Understanding the Sustainability and Equity Benefits of Vancouver's Public E-bike Share System

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Disclaimer

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This project was conducted under the mentorship of the City of Vancouver staff. The opinions and recommendations in this report and any errors are those of the author and do not necessarily reflect the views of the City of Vancouver or the University of British Columbia.

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Executive Summary

Through the Climate Emergency Action Plan, Vancouver strives to see 2/3 of all trips taken by active transportation modes by 2023. In support of that, Vancouver's public bikeshare system was introduced in 2016 and now includes over 2500 bikes, including 500 e-bikes, available to travel between over 240 stations across the city. This study aims to understand the sustainability and equity benefits of this system through the analysis of trip-based data from the systems introduction in 2016 through June 2023. The key takeaways are summarized as follows:

Key Takeaways

1. The system has seen over 5 million rides since its inception.
2. Throughout the year, most rides originate from Downtown and the West End, but waterfront neighborhoods, such as Kitsilano, West Point Grey, and Stanley Park see dramatic increases in ridership during the summer months.
3. Short-term pass holders ride primarily on the weekends and in Stanley Park or along the Seawall. Longer-term pass holders ride during traditional commuting times, mostly downtown and E-W along the 8th, 10th, and 14th Ave bikeways. Community pass members have wider hours of typical use and ride more heavily to and from east of Downtown.
4. Single ride, daily, and monthly membership pass riders have fluctuating ridership values over the year, while community, corporate, and yearly pass riders are more consistent.
5. E-bike usage is less concentrated in Stanley Park than standard bike usage, but more concentrated in the downtown core and in the Broadway Plan area. E-bike charging operations will be a major factor in the concentrations of e-bikes. Mount Pleasant, Downtown and West End are the home to the bulk of the charging stations. A higher percentage of e-bikes trips are traveling north-south on Ontario St compared to classic bike trips.
6. On-bike temperature sensors consistently register temperatures above those collected by the Vancouver Airport (YVR) sensor, on some days registering readings as high as 38°C even when the YVR sensor reads below 30°C.
7. Overall ridership changes in extreme temperature, concentrated in Stanley Park for days above 30C and in the downtown core on days below 2C.
8. Vancouver's public bikeshare system reduced 391 tonnes of CO_2 in 2022 (on average 32.6 tonnes per month). 2023 is set to exceed this, with June 2023 reducing 58 tonnes of CO_2.
9. Mobi's e-bikes fleet reduced 88 tonnes of CO_2 in the past year (on average 7.3 tonnes per month). In June 2023, the CO_2 reduction from e-bike trips was 16 tonnes of CO_2.

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10. Based on the average number of bikes staying docked longer than 30 minutes per day, there are 10 potential stations to prioritize electrification, with each seeing more than 5 bikes per day stay long enough (>30 minutes) to charge.
11. From an equity perspective, prioritizing electrification of stations for community pass members includes stations both in the downtown core as well as reaching out to the edges of the network.

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Introduction

Through the Climate Emergency Action Plan (CEAP), Vancouver strives to see 2/3 of all trips taken by active transportation modes by 2023. To accomplish this, the City and City partners will work to both expand the walking, biking, and rolling network as well as encourage further movement via these sustainable modes through the existing networks [1]. In support of that, Vancouver's public bikeshare system was introduced in 2016 and now includes over 2500 bikes, including 500 e-bikes, available to travel between over 240 stations across the city as of June 2023.

In the Climate Emergency Action Plan, there are further considerations for equity in movement. As we move towards seeing 2/3 trips taken by active transport, the plan calls for minimized burdens for those already struggling and accountability via equity milestones [1]. To that end, Vancouver's bikeshare system aims to support this through flexible pass structures and increasing service areas. Additionally, the introduction of e-bikes into the system reduces cycling barriers for people of different ages, genders, and physical abilities [2].

In order to understand how Vancouver's public bikeshare system has supported, and can continue to support in the future, the CEAP, this study analyzes over 5 million rides to understand rider behavior and offer insight into future improvements to the system based on these findings. In particular, this study investigates the sustainability and equity benefits of both the introduction of e-bikes as well as of the system overall.

Vancouver's Public Bikeshare System

Since 2016, Vancouver's public bikeshare system has been available to take riders around the city. The bikeshare is a docked system that allows riders to start and end their trip at a designated station. To get started, users register for an account on their computer or phone. With an account, users can then use a code to unlock a bike from a dock at any time. When completing the ride, users insert the bike back into any empty dock which then locks [3]. In July 2022, e-bikes were added into the system. By the fall, a total of 500 e-bikes were added to the system. Currently 16 of the stations are electrified, allowing the bikes to charge when they are docked.

