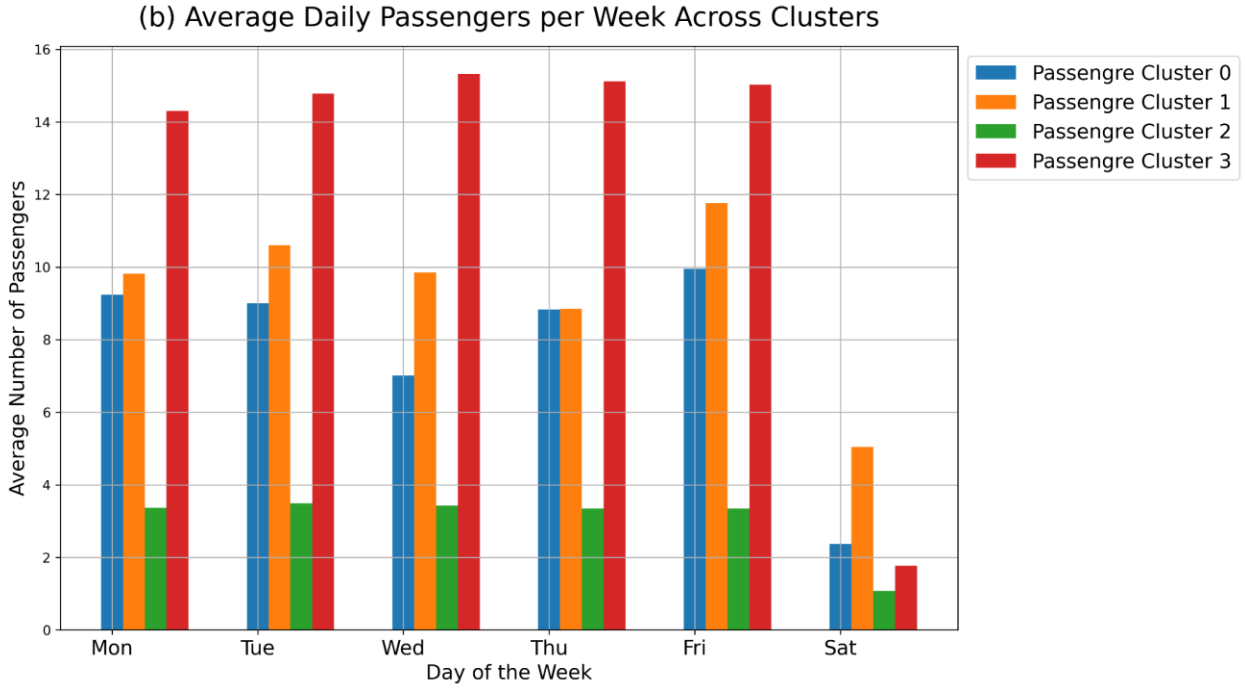
Cluster 3 passengers (frequent) dominate the service during peak commuting hour, but their usage significantly decreases on Saturdays.

- Cluster 3 passengers primarily use the service for commuting

Cluster 1 passengers (random) are more active during off-peak hours

- Cluster 1 passengers are more likely to use the service for random trips





Summary of Passenger Clustering Result

Passenger Cluster	Cluster Counts (Passengers)	Cluster Proportion	Total Rides (Rides)	Total Rides Proportion	Total Ride Days (Days)	Average Daily Rides (Rides/Day)	Average Daily Unique Passengers (Passengers/Day)
0	282	11.2%	32,870	23.0%	2,083	15.8	8.7
1	1,989	78.6%	36,599	25.7%	2,086	17.5	10.1
2	109	4.3%	11,483	8.1%	1,869	5.5	3.0
3	149	5.9%	61,686	43.2%	2,078	29.6	14.8
Total	2,529	100%	142,638	100%	-	68.4	36.6

- Only 5.9% of passenger (149) make 43.2% of trips
- Only 25.7% of trips are made rather ‘randomly’.

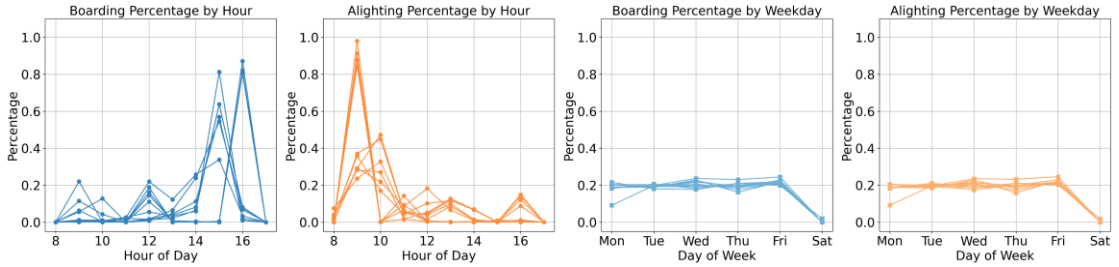
a small group of regular passengers contributes a large portion of the service’s overall usage.

Examples of temporal and weekly usage patterns of bus stop

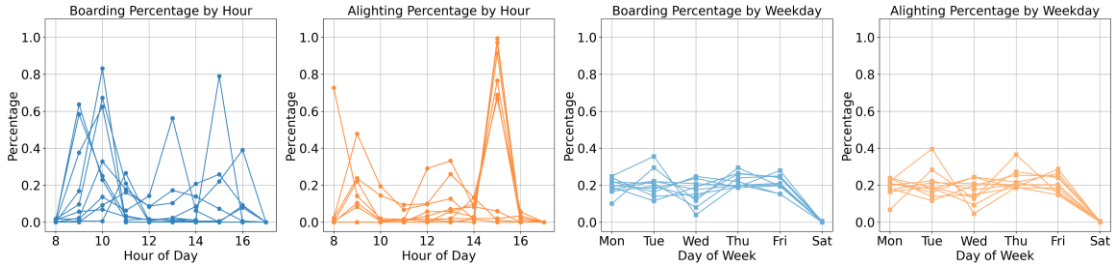
Probability of boarding and alighting at different times of the day and on different days of the week

- Frequent used bus stop have a stable trend of usage pattern
- Random used bus stop have less consistent usage

