Identifying Mobility Pattern Changes before and during the COVID-19 Pandemic on Bikeshare Data in Montreal

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(Graduate Course Project Report)

July 2022

1 Introduction

Cycling, as a kind of active transport mode, has been demonstrated to not only provide healthy lifestyle to people, but also bring environmental benefits (Kraus and Koch, 2021). As the COVID-19 crisis has led to the great change of transport behavior (Li et al., 2021), cycling is a suitable transport mode for pursuing health habits, keeping social distance and reducing the risk of being infected. According to a survey[1] from Statistics Canada in 2020, more commuters are walking or cycling to work rather than taking public transit since the onset of the COVID-19 pandemic.

In literature, some works focus on exploring the mobility pattern changes before and during the pandemic and looking for solutions to stimulate the people's preference over active transport modes (e.g., cycling and walking) (Matekenya et al., 2021; Doubleday et al., 2021; Büchel et al., 2022). This research provides a systematical empirical evidence of bikeshare pattern changes before and during the COVID-19 pandemic. The empirical evidence is analyzed on the Bixi bikeshare data in Montreal. The most important measurements include travel time and trip volume.

2 Goals of this Project

- Process real-world Bixi bikeshare data in Montreal.
- Provide a systematical empirical evidence of mobility pattern changes before and during the COVID-19 pandemic on open bikeshare data in Montreal. Analyze the daily trips and the average travel time.
- Assess lifestyle change over the preference of cycling. Focus on changes in mobility behavior, e.g., commuting at weekday.
- Visualize results and provide a thorough analysis.

[1] https://www150.statcan.gc.ca/n1/daily-quotidien/200810/dq200810a-eng.htm

- If the empirical evidence is appealing, I plan to prepare a paper and submit it to a scientific journal. Otherwise, I will prepare a technical report and make it publicly available.

3 Bixi Open Data

In this section, we introduce how to process the open bikeshare dataset and conduct some preliminary analysis on these data. We also discuss how does the mobility pattern change in terms of trips and average travel time before and during the COVID-19 pandemic.

3.1 Dataset

The dataset for the following analysis is from Bixi open data plan[2], and the data contains trip records, station information, trip duration, and membership information. In particular, each trip record provides start time, end time, start station, and end station, trip duration of each trip and the membership status of user. It allows us to aggregate trip volume with a certain time resolution and analyze trips and travel time in both spatial and temporal contexts.

Figure 1 demonstrates that the bikeshare stations in Montreal are increased swiftly. As there are only 22 additional stations appeared in 2020 comparing to 2019, we can see a significant increase of addition stations in 2021, i.e., 209 additional stations comparing to 2019 and 187 additional stations comparing to 2020. Due to the increased stations and docked bikes, bikeshare service can be accessible to more people who are willing to cycle. The increased stations also make more destinations reachable. Increasing bikeshare stations and docked bikes is an effective policy for stimulating cycling.

3.2 Preliminary Analysis

In particular, we use the data of two years before the COVID-19 pandemic (i.e., 2018 and 2019) as one subset. Another subset is the data of two years during the COVID-19 pandemic (i.e., 2020 and 2021). In what follows, we provide a preliminary empirical evidence of mobility pattern changes before and during the COVID-19 pandemic on open bikeshare data in Montreal.

Table 1 summarizes some basic information of bikeshare trips from 2018 to 2021. In contrast to 2019, the total trips in 2020 are decreased dramatically due to the impact of COVID-19 (e.g., work from home). The total trips in 2021 are very close to the trips in 2019. Figure 2a and Figure 2b plot the pickup trips and dropoff trips, respectively. It is not hard to see the reduction of total trips in 2020. Going back to Table 1, it shows that the average travel time has increased to some extent during the COVID-19 pandemic.

Table 1 also gives the preliminary statistics of trips created by members and occasionals, respectively. The percentage of trips created by members is about 80% for all four years. It shows that the average travel time of member trips is roughly shorter than the average travel time of occasional trips. As a whole, the average travel time of trips during 2020 is significantly greater than other years before.