There are various types of account or membership types available to riders. First, users can check out the bike in a "Pay Per Ride" scheme in which each ride costs $1 to unlock the bike ($1.50 for e-bikes) plus $0.25 per minute ($0.35 for e-bikes). Users can also choose Daily, Monthly, or Yearly passes as well, which require a flat one-time subscription fee, no unlock fee, and additional per minute fees for some rides. Organizations can also sign up to provide corporate memberships to their employees. This provides yearly passes at a discounted rate for employees. Finally,

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Vancouver bikeshare offers a Community Pass. The Community Pass is available through a variety of qualifications including holding certain transit passes (Red Compass Card) or Greater Vancouver Food Bank membership cards, proof of income less than $27,000, referral from a community partner, or a persons with disabilities designation [4]. The various passes and their ride rates are shown in Table 1.

Table 1 Membership Options for Vancouver Bikeshare. Classic bike prices are shown first with e-bike prices in parentheses. Subscription fees are irrespective of bike type.

Pass Type	Subscription Fee	Unlock Fee	Rate 0-30 min (per minute)	Rate > 30 min (per minute)	Rate any amount of time (per minute)
Pay per ride	-	$1 ($1.50)	-	-	$0.25 ($0.35)
Daily	$19	-	$0 ($0.25)	$0.25 (0.35)	-
Monthly	$39	-	$0 ($0.25)	$0.25 (0.35)	-
Yearly	$139	-	$0 ($0.15)	$0.25 (0.35)	-
Corporate	$99	-	$0 ($0.15)	$0.25 (0.35)	-
Community	$20[1]	-	$0 ($0.15)*[2]	$0.25 (0.35)*	-
*Rates from 0-60min and > 60 min					

Methods

Vancouver's public bikeshare has grown since its introduction to the city in 2016. With the introduction of e-bikes in July 2022, this study aims to understand the sustainability and equity benefits of e-bike sharing and the public bikeshare system overall by:

1. Identifying patterns of classic and e-bike usage
2. Quantifying system usage in extreme weather events
3. Assessing CO2 reduction from classic and e-bike share usage patterns
4. Identifying changes for more equitable and accessible e-bike charging station locations

[1] Mobi works with individuals and partners to ensure the cost of community pass is not a barrier to anyone interested in the Community Pass.

[2] There are a few variations of the community pass and some of the passes do not have a per minute charge for e-bikes.

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Data

To fulfill these aims, this study utilizes trip-based data from every trip taken on the public bikeshare system from September 2016 through June 2023. For each trip the recorded information includes the departure station and time, return station and time, rider membership pass type, the trip distance and duration, and whether the bike is a classic bike or an e-bike. Additionally, each bike has an on-board temperature sensor that records the temperature at the departure and return of the bike. Here, departure is defined as the moment the bike is unlocked from the origin dock and return as the moment the bike is locked back into the destination dock. From this, we derive details about the station (location, elevation), the average speed of the trip, and temporal aspects of the trip (e.g., day of week, time of day, time of year). These values are summarized in Table 2.

Table 2 Variables in bikeshare trip data.

Variable	Unit
Departure/Return Time	Date and Time
Departure/Return Station	Name
Departure/Return Temperature	Degrees Celsius
Rider Pass Type	Pass Name
Bike Type	Classic / E-bike
Trip Distance	Meters
Trip Duration	Seconds
Departure/Return Location	Longitude, Latitude
Departure/Return Elevation	Meters
Departure/Return Day of Week	Monday-Sunday
Departure/Return Time of Day	Hour of Day
Departure/Return Time of Year	Spring, Summer, Fall, Winter

For the purposes of this study, some of the trips are excluded. These include trips that are less than one minute long in order to remove cases in which the bike is accidentally checked out and back in immediately. From experiential knowledge, trips of less than 1 minute are often faulty and should be discounted. We also exclude trips conducted for maintenance or managerial purposes. These include trips to or from Mobi workshop or headquarters stations as well as trips for rebalancing by Mobi staff.

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Finally, some parts of the analysis are conducted only on specific time periods, such as only 2022, or only the time in which e-bikes have been in the system and data was available (July 2022-June 2023). In each of these cases, the period of analysis will be noted.

