Does Bike Share Toronto Infrastructure Provide Equitable Access And Does Its Usage Reflect Gentrification?

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Abstract

This work uses the 2020 geographic distribution of Bike Share Toronto docking stations to show that Bike Share Toronto does not provide equitable access to areas of lower income. It also uses Linear Regression to measure the extent to which Bike Share Toronto's historical ridership usage in 2018 is associated with areas of gentrification by using the change in census tract demographics between the 2006 and 2016 censuses. All code can be found here.

1 Introduction

A bicycle-sharing system is an environmentally-friendly, sustainable mode of transportation that benefits residents with exercise, an expanded transportation network, as well as reduced travel time and costs. These systems are commonly close to subway stations and serve to get a rider through the first or last kilometre towards their final destination. In Toronto, compared to over $100 for a monthly TTC pass, an annual Bike Share Toronto (BST) membership costs just $99 and grants members unlimited rides of up to 30 minutes. Bike share users can also save on costs related to bike maintenance and bike theft.

But in spite of its affordability, many argue that BST is inaccessible to lower socio-economic populations for a multitude of reasons. First, while rides are limited to 30 minutes to ensure bike availability, any additional time is charged at a costly rate of $4 for every 15 minutes. Also use of a smartphone/computer and a credit card is required to register for a membership online. Additionally for those without a membership, single trips costs $3.25/trip and BST does not accept cash or Presto. But one of the largest barriers to equitable access and uptake may be the geographical coverage of BST docking stations being limited to high-income or tourist areas.

Amidst these criticisms, many feel bike sharing is a sign of gentrification with vastly different stigmas associated between those who cycle out of necessity vs. those who cycle by choice. Gentrification implies reinvestment in formerly marginalized communities which means new services and amenities, better safety, and more political support. But often issues arise with rising living costs, displacement of long time residents, and the degradation of established local cultures. Also, the existence of bike infrastructure is used by developers to promote rising condos.

Started in 2011, BST currently offers 4,500 bikes and 465 docking stations. The system is publicly owned by the city and received a $7.5M expansion in 2019. Yet, having already run a deficit of $2.3M in 2018(the, 2020), the city does not prioritize providing equitable access for all Torontonians since unlike Hamilton and Vancouver bike share programs, BST does not have an equity initiative which subsidizes memberships for low income residents.

In this work I assessed if BST's recent expansion has provided more equitable access, visualized the usage differences between BST annual vs. casual members, and explored the relationship between gentrification and bike share usage across different census tracts of Toronto. I found evidence showing that the geographical coverage of BST stations are disproportionately in dissemination areas with higher median income, which is reflected in a higher proportion of rides originating in higher earning census tracts. As for comparing annual vs. casual users, annual users bike faster, and use BST consistently even during the colder, travel off-season months. While casual users primarily use it during the weekend in warmer times

of the year. Finally, a Linear Regression model shows that there are features that measure gentrification which are significant in determining how many BST trips originate from each census tract.

2 Related Work

Previous work (Flanagan, 2016) explored if investment in cycling infrastructure (bicycle lanes, bicycle parking, and bicycle sharing stations) mirrored gentrification in the major cities Portland, OR and Chicago, IL. Portland was chosen for its reputation as a cyclists' haven and its rapid gentrification. While Chicago has recently started its bicycle share program and has a larger, more diverse population. They used US Census data 20 years apart (1990 to 2010) to measure the gentrification of census tracts as well as data associated with population density and proximity to transit. Linear Regression then provided evidence that cycling infrastructure investment is related to both characteristics of existing privilege and incoming populations of privilege. However, their analysis did not use actual bike share ridership volumes nor did they use housing rental costs as a measure of gentrification.

Other work (Hosford and Winters, 2018) compared the socioeconomic characteristics of areas inside and outside the service area of BST 2017 station locations. They categorized Toronto census dissemination areas (DA) into five quintiles of socioeconomic status. They then determined the proportion of each DA quintile that were within a 500m service area radius of a BST docking station to show that more effort is needed to increase the spatial access of BST for the lower socioeconomic population. This work did not consider gentrification or use actual BST ridership volumes.

Since both previous works used just the fixed installation points of bike share stations, I believe I can provide insight by using the historical ridership data of BST that measures actual usage.

3 Data

This section outlines the data sources used in this work.