[2] https://bixi.com/en/open-data

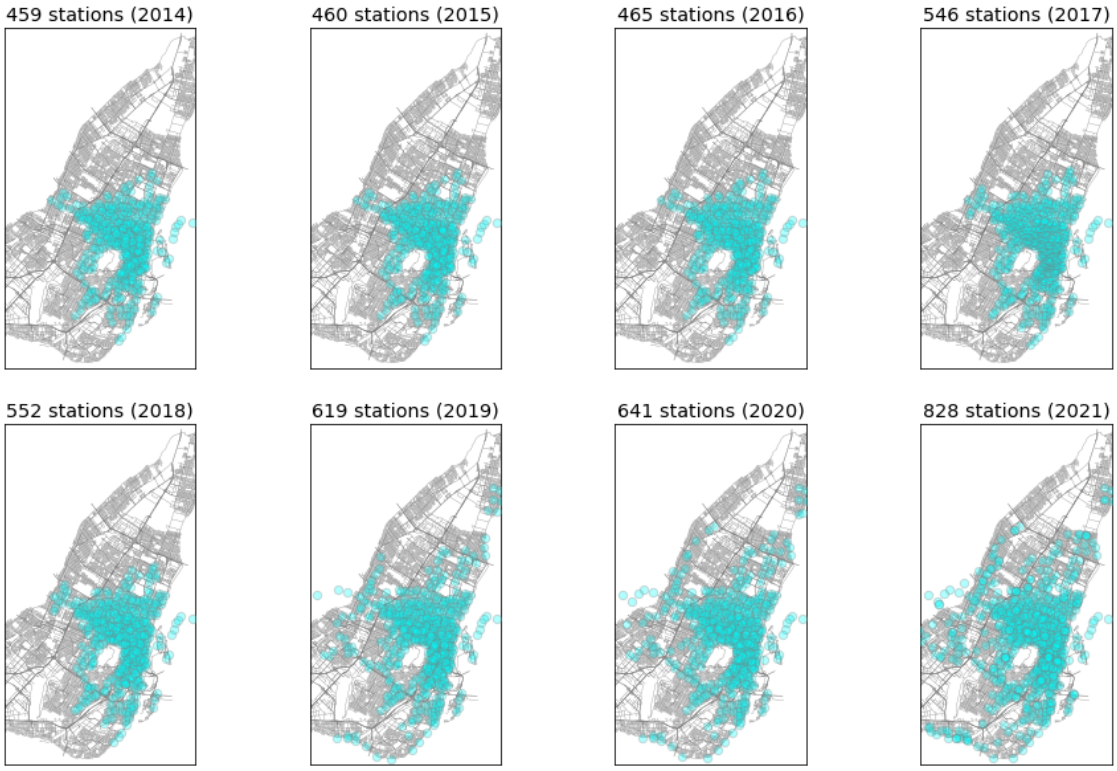


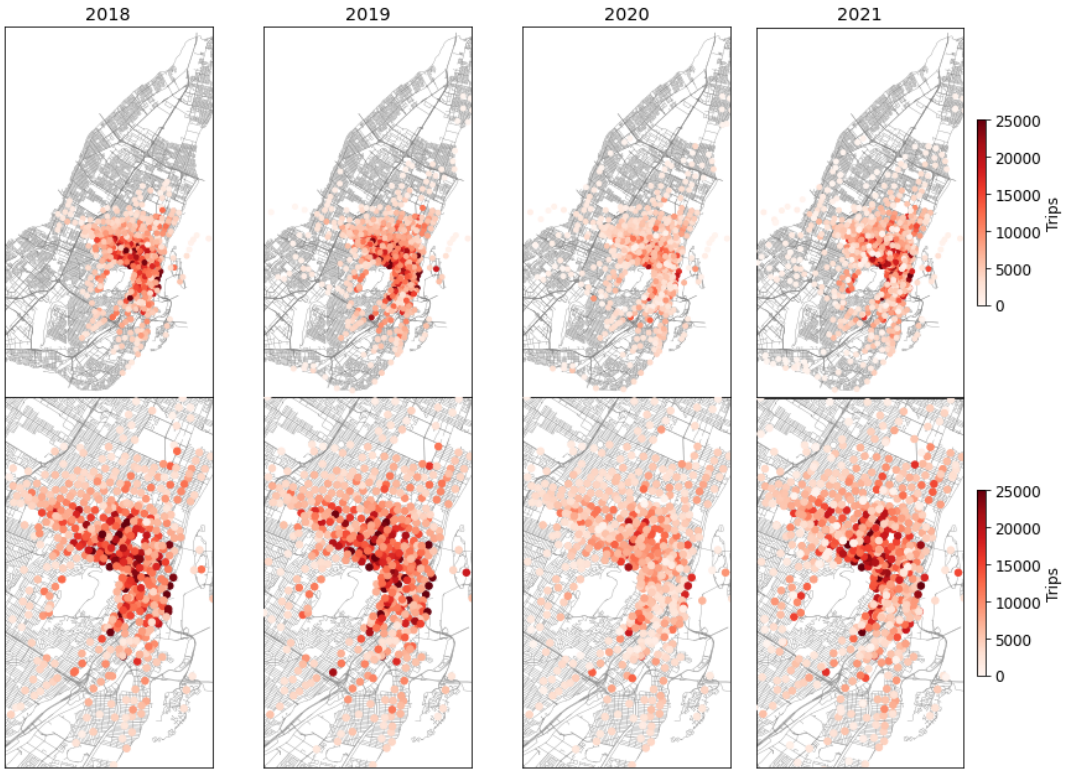
Figure 1: Illustration of Bixi bikeshare stations in Montreal during 8 years from 2014 to 2021.

Figure 3a shows the travel time distributions of all trips in 2018, 2019, 2020, and 2021, respectively. While travel time distributions of trips in 2018 and 2019 are very consistent, they show remarkable differences with travel time distribution of trips in 2020. It demonstrates that the peaks of travel time distribution before the COVID-19 pandemic are higher than the peaks of travel time distribution during the COVID-19 pandemic. There are relatively more trips with longer travel time in 2020 and 2021. Table 1 has also revealed that the average travel time during the COVID-19 pandemic is greater than the average travel time before the COVID-19 pandemic.

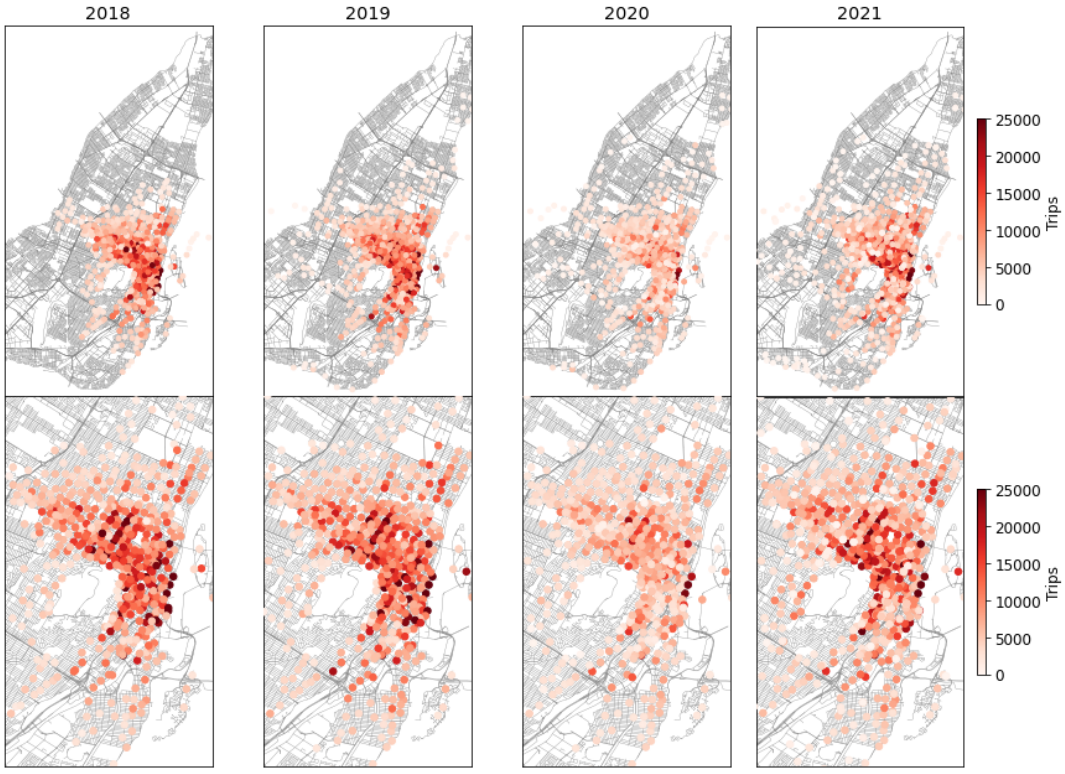
Figure 3b shows the travel time distributions of member trips. The peaks of travel time distribution in 2018 and 2019 are higher than the peaks of travel time distribution during the COVID-19 pandemic (i.e., 2020 and 2021). It seems that there are relatively more trips with longer travel time in 2020. Figure 3c shows the travel time distributions of occasional trips. Notably, the characteristics of these distributions are rather different from both Figure 3a (all trips) and Figure 3b (member trips).

4 Mobility Pattern Changes

In this section, we give empirical evidence of mobility pattern changes in the bikeshare system from the perspectives including commuting and cycling lifestyle.