Analysis

In some cases, spatial and temporal analysis of a particular feature are examined. For spatial analysis, the patterns are identified by visualizing desire line maps [5]. Desire lines are straight lines drawn between an origin and a destination, in this case the departure and return stations of the bike trip. As the data does not include exact paths taken by the user, the desire line represents how a person might travel *if* they could travel in a straight line. Aggregating across many users can reveal corridors of use in which the more people cross through a point, the more popular it is. We compute desire lines by first segmenting the space into equally sized hexagons (Figure 1).

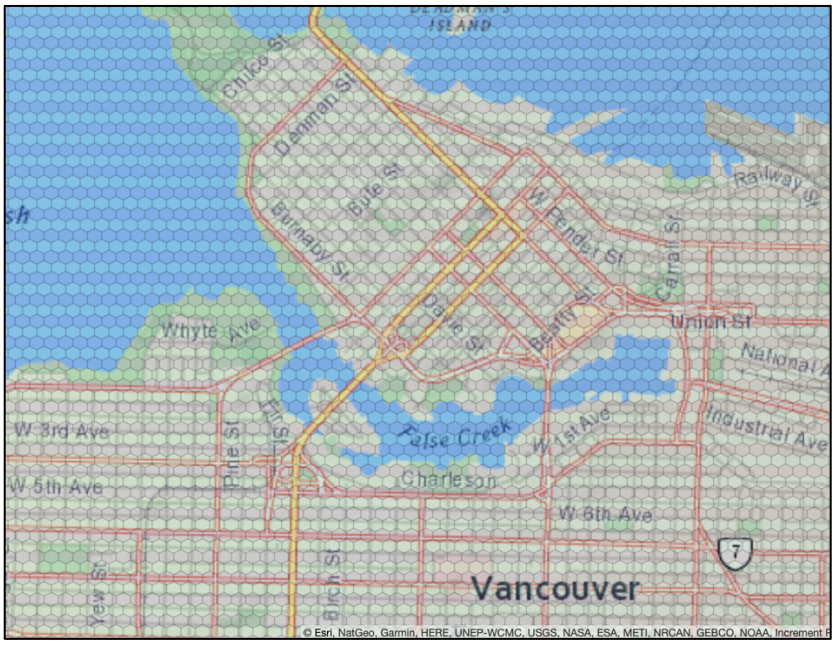

Figure 1 Hexagon division of space.

To start, each of the hexagons has a value of zero, meaning no desire lines have passed through it. Then, for each trip, a straight line is drawn between the departure and return stations. Any of the hexagons that intersect this line get a value of 1 added to it, meaning one trip has passed through it. This goes on for every trip, until every trip has been added to all of the hexagons it intersects. A schematic of this process is shown in Figure 2. Here, the color gets lighter and redder as more lines pass through it.

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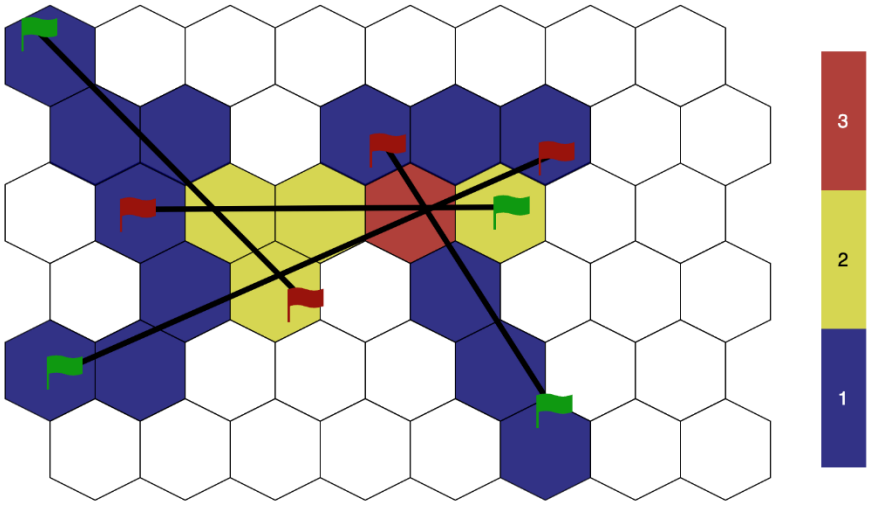

Figure 2 Schematic of computing desire lines. Each line that passes through a hexagon adds one to its total count, making the color lighter and more red.

Temporal analysis of the system is shown through an activity matrix, in this case analyzing time of day and day of week ridership. An activity matrix visualizes the amount of ridership in each hour of the day / day of the week combination. An example is shown in Figure 3.