Historical BST Ridership: Provided by Open Data Toronto, this big data source (Toronto, 2020a) contains over 1.8M rides taken in 2018. Each record contains:

- trip start & end date and time
- trip start & end station
- trip duration
- member type (annual or casual)

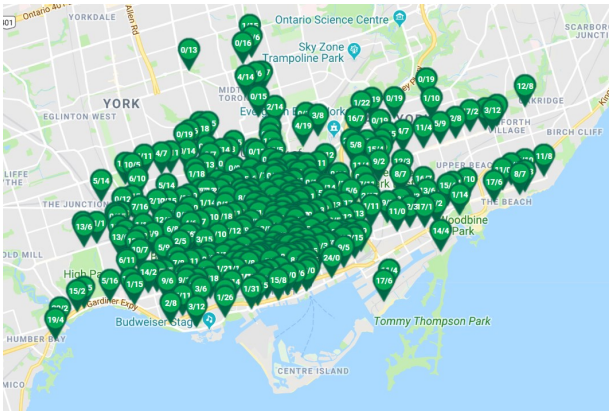

Figure 1: Geographical distribution of BST's 465 docking stations in 2020

Unfortunately no user demographic variables are provided and I do not know the actual streets traversed nor could I measure the number of bike transfers a rider may take on a trip. Previous work (blo, 2020) has already analyzed 2017 BST ridership data so I leveraged their data cleaning and visualizations code for the 2018 BST data.

BST 2020 Docking Station Network: For each of BST's 465 docking stations shown in Figure 1, I obtained the GPS coordinates (Toronto, 2020b).

2006 and 2016 Census: For each of Toronto's 3,703 dissemination areas and 1,151 census tracts(Canada, 2016), the following socioeconomic factors were used:

- median income
- population density
- average age (2016 only)
- % without a high school diploma
- median home price
- average rental costs
- 5 year mobility status, movers

A dissemination area (DA) is the census's smallest geographical level that information is collected at and typically contains 400-700 residents. A census tract (CT) is a larger, more stable geographical area and typically contains 2.5k-8k residents.

In addition the census shape files were obtained for both of Toronto's DAs and CTs.

TTC Subway Station Network: For each station, I obtained the GPS coordinates.

4 Methodology

This section outlines the process for the three analysis components.

Median Income Quintile Analysis: First, DAs areas and CTs were split into quintiles determined by median income. Since the docking station where each ride started is known, I mapped each docking station inside a census tract. Figure 2 shows Toronto's census tracts by median income and it is evident that high income earners are concentrated in the downtown core. It is also clear

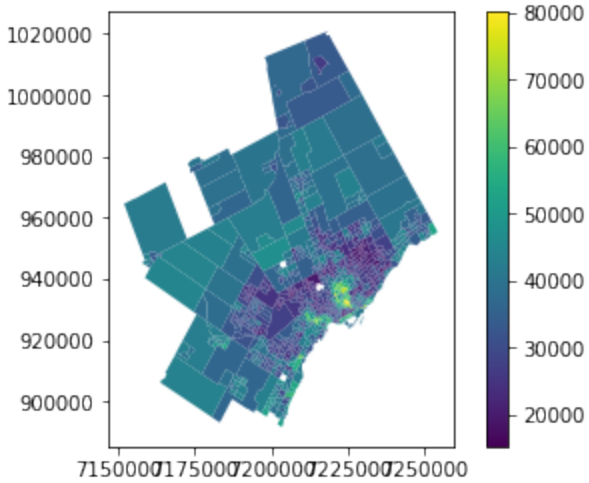

Figure 2: Median income of each census tract.

from Figure 3, which shows the start location of every BST ride in 2018, that BST's network covers only a fraction of Toronto. Then, the percentage of trips started in each census tract quintile was determined. The reason for opting to use larger CTs as opposed to DAs is I believe DAs were too small to represent the demographics of those who ride. After contacting the City of Toronto, I was informed that 2019 ridership data will not be made available until 2021. However, I was able to use the current 2020 BST station locations to determine which DAs are within the BST service area. To do so, I determined which DAs are within 500m of a docking station. Then, I calculated the percentage of DAs within the BST service area by median income quintile. Figure 4 shows each docking station's 500m radius. As a result, Figure 5 shows