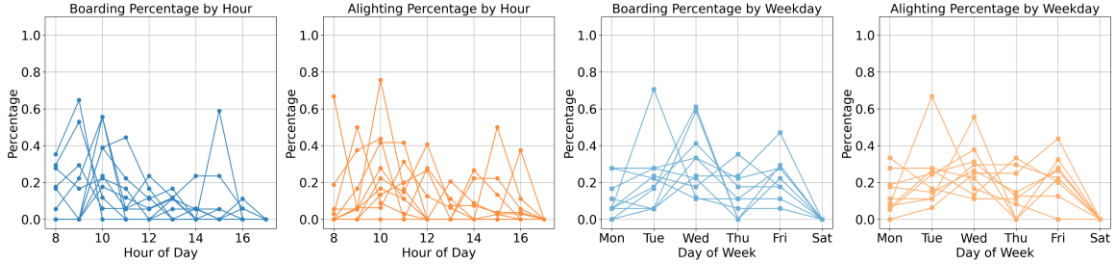
(a) bus stops ranked 1-10 by boarding events



(b) bus stops ranked 201-210 by boarding events

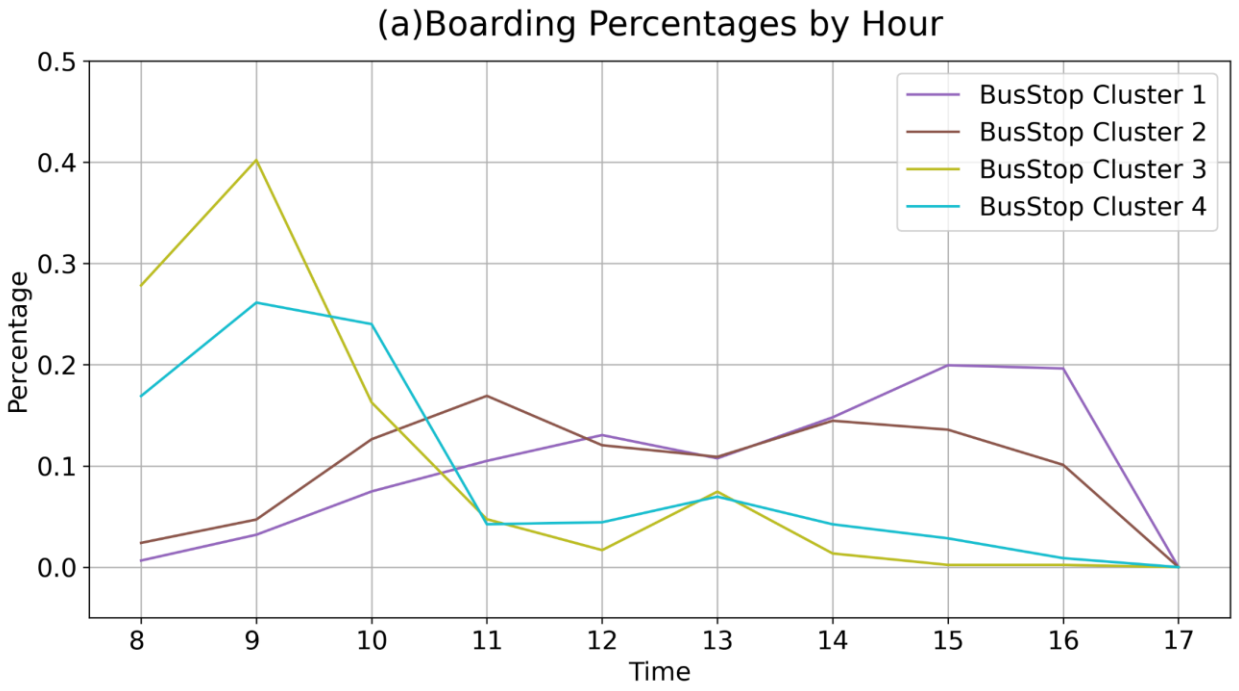


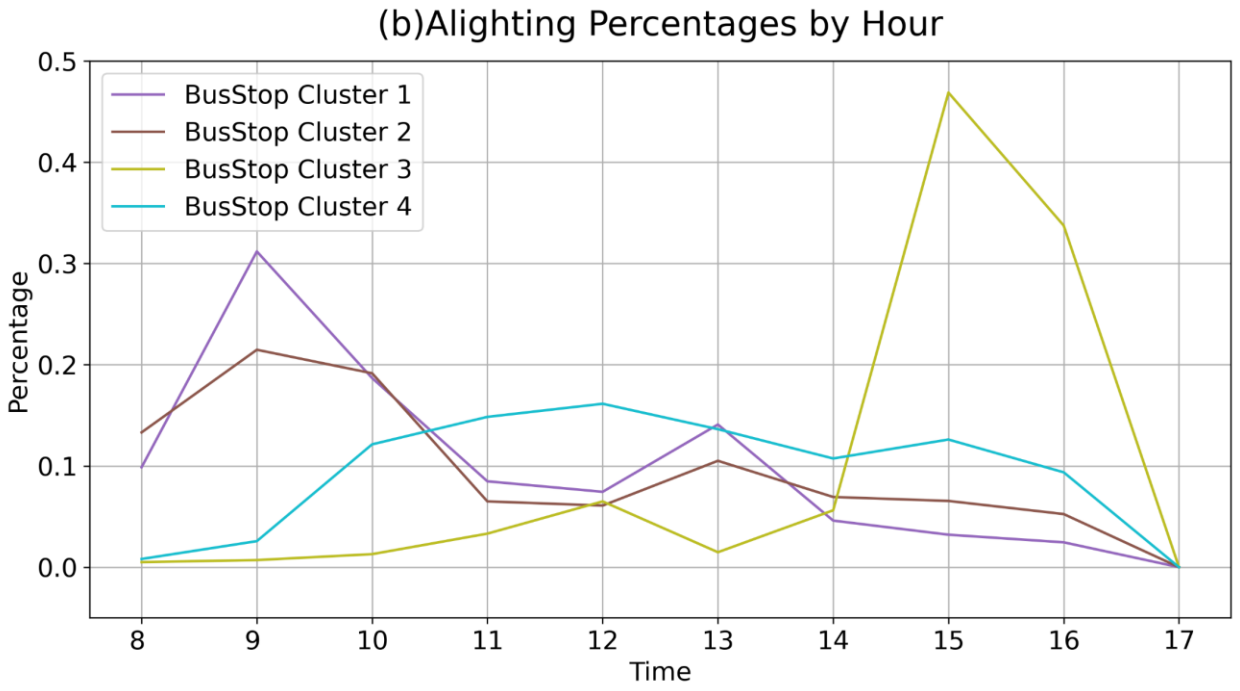
(c) bus stops ranked 1001-1010 by boarding events