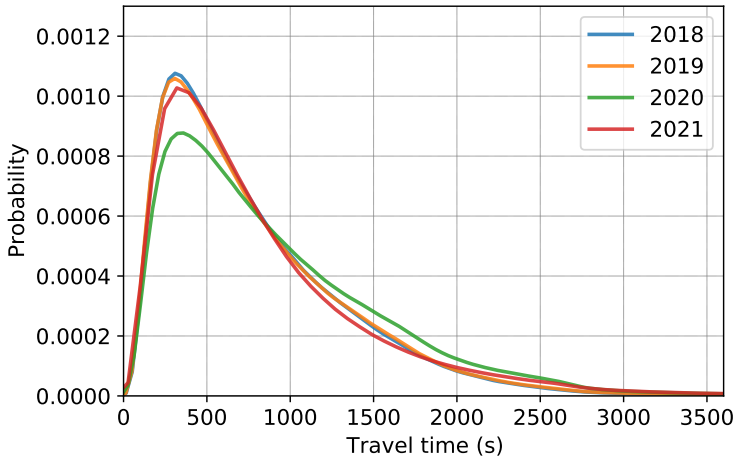


(a) Pickup trips

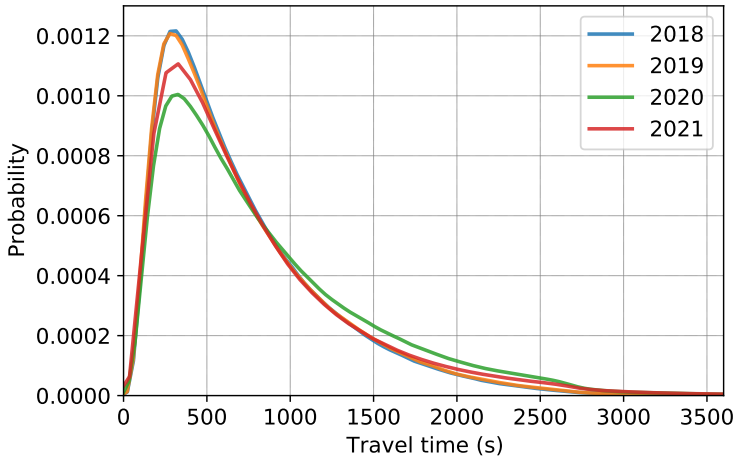


(b) Dropoff trips

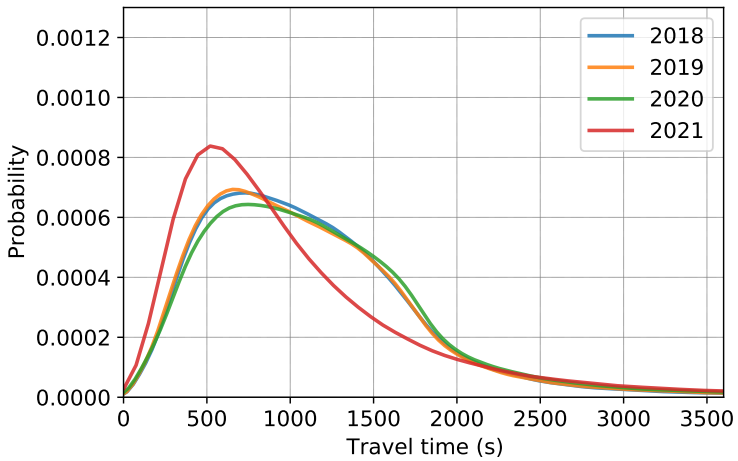
Figure 2: Visualization of trips of Bixi bikeshare in Montreal from 2018 to 2021.



(a) From 2018 to 2021



(b) From 2018 to 2021 (trips created by members)



(c) From 2018 to 2021 (trips created by occasionals)

Figure 3: Histograms of travel time of bikeshare trips.

Table 1: Preliminary statistics of Bixi bikeshare data.

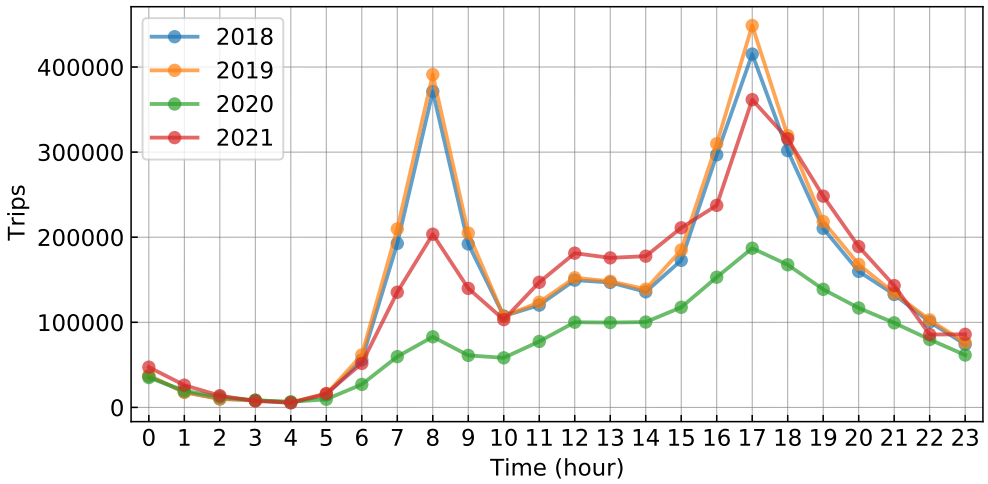
	2018	2019	2020	2021
Stations	552	619	641	828
Total trips	5,277,541	5,597,845	3,264,741	5,490,043
Average travel time (s)	800.68	811.28	936.33	863.88
Members				
Total trips	4,385,520	4,592,783	2,600,969	4,522,011
Trip ratio	83.10%	82.05%	79.67%	82.37%
Average travel time (s)	725.57	731.55	858.25	804.42
Occasionals				
Total trips	892,021	1,005,062	663,772	968,032
Trip ratio	16.90%	17.95%	20.33%	17.63%
Average travel time (s)	1169.99	1175.60	1242.28	1141.61
Weekday (members)				
Total trips	3,429,092	3,595,191	1,879,459	3,309,218
Trip ratio	78.19%	78.28%	72.26%	73.18%
Average travel time (s)	721.35	726.07	836.09	780.53
Weekend (members)				
Total trips	956,428	997,592	721,510	1,212,793
Trip ratio	21.81%	21.72%	27.74%	26.82%
Average travel time (s)	740.68	751.31	915.99	869.61