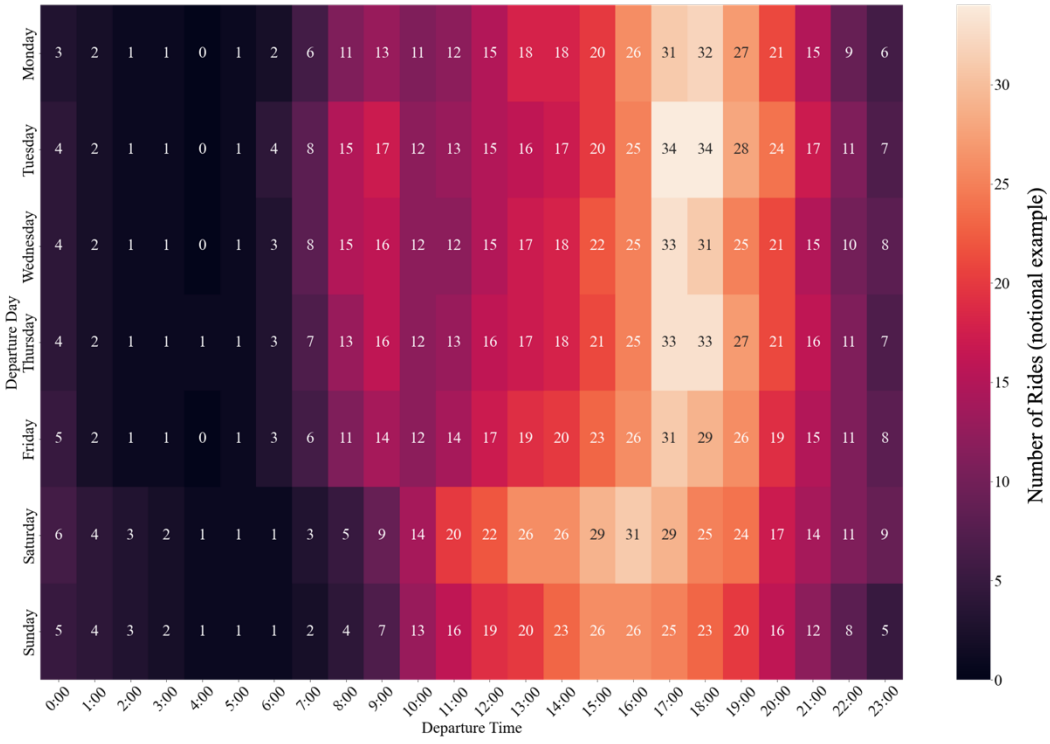

Figure 3 An example of an activity matrix of ridership values. The day of the week is shown on the y axis and the hour of the day from midnight (0) to 11pm (23) is shown along the x axis.

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Lighter values represent higher ridership and darker values represent low ridership for that day of week / hour or day combination. In the above example, the highest ridership would be Tuesdays at 5pm (17:00) and 6pm (18:00).

Findings

Overall Analysis of the System

Since its inception in 2016, Vancouver's public bikeshare system has grown in the number of stations, bikes, and subsequent rides. June 2023 saw total ridership crest 5 million rides. Ridership is highest in the summer months, with each peak ridership exceeding that of the previous year (Figure 4). The only exception to this is summer 2020, which saw a drop in ridership from summer 2019 likely due to the COVID-19 pandemic and lockdown measures. July 2023 has recorded the highest ridership to date with 186,064 rides, however projections for August 2023 are set to exceed this.