Boarding and alighting percentages by hour for different bus stop clusters

Cluster 3 bus stops exhibit a high percentage of morning boardings and evening alightings.
→stops are likely near **residential areas**
Cluster 1 bus stops have a high boardings in the evening and alightings in the morning
→stops are likely near **workplaces**





Summary of Bus Stop Clustering Results

Bus Stop Cluster	Cluster Counts (Bus Stop)	Cluster Proportion	Total Rides (Rides)	Total Rides Proportion	Average Yearly Rides (Rides)	Average Yearly Unique Passengers (Passengers/Year)	Average Yearly Usage Days (Days/Year)
1	54	2.4%	42,816	30.0%	786.5	40.4	181.1
2	798	35.4%	36,141	25.3%	31.3	3.7	23.7
3	117	5.2%	30,678	21.5%	253.9	3.4	206.3
4	1,283	57.0%	33,003	23.1%	22.8	2.1	20.9
Total	2,252	100%	142,638	100%	-	-	-

Cluster 1 (near workplaces) and Cluster 3 (near residential areas) stops together account for only 7.6% (2.4% and 5.2%) of all bus stops, but they share more than half of the total usage (51.5%)

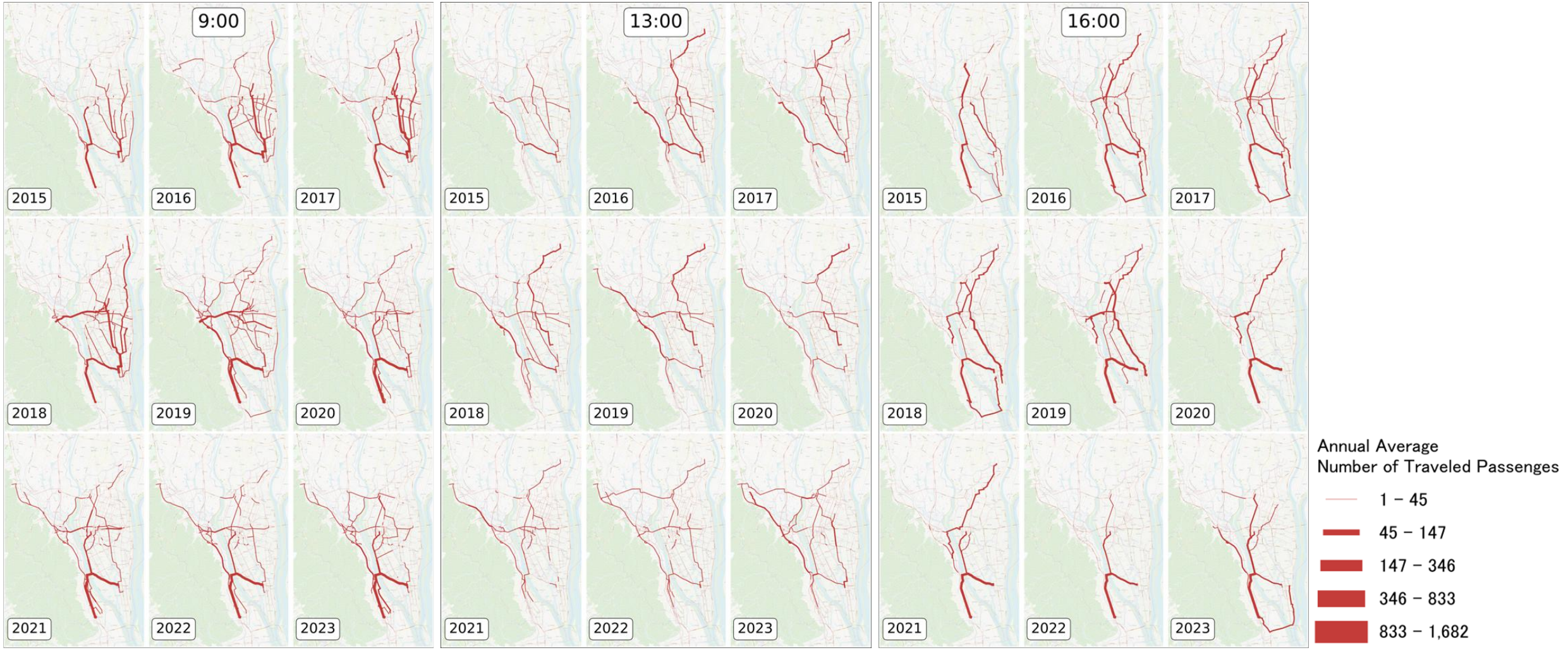
- Bus stops for commuting are frequently used

Cluster 4 stops having the largest number of stops but the lowest usage frequency