4.1 Weekday and Weekend Cycling Patterns

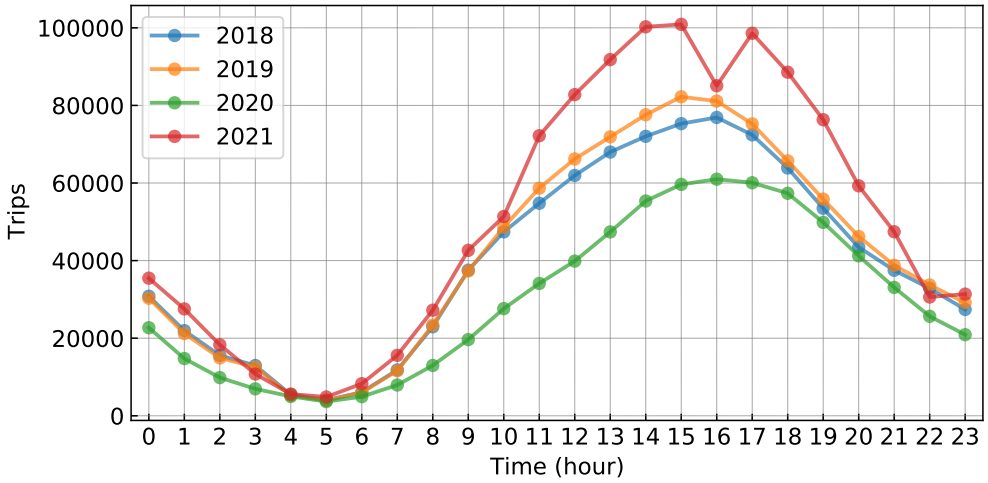
Trips in the bikeshare system include member trips and occasional trips. As summarized in Table 1, a dominant portion of trips was created by members, i.e., $\approx 80\%$ for all four years. As can be seen, members are active users for cycling and contribute most trips in the bikeshare system. To eliminate the impact of occasional trips, we extract the member trips in the mobility pattern analysis. We intend to identify the mobility pattern change of commuting only using these member trips.

Figure 4a shows four hourly aggregated trip volume curves of trips in weekdays of 2018, 2019, 2020, and 2021, respectively. It demonstrates two remarkable peaks for all four years, i.e., one is during the period of 8:00-9:00 and another is during the period of 17:00-18:00. During the off-peak hours, the trip volumes are relatively lower. Therefore, we identify the periods of 8:00-9:00 and 17:00-18:00 as the morning commuting period (i.e., morning peak hour) and the afternoon commuting period (i.e., afternoon peak hour), respectively.

Figure 4b shows four hourly aggregated trip volume curves of trips in weekends of 2018, 2019, 2020, and 2021, respectively. It does not show two peaks as Figure 4a for weekday. As shown in Figure 4b, most bike trips are created in the afternoon (from 12:00 to 18:00) in which people are willing to cycle for health benefits. This phenomena can also be verified by the relatively longer travel time in 2020 and 2021 comparing to 2018 and 2019 (see Figure 5a and 5b). In particular, people tend to have a relatively longer ride in 2020 at all time periods.



(a) Weekdays

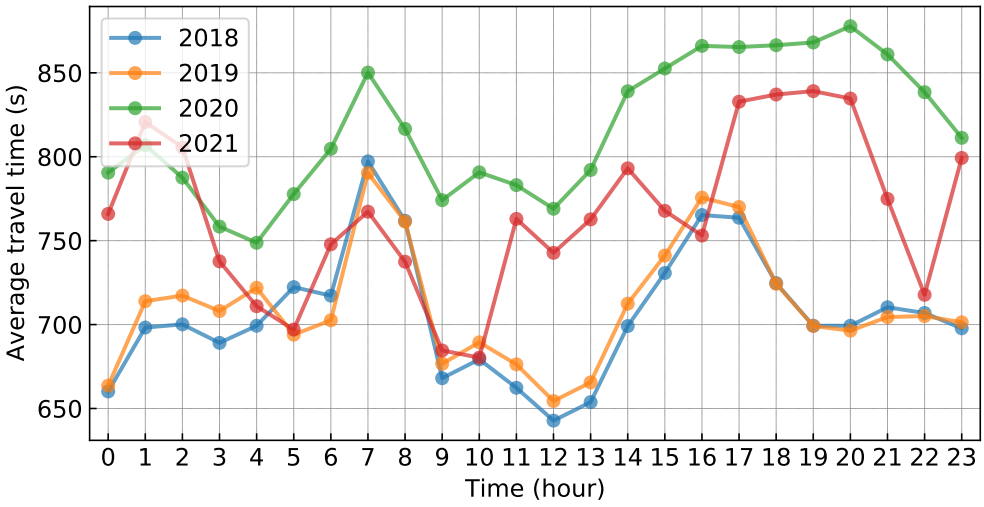


(b) Weekends

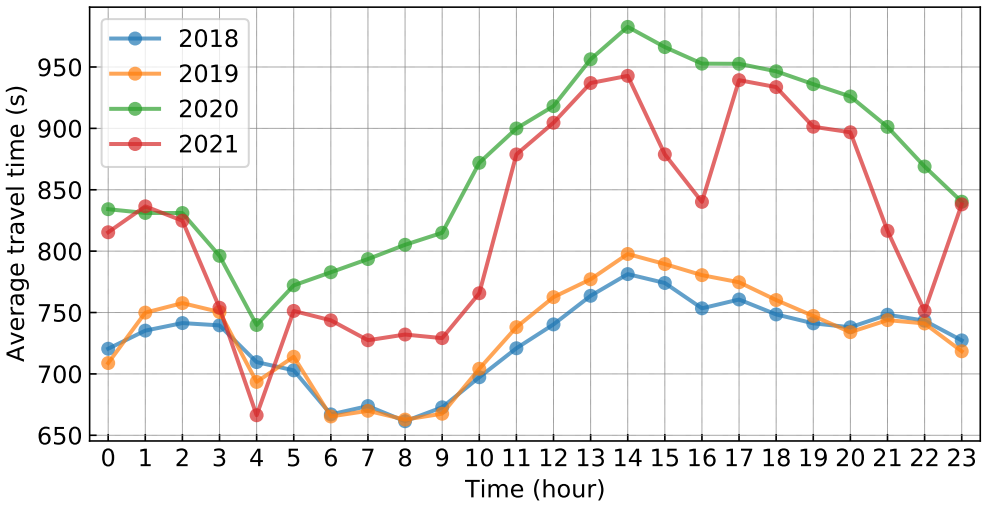
Figure 4: Hourly aggregated trip volume curve of member trips.

In fact, by analyzing trips (see Figure 4a and Figure 4b) and average travel time (Figure 5a and Figure 5b), these trip curves and average travel time curves of 2018 and 2019 are very consistent. It seems that essential mobility patterns are not changed over two years. But with the crisis of COVID-19, we can observe great changes from either trip curves or average travel time curves in 2020 and 2021.

Table 2 summarizes the commuting trips and average travel time of member trips at the peak hours of weekday. Before the COVID-19 pandemic, trips of the afternoon peak hour are greater than the morning peak hour. But the average travel time of both two peak hours is very close. During the COVID-19 pandemic, by contrast to the morning peak hour, there are more people that are willing to ride a bike in the afternoon peak hour. Another remarkable evidence is that the average travel time of the afternoon peak hour is significantly greater than the morning peak hour. It is not difficult to see that the cycling preference has been enlarged under the crisis of pandemic, though the total traffic has been decreased.



(a) Weekdays



(b) Weekends

Figure 5: Hourly aggregated average travel time curve of member trips.

Table 2: The commuting trips and average travel time of member trips at the peak hours of weekday. The trip rate indicates the trips of peak hours in total trips.