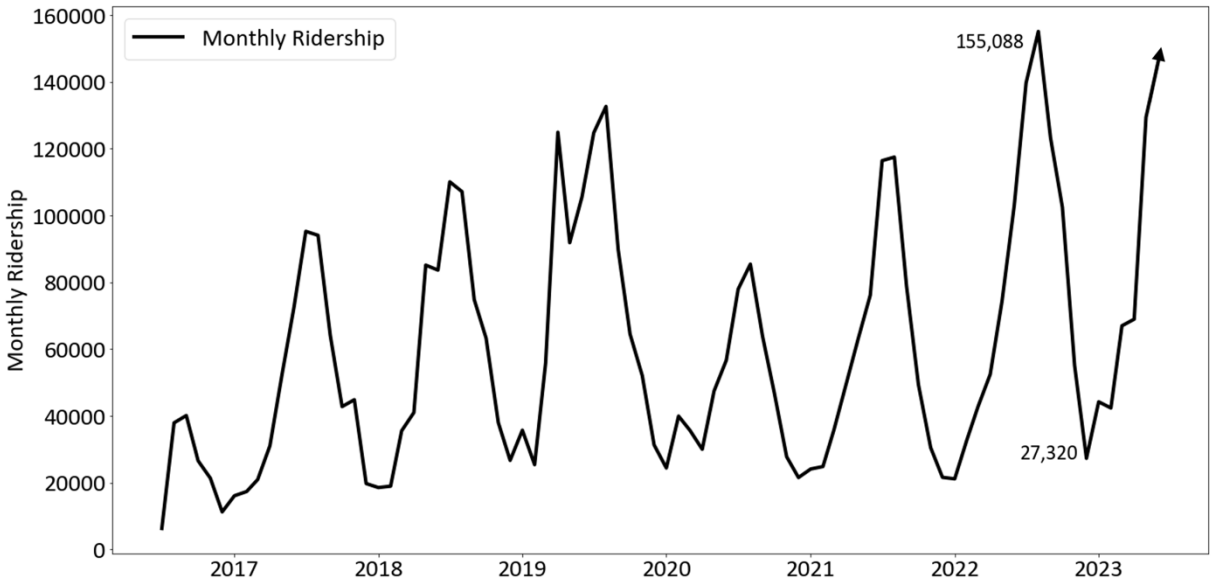

Figure 4 Monthly ridership of the bikeshare system from its inception in 2016 through June 2023

While the winter months see decreased ridership from the surrounding summer months, the baseline continues to rise, with the lowest ridership of winter 2016-2017 in December 2016 at 11,278 and the lowest ridership of winter 2022-2023 in December 2022 at 27,320.

Key Takeaway #1: The system has seen over 5 million rides since its inception.

Just as the ridership counts ebb and flow throughout the year, so too do the stations in which the rides start and end. While downtown core neighborhoods see a consistently high

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number of trips, Vancouver is home to beautiful biking paths along the Seawall, including around Stanley Park, and these paths see increased ridership in the summer months. For 2022, the Downtown and West End neighborhood stations had the greatest number of departures and returns for the whole year. Partially, this is due to the higher number of stations in these neighborhoods in comparison to others, although the West End trails both Mount Pleasant and Kitsilano (**Table 3**). **Figure 5** shows a map of the neighborhood boundaries.

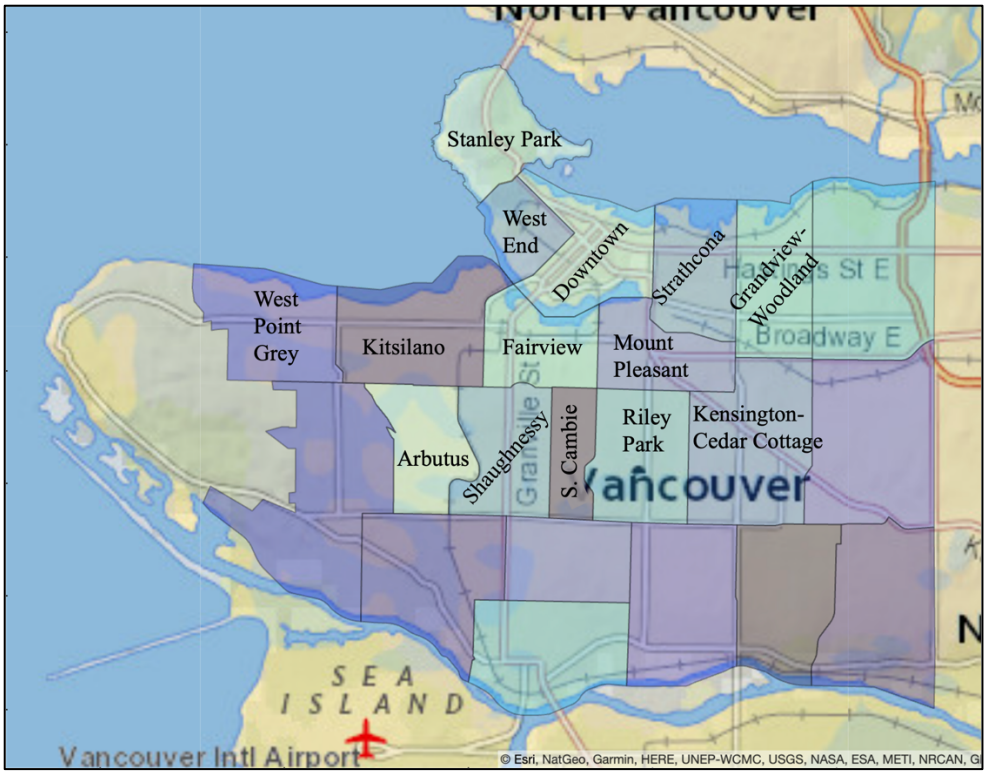

Figure 5 Boundaries of Vancouver neighborhood designations used in this report.