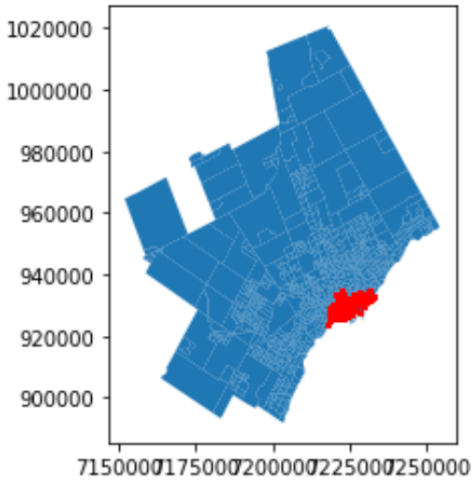

Figure 3: Geographical location of all BST stations in 2018

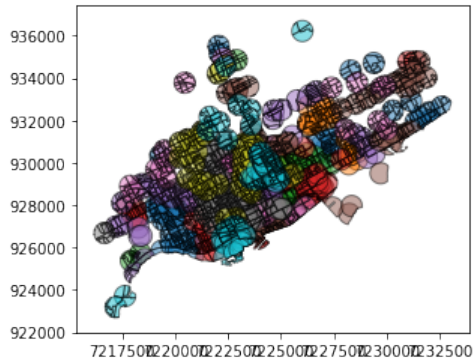

Figure 4: 500m radius around each BST station docking in 2020

the DAs within 500m of a BST docking station which are primarily in the downtown core. Figure 6 shows areas of Toronto that are not within 500m of a docking station.

Annual vs. Casual Users Visualizations: The next phase was exploring usage between annual membership users and casual users. Annual members pay $99/year for unlimited rides below 30 minutes. While casual members pay $3.25 per ride, $7 for a day pass , or $15 for a 3-day pass. The argument made is that annual members rely on BST for their commute, while casual users typically represent families and tourists. Given the limitations of the ridership data, this is the reasonable extent to which I could explore the dichotomy between those who bike out of necessity vs. those who bike for pleasure. To compare these two types of users, each trip's duration was calculated by subtracting the start time from the end time. I also used the GPS coordinates of start and

end stations to estimate each trip's distance. Moreover, the hour, day of the week, and month of each trip was also extracted.

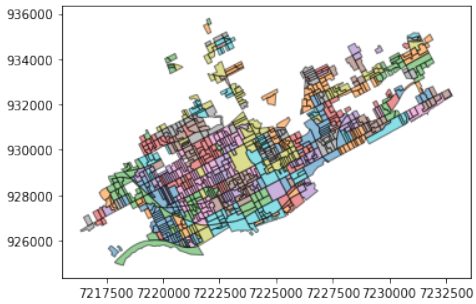

Figure 5: Dissemination areas within 500m of a BST station docking in 2020

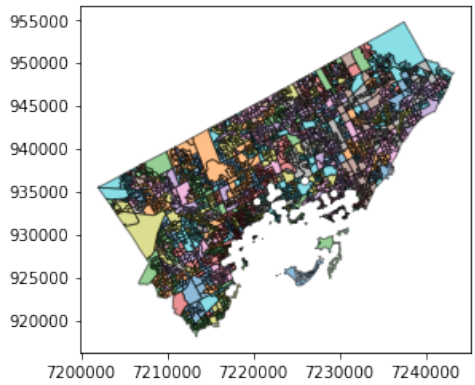

Figure 6: Toronto areas not within 500m of a BST station docking in 2020

Linear Regression Model: In order to identify privileged areas and gentrified areas, I used 2006 and 2016 census tract data containing a variety of socioeconomic factors. Furthermore, using TTC station coordinates I measured the proximity of each census tract centroid to a subway station and to downtown Toronto designated as St. Patrick Station. My main assumption is the user demographics of pickups at each bike station depends on each BST station's surroundings/census tract.

I created a Linear Regression model where the dependent variable is the number of trips starting in each census tract and the independent variables are the 2016 census socioeconomic factors, the change in socioeconomic factors over the 10 year period between the two censuses, as well as the proximity of each census tract to the nearest TTC subway station and downtown. High income, high population density, high home prices, high rental costs, and a low % of those without a high school diploma are associated with greater areas of wealth that may attract bicycle sharing infrastructure investment. While gentrification is reflected with large increases in: income, the proportion of those with the mobility status of mover, home prices, rental costs, and a decrease in the % of those without a high school diploma. Finally, it is believed that areas with close proximity to a TTC station and the downtown core may also play a role in the installation of BST docking stations.

For census tracts without a BST docking station, the dependent variable has the value of zero. After removing census tracts with missing data, only 919 census tracts remained and 1.3M rides were mapped to just 99 census tracts.

5 Results

This section illustrates the findings from the three analysis components.