	Trips		**Average travel time (s)**	
	8:00-9:00	17:00-18:00	8:00-9:00	17:00-18:00
2018	371,235 (8.47%)	415,217 (9.47%)	761.83	763.63
2019	391,241 (8.52%)	448,709 (9.77%)	761.33	770.02
2020	82,963 (3.19%)	187,071 (7.19%)	816.60	865.35
2021	203,506 (4.50%)	361,641 (8.00%)	737.44	832.78

Figure 6a and Figure 6b show the travel time distributions of morning peak hour and afternoon peak hour of member trips, respectively. Referring to Table 2, although the average travel time of afternoon peak hour is greater than morning peak hour, the travel time distribution of the morning peak hour seems to be fatter than the afternoon peak hour. Among these four years, the peak of travel time distribution in 2020 is lowest. There are relatively more trips with longer travel times in 2020.

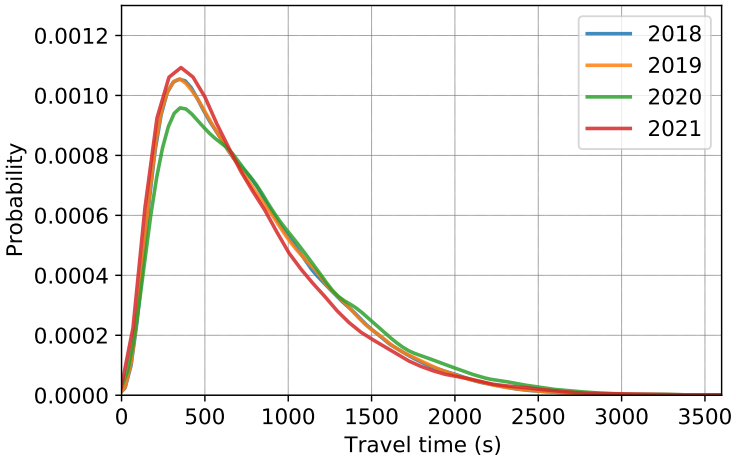
We next analyze the commuting from the spatial context. Figure 7a and Figure 7b show the member trips of the morning peak hour in weekday. As can be seen, the pickup trips are created in most spatial stations, but most of these trips are with the destination of Downtown of Montreal. Figure 8a and Figure 8b show the member trips of the afternoon peak hour in weekday. The pickup trips are mostly created at Downtown, but not as concentrated as Figure 7b. Figure 8b demonstrates the consistent trips with Figure 7a. These findings can verify the commuting of member trips.

In addition, we analyze the member trips in weekend. Figure 9a and Figure 9b show the member trips of the afternoon at weekend. It does not show any great differences between pickup trips and dropoff trips, which is different from the trips at peak hours of weekday. For weekend, people are willing to ride a bike for health benefits and therefore it does not show clear spatial concentration at Downtown. Note that the trips created in weekend are also with relatively longer travel times when comparing to weekday (Table 1). In addition, as shown in Figure 4b, most of member trips in weekend are created during the afternoon, which also demonstrate the cycling preference of people for health benefits.

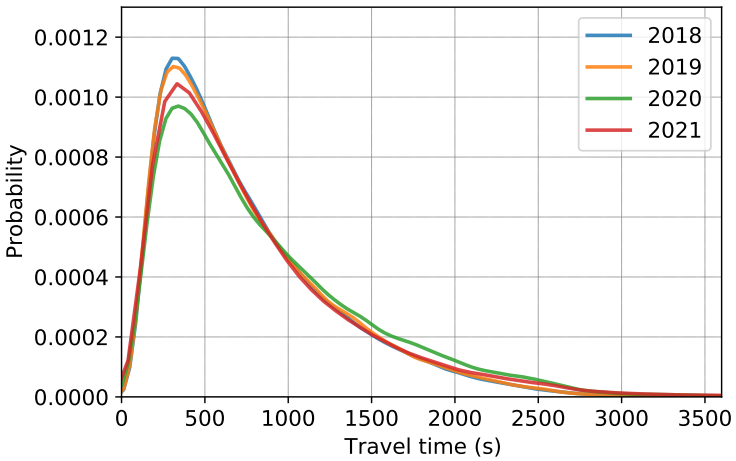
4.2 Lifestyle Change for Cycling: Longer Trip Means A Lot

Recall that the bikeshare stations, as a kind of infrastructure, has been substantially increased (see Figure 1). To make fair and comparable analysis, we only take into account 552 bikeshare stations (corresponding to 2018) for the following analysis. Through analyzing travel time of member trips, it is possible to reveal the preference of cycling underlying bikeshare data. Notably, since the start station ID and end station ID of 2021 do not match the station ID of 2018, we only consider 2018, 2019, and 2020 for analysis.

Table 3 summarizes the commuting trips and travel time of member trips within 552 stations in weekday. Comparing to Table 2, it exhibits the consistent trip rates between 552 stations and 619 stations. In 2019, the average travel time of trips over 552 stations is a