Table 3 Number of stations and docks in each neighborhood as of June 2023.

Neighborhood	Number of Stations	Number of Docks
Downtown	52	1052
Mount Pleasant	41	737
Kitsilano	31	619
West End	27	556
Grandview-Woodland	24	396
Fairview	22	380
Strathcona	14	218
Stanley Park	7	151
South Cambie	7	122

Riley Park	6	112
Kensington-Cedar Cottage	6	104
West Point Grey	3	76
Shaughnessy	1	20
Arbutus-Ridge	1	18

Figure 6 shows the ranking of number of trips starting or ending in each neighborhood throughout 2022, with the highest ranking at the top and the lowest at the bottom. Each line represents a neighborhood and can be traced from January to December. A few of the neighborhoods—West Point Grey, Arbutus-Ridge, and Shaughnessy—had their first station added in the midst of 2022 and thus do not begin their lines until the addition of the station.

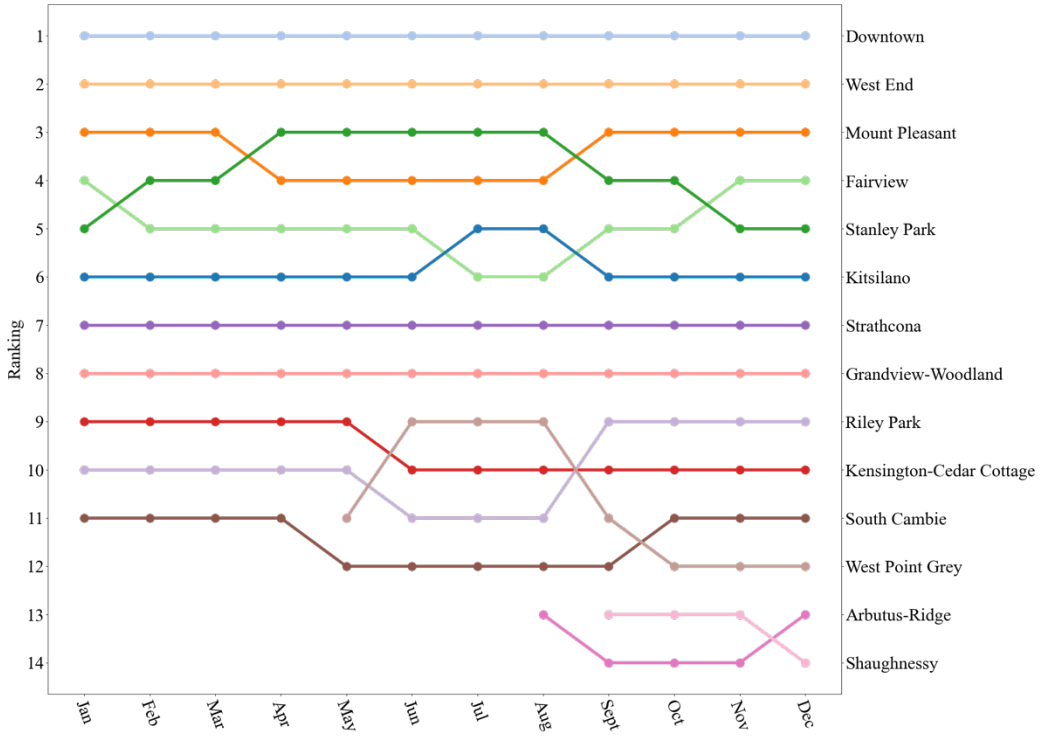

Figure 6 Map of neighborhood boundaries and rankings of total number of trips (departures and returns) throughout 2022.

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Key Takeaway #2: Throughout the year, most rides originate from Downtown and the West End, but waterfront neighborhoods, such as Kitsilano, West Point Grey, and Stanley Park see dramatic increases in ridership during the summer months.