- Cluster 4 stops could be randomly used bus stops

Hourly vehicle trajectory patterns over years

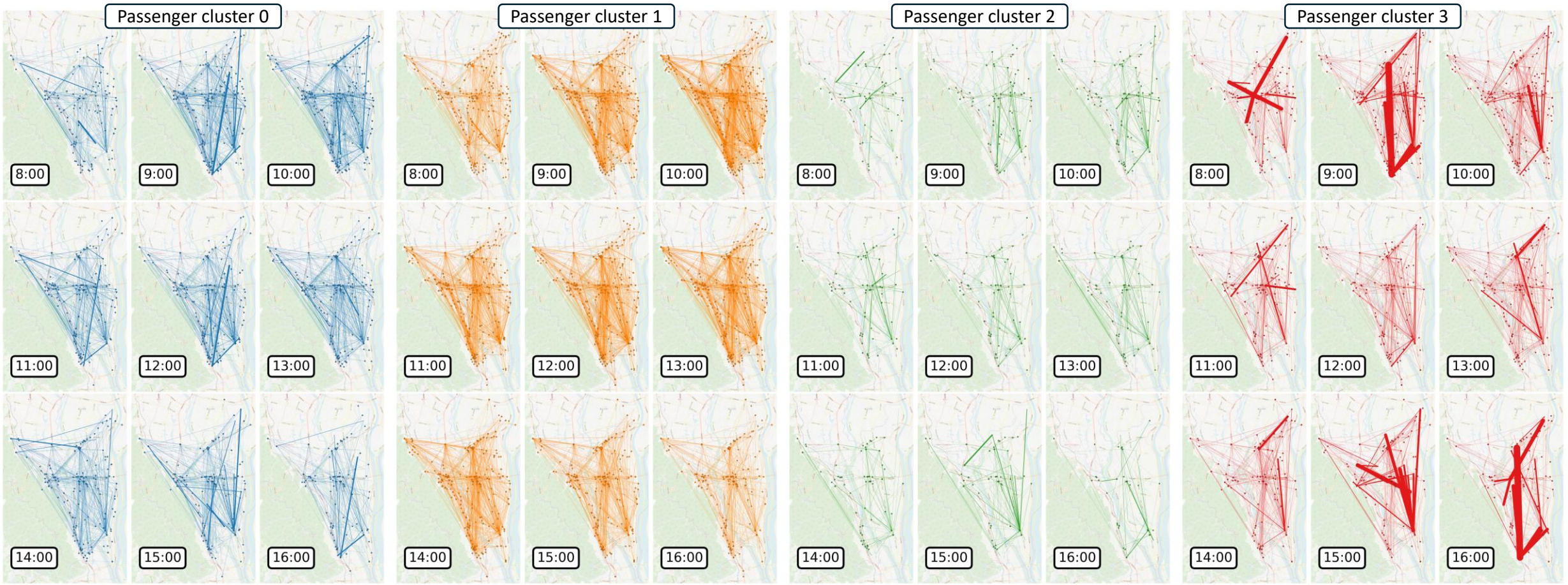
During peak hours, the trajectories become more concentrated.
During these busy periods, certain corridors experience higher demand.



(a) Vehicle Trajectory at 9:00 (b) Vehicle Trajectory at 13:00 (c) Vehicle Trajectory at 16:00

OD distributions of each time interval for different passenger clusters

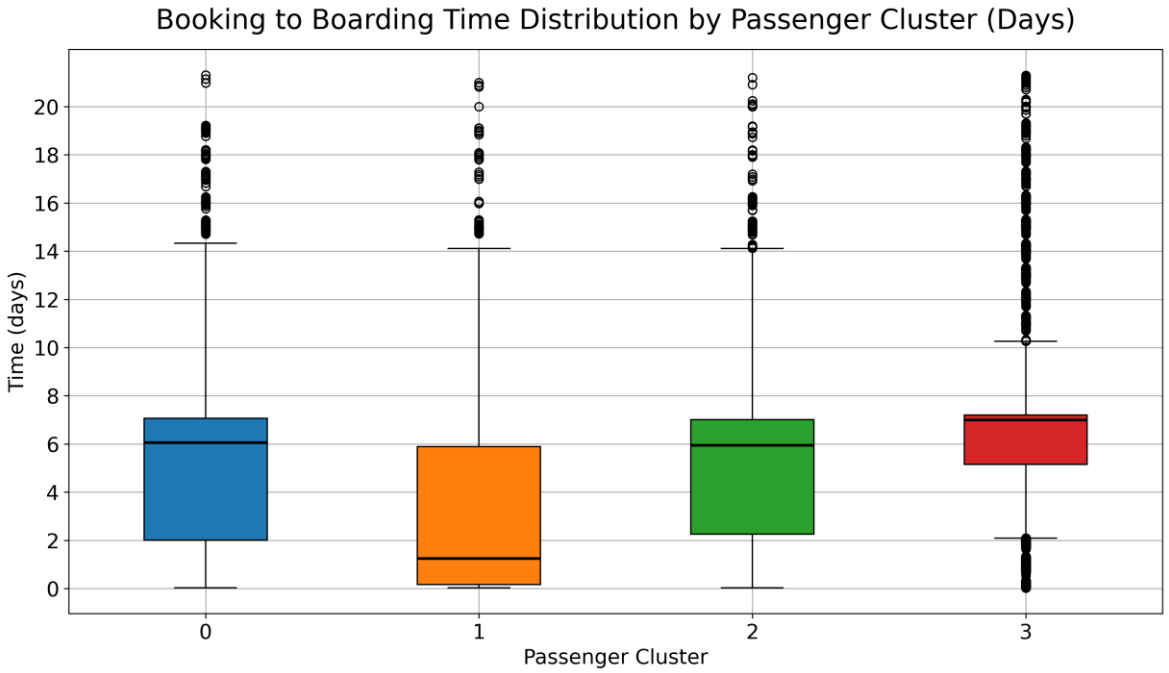
Many peak-hour trips span long distances, mainly by regular passengers (Cluster 3).