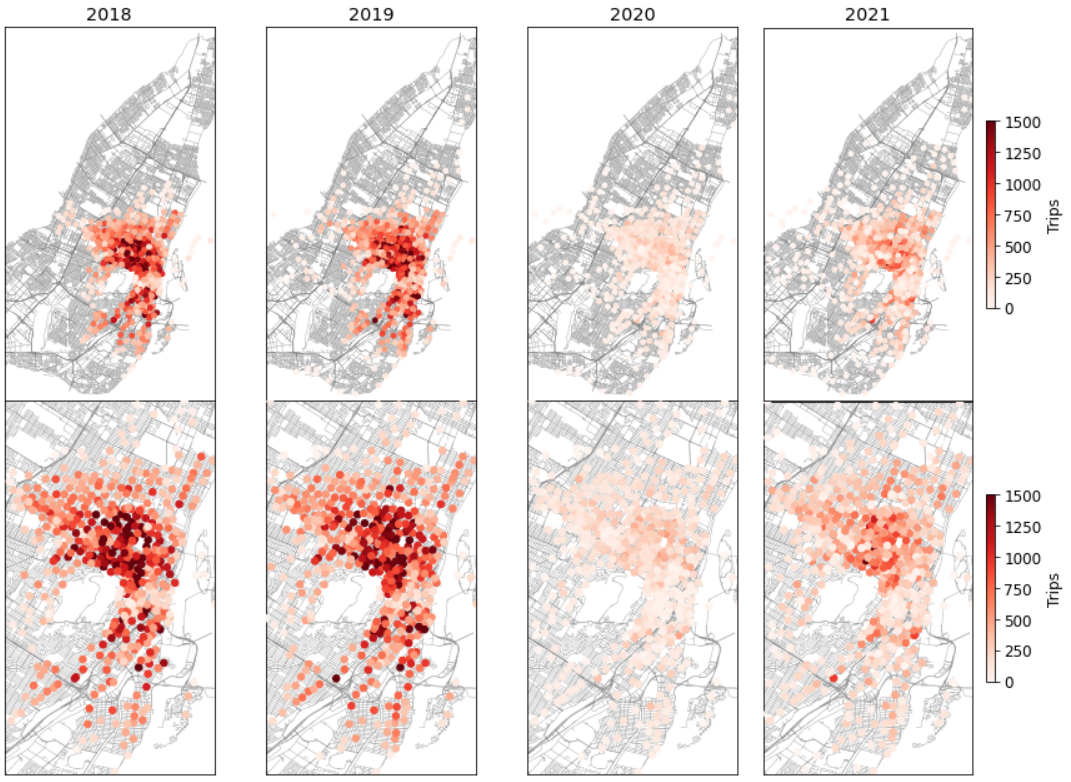


(a) Morning peak hour

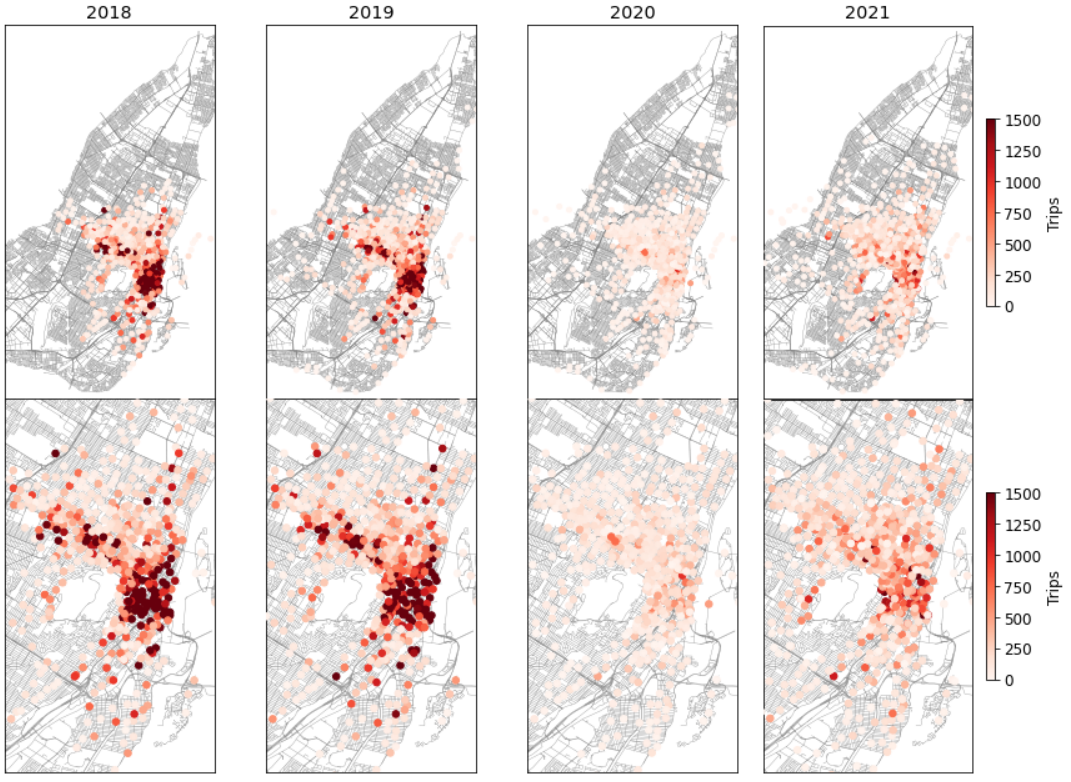


(b) Afternoon peak hour

Figure 6: Histograms of travel time of member trips of two peak hours at weekday. Here, we identify 8:00-9:00 and 17:00-18:00 as the morning peak hour and the afternoon peak hour, respectively.