Median Income Quintile Analysis[1]: Interestingly, Table 1 shows the highest median income quintile are where nearly half of all rides started. While the two lowest median income quintiles have less than 20% each. This finding demonstrates the fact that higher income areas use BST more.

Table 1: % rides started within each census tract by median income quintile

Median Income Quintile ($)	**% 2018 Rides (n=1.8M)**
(15,173, 25,011]	15.05%
(25,011, 29,813]	18.86%
(29,813, 34,826]	10.55%
(34,826, 41,600]	9.07%
(41,600, 80,128]	46.47%

Furthermore, Table 2 reinforces the observation that BST availability favours wealthier areas since of the 830 DAs within a docking station, the higher income quintiles have disproportionately higher access to the BST network.

Annual vs. Casual Users Visualizations: From Figure 7, one can see that both casual and annual members bike similar distances with a peak at around 2km. However, casual member rides last longer implying that casual members bike slower

[1]Median total income in 2015 of recipients aged 15 years and over in private households ($)

Table 2: % dissemination areas within the Bike Share Toronto service area by median income* quintile

Median Income Quintile ($)	**% DAs (n=3,702)**	**% DAs Within 500m of a Docking Station in 2020 (n=830)**
(11,071, 23,808]	20%	16.01%
(23,808, 27,840]	20%	11.45%
(27,840, 33,621]	20%	20.57%
(33,621, 45,184]	20%	27.22%
(45,184, 113,408]	20%	24.75%

than annual members. This makes sense since annual members use BST for their rush hour commute.

Additionally, Figure 8 shows that annual member trips have a bimodal distribution with spikes in the morning and in the evening which reflects 9-5 commutes. While casual members show consistent use during the afternoon and evening without any drastic spikes.

Figure 9 shows about 75% of all rides are done by annual members. It is evident that in the Spring and Summer, more tourists and families with kids off school buy day passes and use BST to explore the city. While in the Fall and Winter at the beginning and end of the year, hardly any casual members use BST since all the kids are in school and there are fewer tourists. As for annual members, they too are the most active in the warmer months but there are still a large proportion of annual member biking in the colder months.

Figure 10 shows the average number of rides each day for each quarter of the year. It again shows that casual members bike in the Spring and Summer, but less so in the colder months. On the weekends, less annual members and more casual members bike. While on weekdays, there are more annual members especially in Q1 and Q4.

Linear Regression Model: Figure 11 provides the summary of the fitted model with coefficient values and p-values. The R-squared of the model was quite low at 0.332. Significant independent variables (p-value ≤ 0.05) include a census

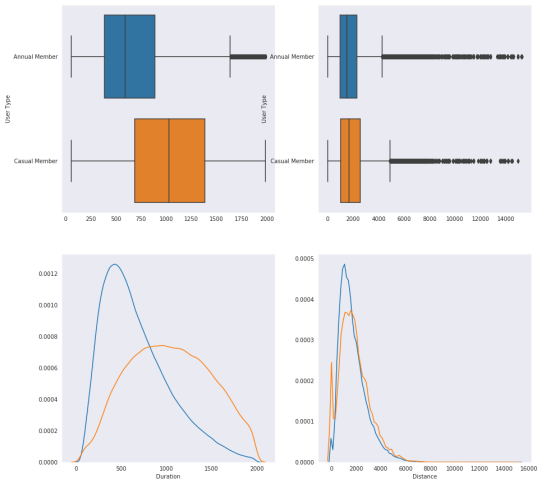

Figure 7: Duration and distance boxplots and distributions of all 2018 BST Trips. Annual members are represented with blue and casual members with orange.

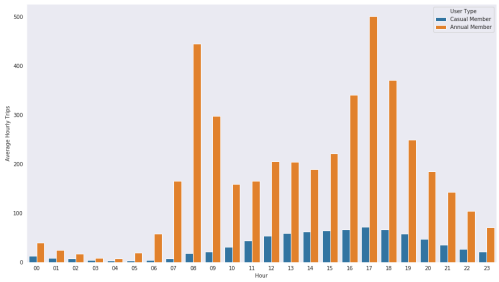

Figure 8: Average annual and casual member trips for each hour.

tract's 2016: population density, rent cost, home value, percentage without a high school degree, and number of mover's within the last 5 years. Out of the features measuring gentrification, the home value change, population density change, and the percentage without a high school degree change were significant. Other significant variables are also a census tract's proximity to a TTC station and downtown.