In advance booking time and DRT Operation sta

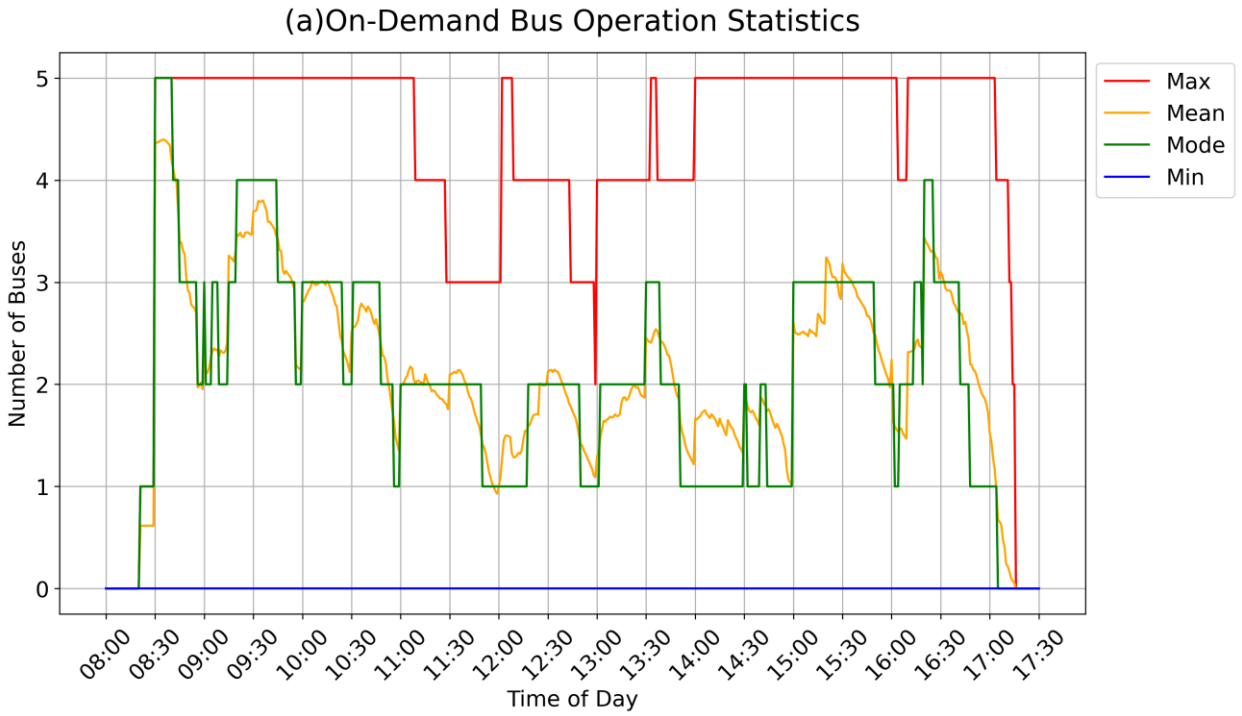
Cluster 3 passengers book trips **one week** in advance

Cluster 1 passengers book trips **one day** in advance



Vehicles are **efficiently used** during the times when cluster 3 passengers are making a significant number of trips (8:30, 9:15 - 9:30, and 16:15)

During the daytime, only two vehicles are in operation.



Summary

- **Uneven usage**
  A small group of regular passenger accounts for a substantial share of bookings, particularly during peak periods.
- **Long travel distance**
  Travel distance may often become beyond 15km, the vehicle may be occupied up to 1 hour.
- **Misaligned objective**
  Although regular passenger may contribute to higher vehicle utilization and operational efficiency, efficiency improvement is not the primary objective of DRT.
- **Evaluation perspective**
  Evaluating flexible transport systems primarily in terms of operational efficiency is insufficient.

Reform Strategies for Future Service Design

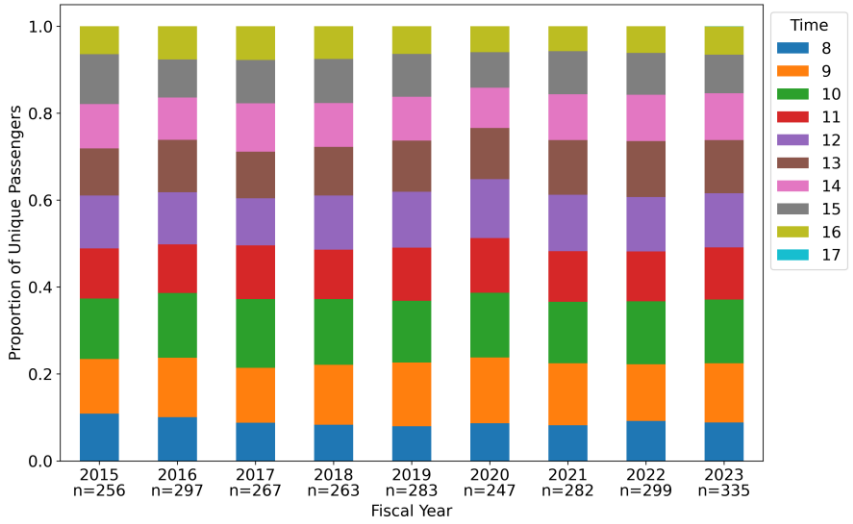
- **Reform of On-Demand Service and Fixed-Route Bus Services**
  Serve as a feeder service for fixed-route buses, adjusting service areas and frequencies to enhance efficiency and meet the needs of frequent travelers.
- **Dynamic Pricing Strategies**
  Adjusting fares during peak hours to reduce congestion and better distribute demand throughout the day.
- **Heavy-User Usage Cap**
  Set request limits for frequent users to prevent excessive consumption and maintain service fairness.
- **Other-User Priority Allocation**
  Prioritise occasional riders during allocation to improve inclusiveness and reduce access imbalance.

Thank you very much!!