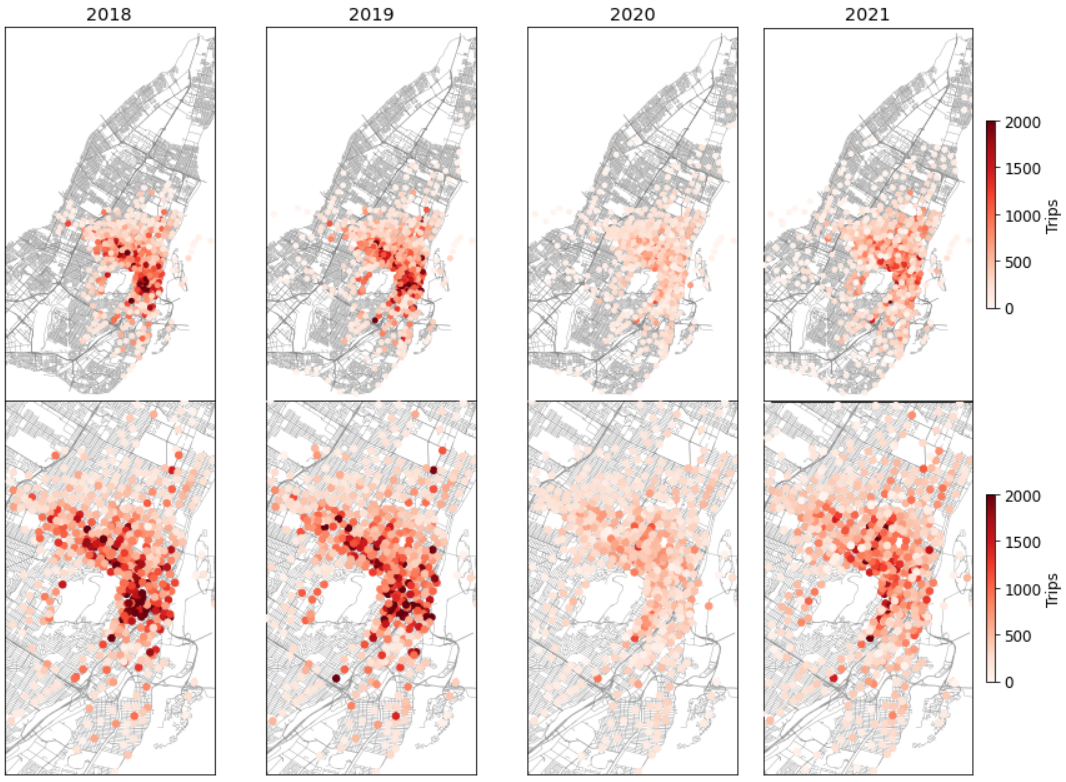


(a) Pickup trips

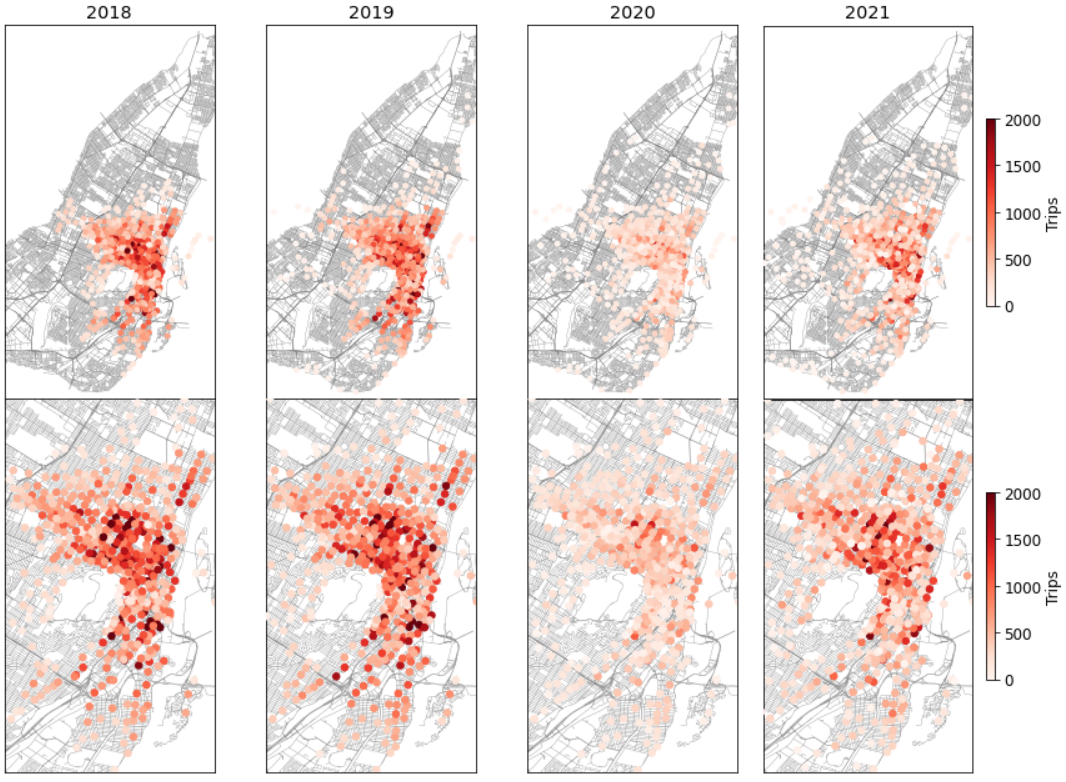


(b) Dropoff trips

Figure 7: Visualization of member trips of the morning peak hour at weekday in Montreal from 2018 to 2021.

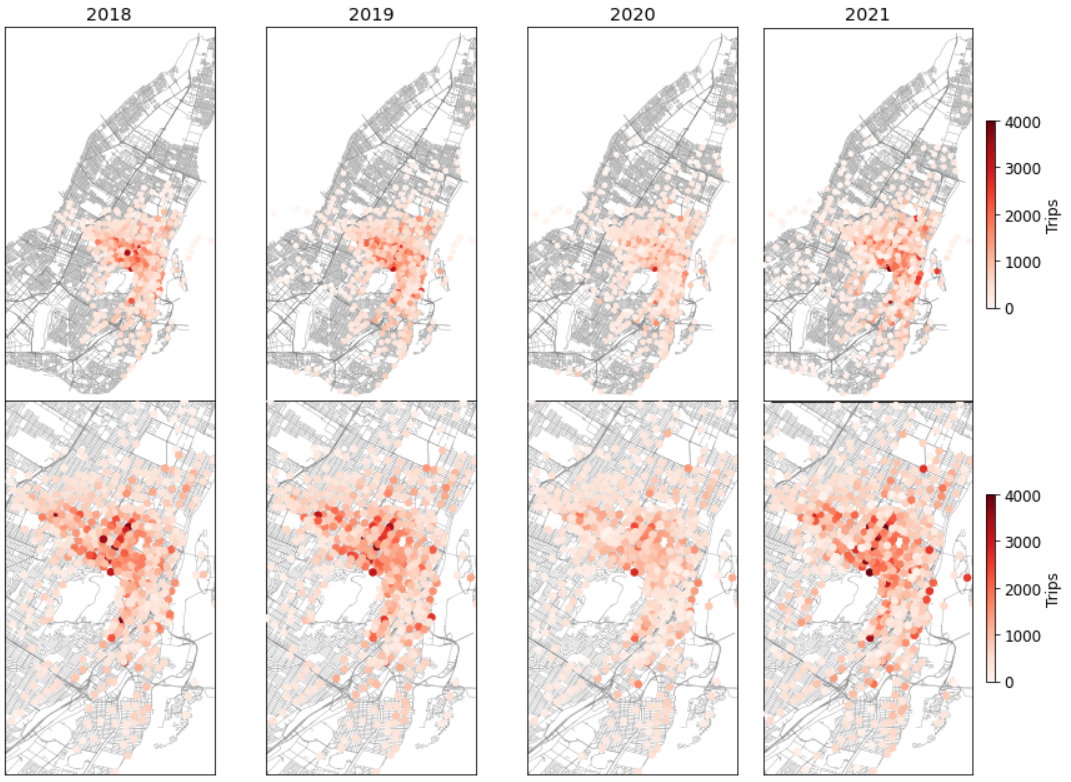


(a) Pickup trips

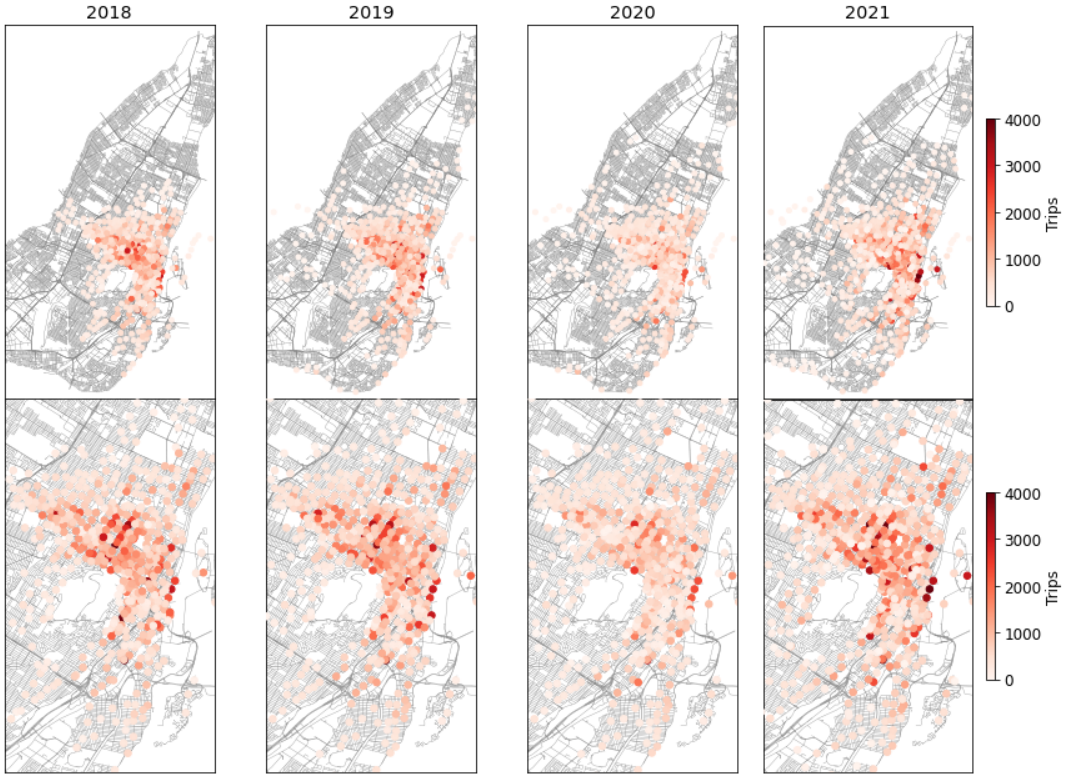


(b) Dropoff trips

Figure 8: Visualization of member trips of the afternoon peak hour at weekday in Montreal from 2018 to 2021.