6 Discussion

From the Median Income Quintile Analysis, it is straightforward to conclude that the BST's service area and usage disproportionately favours the higher income areas of Toronto. From the an-

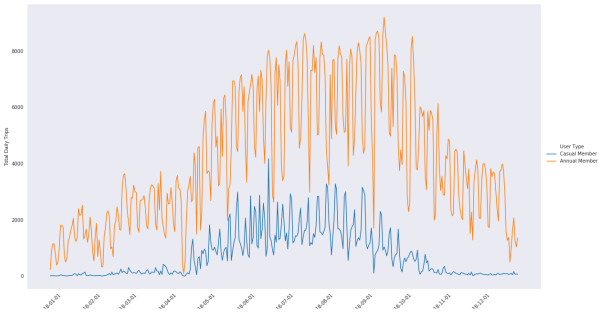

Figure 9: Daily 2018 volumes for both annual and casual members.

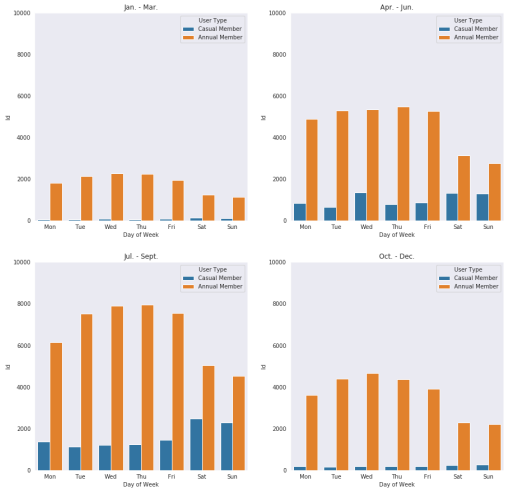

Figure 10: Average annual and casual member trips for each hour

nual vs. casual members visualizations, it evident that their two usage patterns differ since those who bike out of necessity bike during rush hour at all seasons in the year while those who bike of pleasure do so on the weekends in the warmer months. Finally the Linear Regression model shows that there are significant features associated with gentrification, but features measuring proximity to transit and the downtown core are also significant. Furthermore, this analysis can be improved by considering factors such as vandalism and the slope of the terrain.

Overall, Toronto is becoming more bicycle-friendly with a growing, robust bicycle-sharing system. However there are equitable access concerns and areas associated with gentrification receive more BST infrastructure investment. However, while BST is currently losing money with

	coef	std err	t	P>|t|
Intercept	1.507e+04	5673.422	2.656	0.008
popDensity_2016	-0.3189	0.075	-4.228	0.000
unemploymentRate_2016	-319.0917	182.010	-1.753	0.080
medianIncome_2016	-0.0760	0.049	-1.553	0.121
avgAge	-111.2460	83.183	-1.337	0.181
avgRent_2016	4.1247	1.260	3.272	0.001
homeValue_2016	-0.0146	0.003	-5.533	0.000
noDegreePct_2016	-263.3515	106.603	-2.470	0.014
mover5yearPct_2016	215.8282	36.190	5.964	0.000
unemploymentRate_change	-112.8344	147.096	-0.767	0.443
medianIncome_change	0.0020	0.034	0.057	0.954
avgRent_change	-1.7837	1.327	-1.344	0.179
homeValue_change	0.0205	0.004	4.575	0.000
popDensity_change	1.5530	0.177	8.754	0.000
noDegreePct_change	348.7836	134.635	2.591	0.010
mover5yearPct_change	23.3269	31.389	0.743	0.458
proximityTTC	0.8649	0.116	7.476	0.000
proximityDowntown	-0.8727	0.101	-8.639	0.000

Figure 11: Linear Regression model where the dependent variable is the number of rides started in each census tract.

expansion costs, it may not make long term economic sense to place stations in sparely populated areas away from the downtown core. Therefore, further work is required to understand the trade-off between serving lower-income areas and maximizing BST's usage, revenue, and impact on Toronto's transportation network.

References

2020. Bike share toronto gets $7.5-million expansion despite operating losses.

2020. Exploring toronto bike share ridership using python.

Statistics Canada. 2016. Chass data centre.

Elizabeth Flanagan. 2016. Riding tandem: Does cycling infrastructure investment mirror gentrification and privilege in portland, or and chicago, il.

Hosford and Winters. 2018. Who are public bicycle share programs serving? an evaluation of the equity of spatial access to bicycle share service areas in canadian cities.

Open Data Toronto. 2020a. Bike share toronto ridership data.

Open Data Toronto. 2020b. Bike share toronto stations.