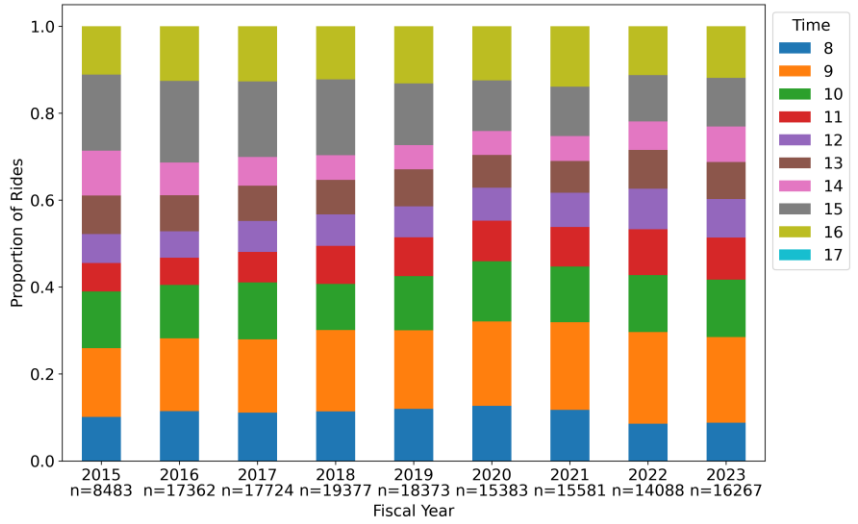
du.ran.d4@s.gifu-u.ac.jp

Temporal patterns of DRT

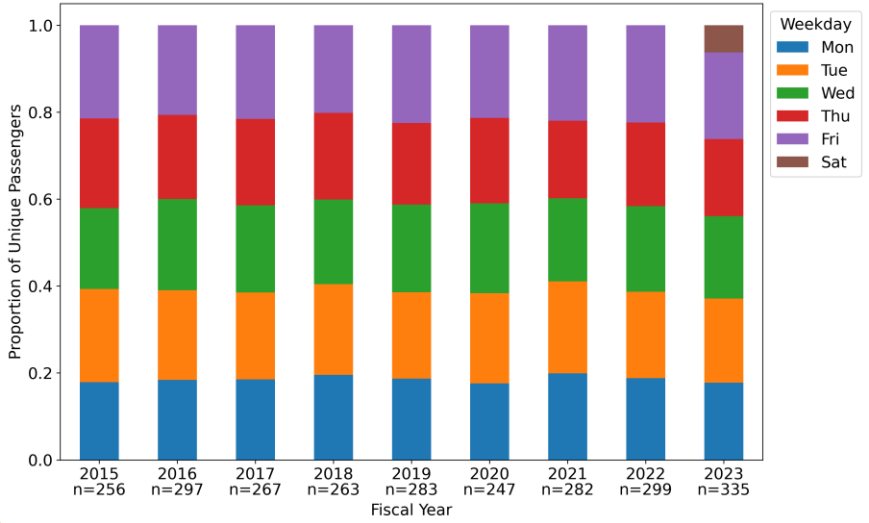
(a) Proportion of Unique Passengers by Time per Year



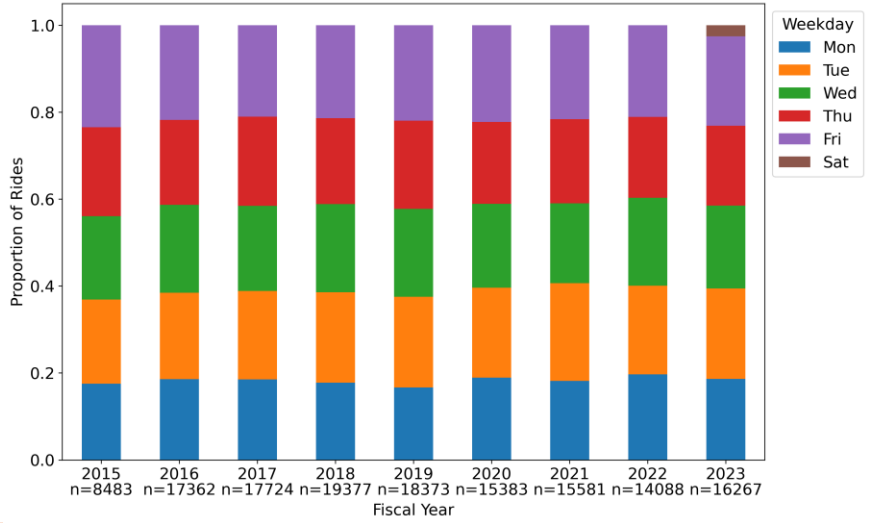
(b) Proportion of Rides by Time per Year