(a) Pickup trips



(b) Dropoff trips

Figure 9: Visualization of member trips of the afternoon (12:00-18:00) at weekend in Montreal from 2018 to 2021.

little smaller than the average travel time of trips over 619 stations. In 2020, the trip rates between 552 stations and 641 stations are even same. The average travel time of trips over 552 stations is a little smaller than the average travel time over 641 stations, while the average average travel time in 2020 is greater than both 2018 and 2019. These may demonstrate that people are willing to ride a bike with relatively longer travel times in 2020.

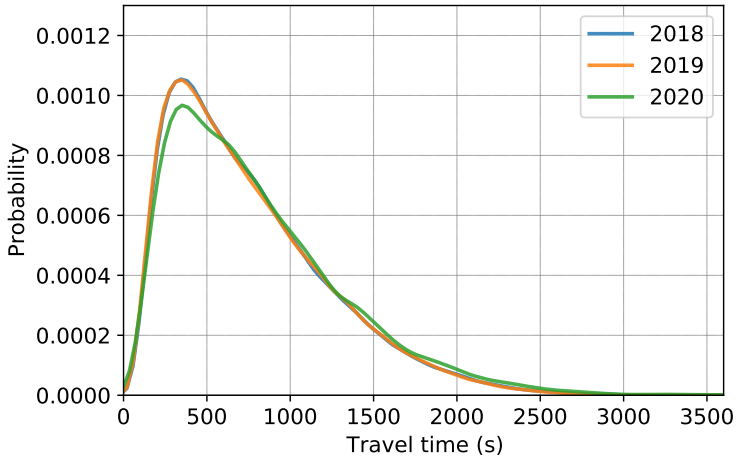
Table 3: The commuting trips and average travel time of member trips (within 552 stations) at the peak hours of weekday. The trip rate indicates the trips of peak hours in total trips within 552 stations.

	Trips		**Average travel time (s)**	
	8:00-9:00	17:00-18:00	8:00-9:00	17:00-18:00
2018	371,235 (8.47%)	415,217 (9.47%)	761.83	763.63
2019	364,190 (8.50%)	413,590 (9.65%)	759.40	761.59
2020	77,190 (3.20%)	173,608 (7.19%)	806.77	843.40

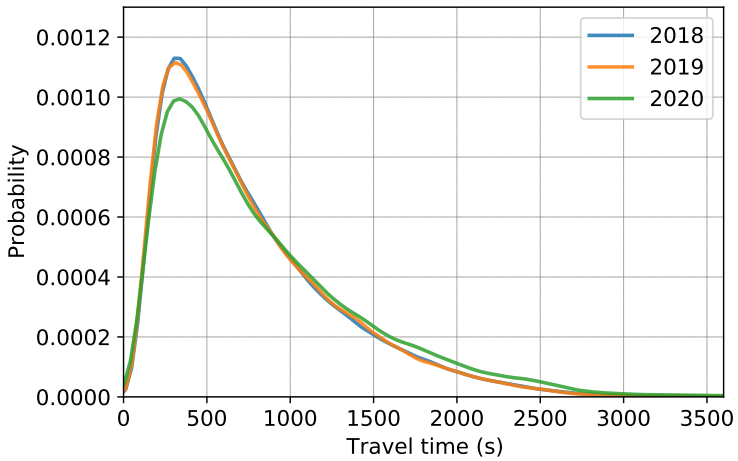
Figure 10a and Figure 10b show the travel time distribution of member trips at peak hours. While the average travel time of afternoon peak hour is greater than morning peak hour, the travel time distribution of afternoon peak hour is fatter than morning peak hour. Observing travel time distributions corresponding to different years, the distributions in 2018 and 2019 are completely coincident. This implies no mobility pattern changes from 2018 to 2019. The peak of distribution in 2020 is lower than other two years, but there are relatively more trips with longer travel times. This illustrates that, during the COVID-19 pandemic, people are willing to ride a bike for their commuting with relatively longer distances.

5 Conclusion

In this report, we give a thorough empirical analysis for identifying mobility pattern changes before and during the COVID-19 pandemic on open bikeshare data in Montreal. Through processing data, there are about 80% trips that are created by members, and these member trips are representative for exploring the mobility change before and during the COVID-19 pandemic. By analyzing commuting trips in the peak hours of weekday, it demonstrates that there are more people that are willing to cycling for the afternoon peak hour than the morning peak hour in 2020 and 2021. The average travel time of member trips for commuting and weekend's cycling in 2020 and 2021 is greater than both 2018 and 2019. Both trips and average travel time of 2018 and 2019 do not show any differences, which demonstrate no mobility pattern change over two years. It is not hard to conclude that the pandemic leads to a sequence of mobility changes over commuting and attitude for healthy lifestyle. This report provides a data-driven empirical analysis for bikeshare system in Montreal and reveals some findings of cycling behavior, and it can help decision-making processes in the bikeshare system.



(a) Morning peak hour



(b) Afternoon peak hour

Figure 10: Histograms of travel time of member trips (within 552 bikeshare stations) of two peak hours at weekday. Here, we identify 8:00-9:00 and 17:00-18:00 as the morning peak hour and the afternoon peak hour, respectively.

Appendix

Supplementary Material

- Geobase of the road network in Montreal is available at https://donnees.montreal.ca/ville-de-montreal/geobase.
- Open Montreal transport data is available at https://donnees.montreal.ca/collections/transport.
- Counts of bicycles of cycle lanes are available at https://donnees.montreal.ca/ville-de-montreal/velos-comptage.
- GeoPandas 101: Plot any data with a latitude and longitude on a map: https://towardsdatascience.com/geopandas-101-plot-any-data-with-a-latitude-and-longitude-on-a-map-98e01944b972

Acknowledgement

Xinyu Chen would like to thank the following researchers for providing helpful discussion:

- Zhanhong Cheng (Ph.D., McGill University): Suggestion for Geospatial data visualization tools.
- Xiaowei Gao (Ph.D. student, University College London): Discussion about possible directions for exploring cycling behaviors.

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