People use the system in many ways. The ridership data includes what type of pass the rider of each trip had. While people are free to choose any pass type, there are trends that emerge as certain pass types are more cost-effective for certain purposes. For example, casual or visiting riders might find it more advantageous to purchase a daily or single ride pass while locals or commuters may find a monthly or yearly pass more financially beneficial. By computing the desire lines for various pass types—pay per ride, daily, monthly, yearly, corporate, and community passes—we see varying spatial patterns of use **(Figure 7).** Pay per ride and daily pass types are often used in and around Stanley Park or along the waterfront. A low percentage of these riders stray outside of the core system area. Meanwhile, monthly, yearly, and corporate passes have high activity in the downtown neighborhoods, near Olympic Village, and along the more southern east-west bikeways between 8th Ave and 14th Ave, and Arbutus St and Fraser St. Community pass members have higher concentration of travel from east of Downtown Vancouver and more travel to the southeast region of the station coverage than users with other pass types. There are hotspots for this pass type at a few of the major transit locations outside of the core including around the Commercial-Broadway and Science World SkyTrain stations.

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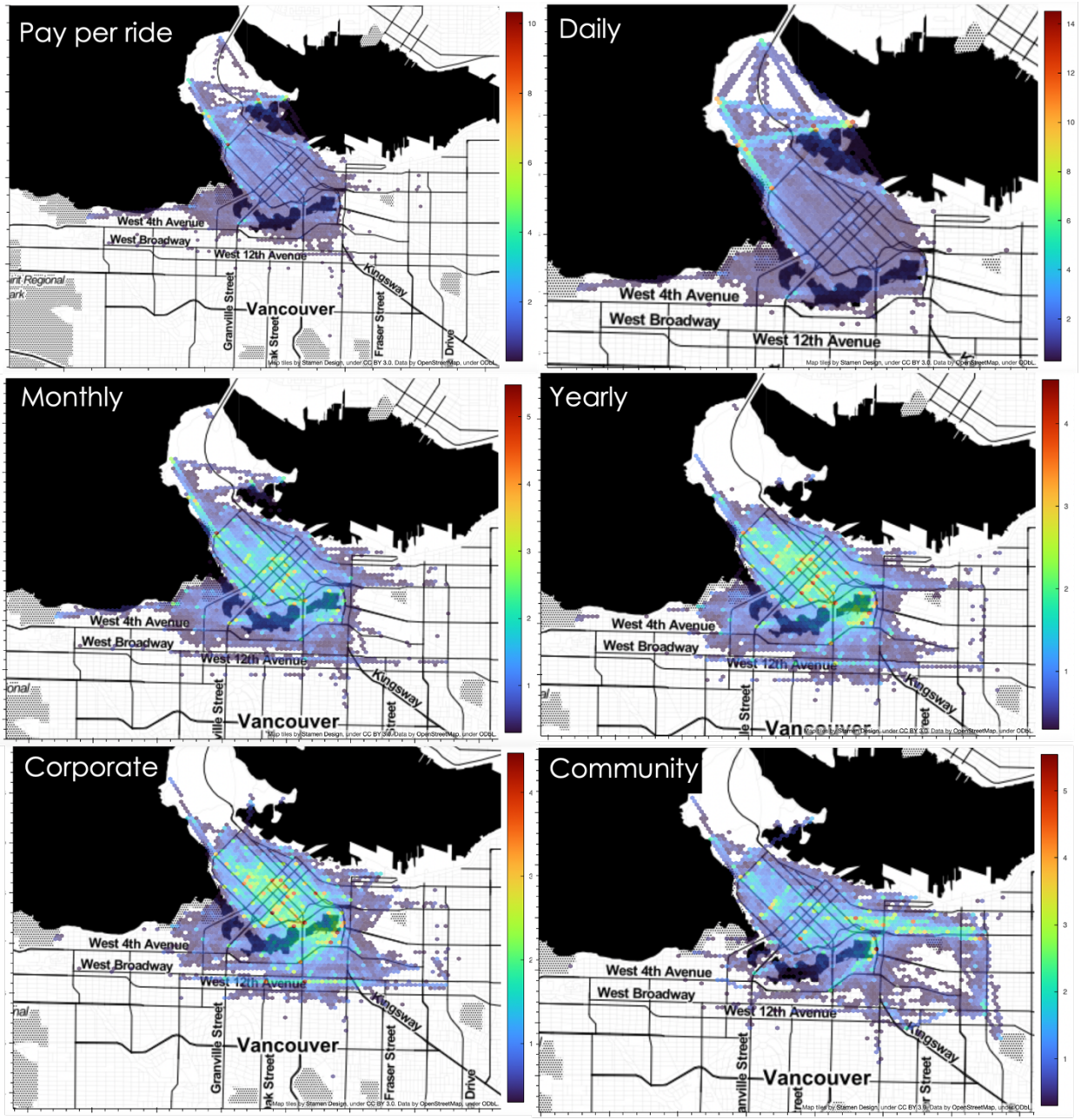

Figure 7 Spatial patterns of rides for six pass types shown through desire lines. Lighter, more red color represents a greater number of desire lines passing through that hex, while darker, bluer color represents lower amounts.