(c) Proportion of Unique Passengers by Weekday per Year

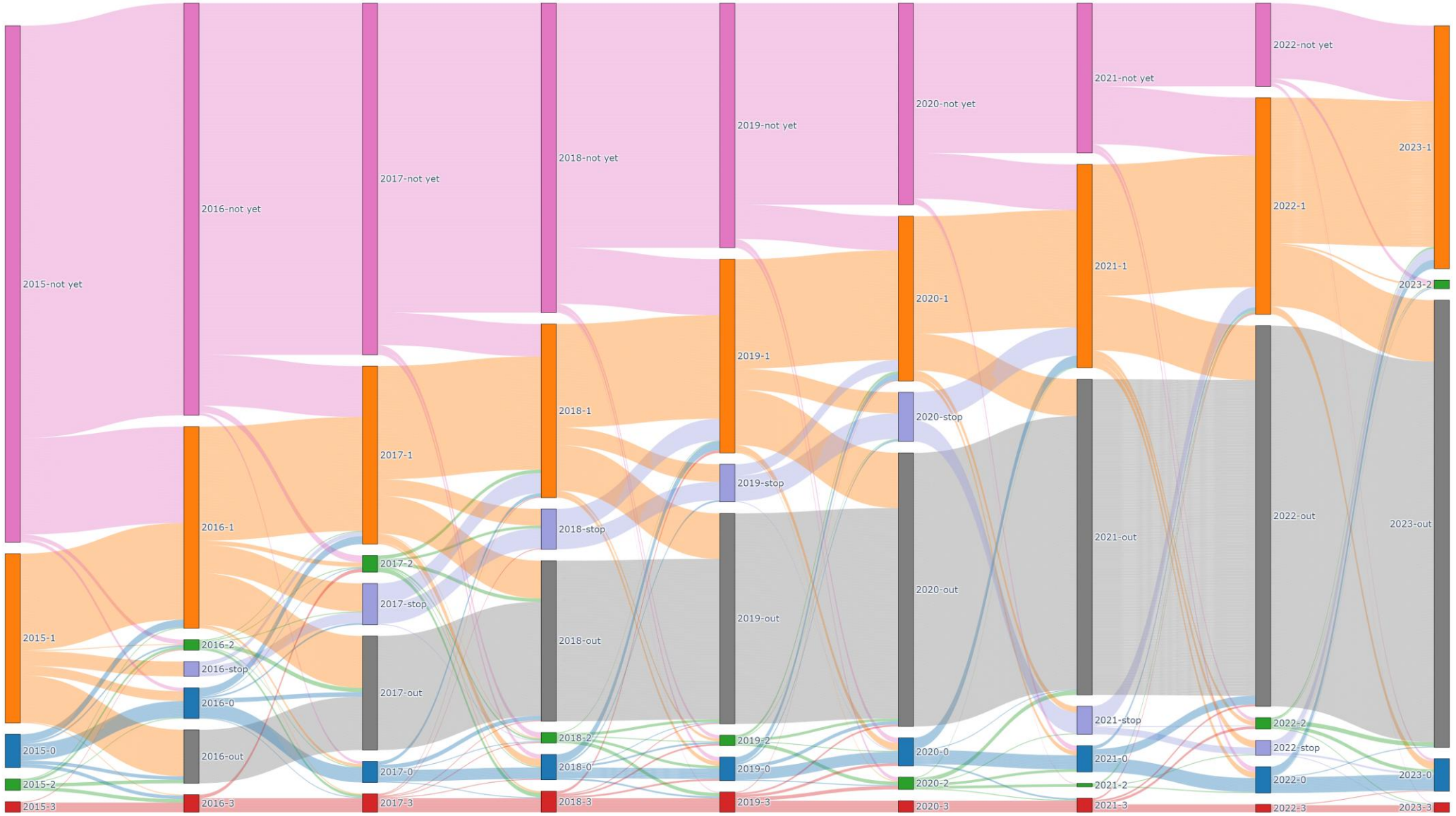


(d) Proportion of Rides by Weekday per Year



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

Sankey diagram of individual passenger cluster transition over fiscal years

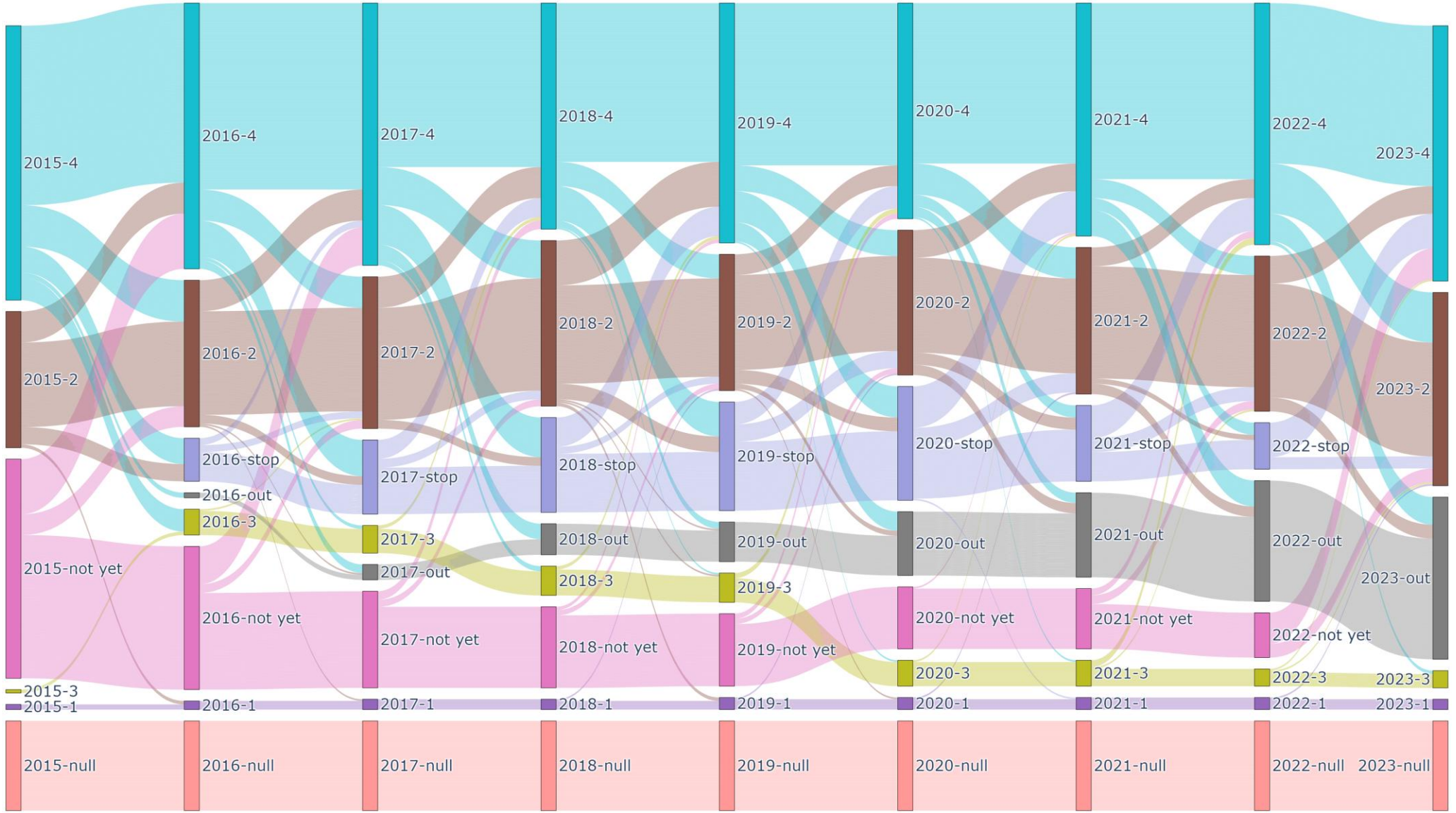


Cluster 1 (random) high turnover

Cluster 3 (frequent) remains stable

Cluster 3 (frequent) Increased in 2016

Sankey diagram of bus stop cluster transition over fiscal years

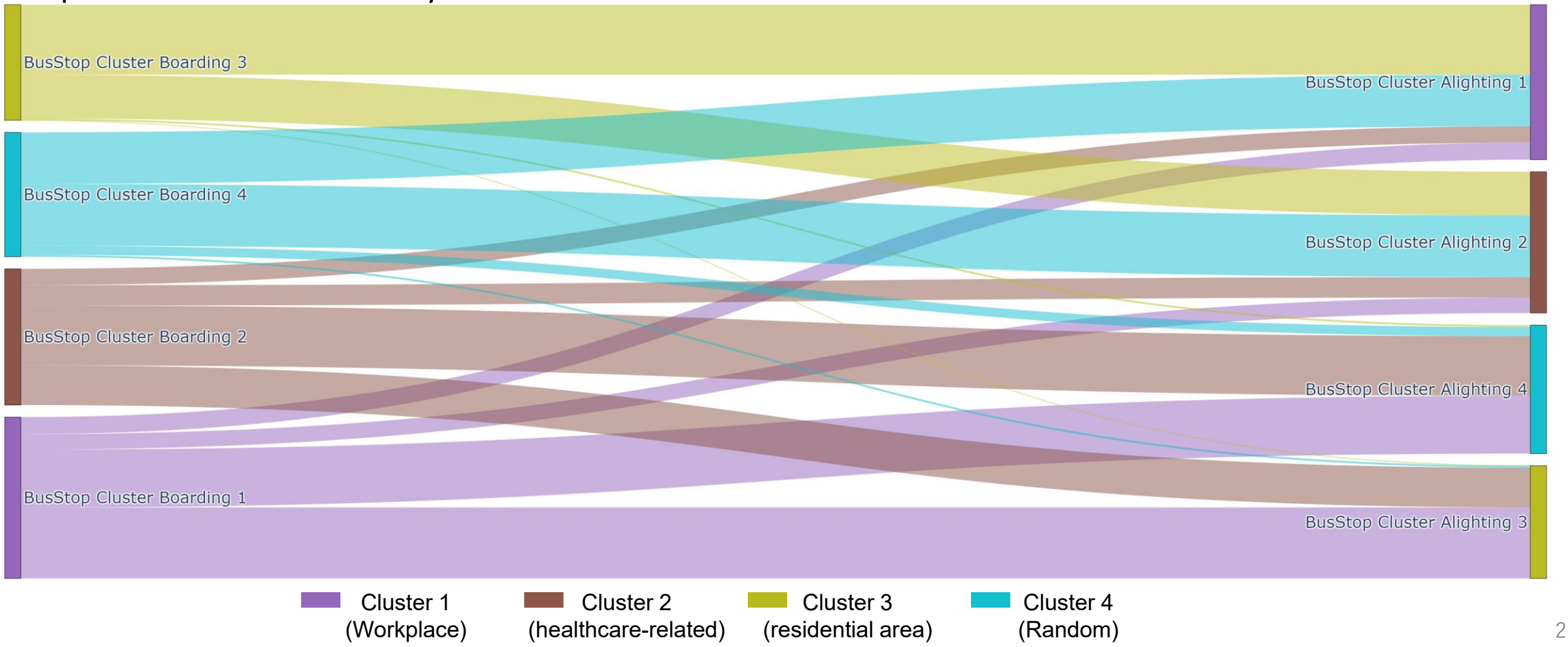


Cluster 3 increased around 2016

stop-level transitions remained milder than passenger-level changes.

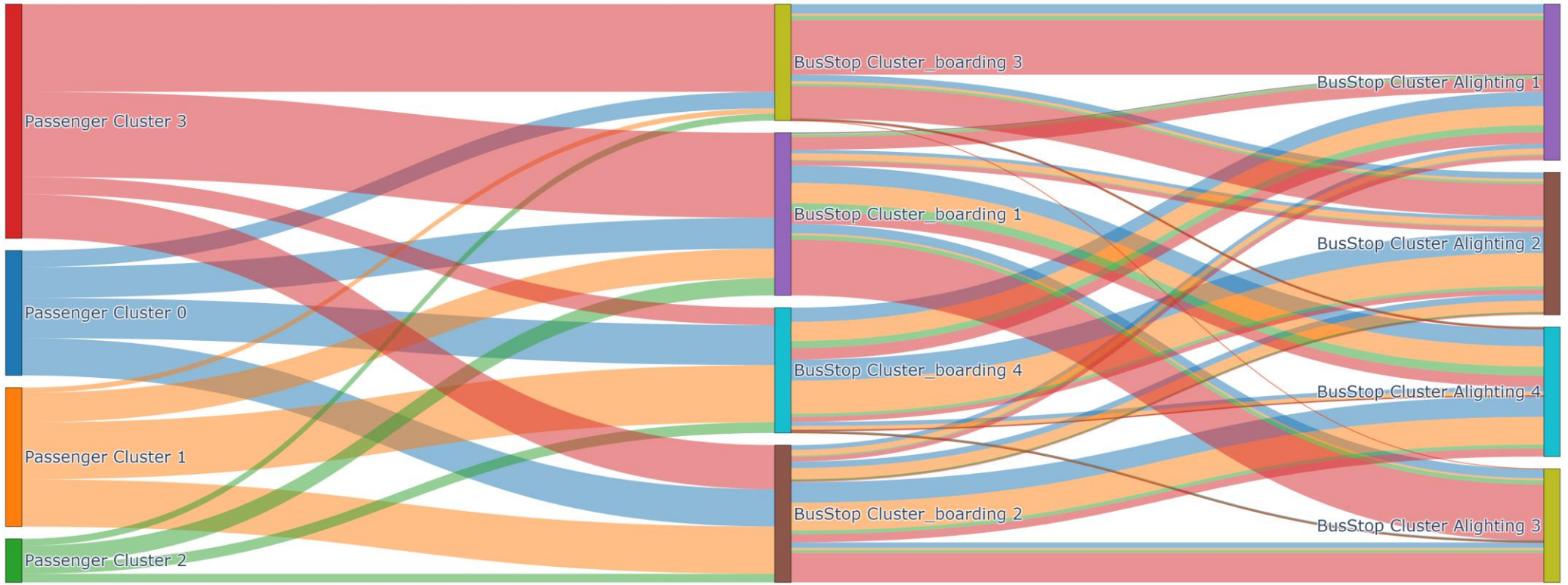
Transition of bus stop from boarding to alighting

- Frequent interactions between Cluster3 (residential) and Cluster1 (workplace) indicate notable commuting patterns.
- Limited interactions between Cluster3 (residential) and Cluster4 (random) suggests that random or occasional trip interactions are relatively rare.



Relationship between passenger and bus stop clusters

- Most passengers departing from Cluster 3 stops (residential areas) and heading to Cluster 1 stops (near workplaces) are Cluster 3 passengers (regular passengers)→Daily commutinng
- passengers who board at Cluster 4 stops (randomly used) and travel to Cluster 1 stops (near workplaces) are largely Cluster 1 passengers (random passengers) → occasional trip to work



Passenger	Cluster 0	Cluster 1 (Random)	Cluster 2	Cluster 3 (Regular)
Bus Stop	Cluster 1 (Workplace)	Cluster 2 (healthcare-related)	Cluster 3 (residential area)	Cluster 4 (Random)

DRT operation statistics

- Vehicles are efficiently used during the times when cluster 3 passengers are making a significant number of trips (8:30, 9:15 - 9:30, and 16:15)
- During the daytime, only two vehicles are in operation.