We also see varying temporal patterns of use for users of different pass types. We can look at the activity matrix for each pass type, aggregated across the entire year to identify patterns in the day of week and time of day with the highest ridership (**Figure 8**). Further confirming that short-term passes (pay per ride and daily passes) are better suited for casual riders, the highest ridership for those passes are seen on the weekends, heavily on Saturdays between 11am and 7pm. The

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monthly passes potentially serve dual purposes: as a cost-effective alternative to time periods longer than single day riding while still being used casually or for commuting, potentially at a shorter time scale than a full year for fair-weather riders. This is reflected in ridership peaking both on weekend days and weekday evenings (4-7pm).

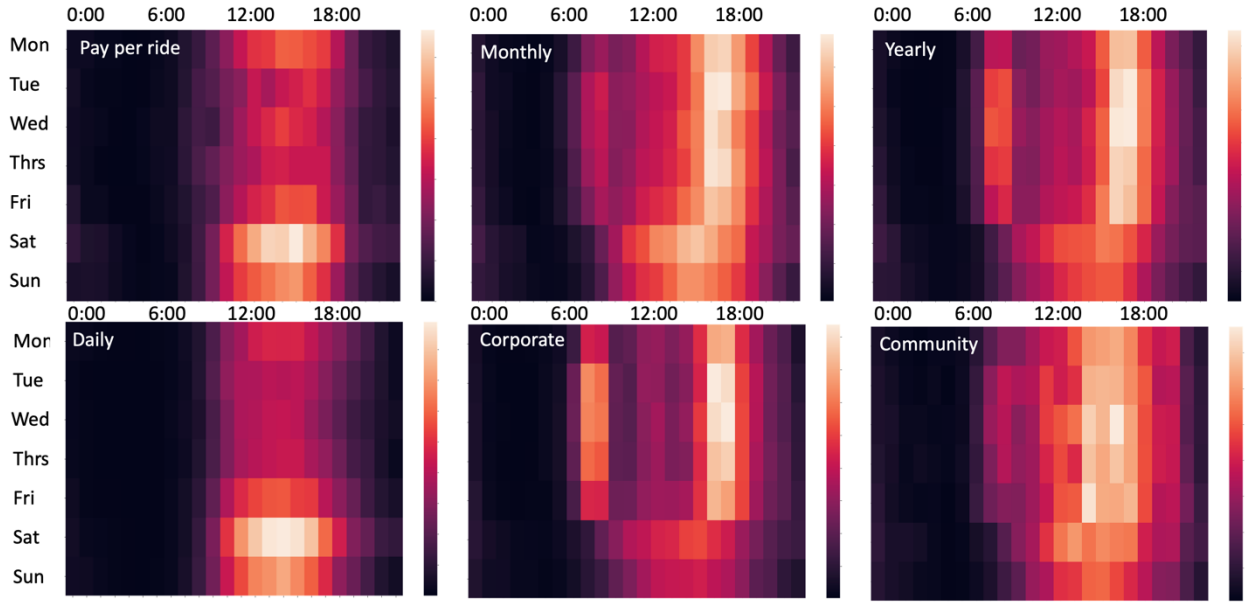

Figure 8 Temporal patterns of ridership for each pass. Each row is a day of the week, and each column is an hour. Lighter colors signify higher ridership.

Yearly and corporate passes have the highest ridership during traditional commuting times, 7-9am and 5-7pm. More rides are taken during the evening commute than the morning commute by most long-term pass holders. Finally, community pass members have a wider spread of ridership peak times, with the highest number of rides occurring weekdays from 2-6pm and during the day on the weekends.

Key Takeaway #3: Short-term pass holders ride primarily on the weekends and in Stanley Park or along the Seawall. Longer-term pass holders ride during traditional commuting times, mostly downtown and E-W along the 8th, 10th, and 14th Ave bikeways. Community pass members have wider hours of typical use and ride more heavily to and from east of Downtown.

Ridership varies between the pass types on multiple time scales including not just time of day and day of week but also time of year. Consistent with the spatial patterns and small-scale temporal patterns, daily and pay per ride users peak in the summer months, an ideal time for casual riding and visitors to Vancouver. While all pass types see some increase in ridership in the warmer months of the year, the difference is starkest for these causal riders. Yearly, corporate, and

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community pass members ride more consistently throughout the year (**Figure 9**). The oscillations in ridership are due to the weekly fluctuations in ridership values as well.

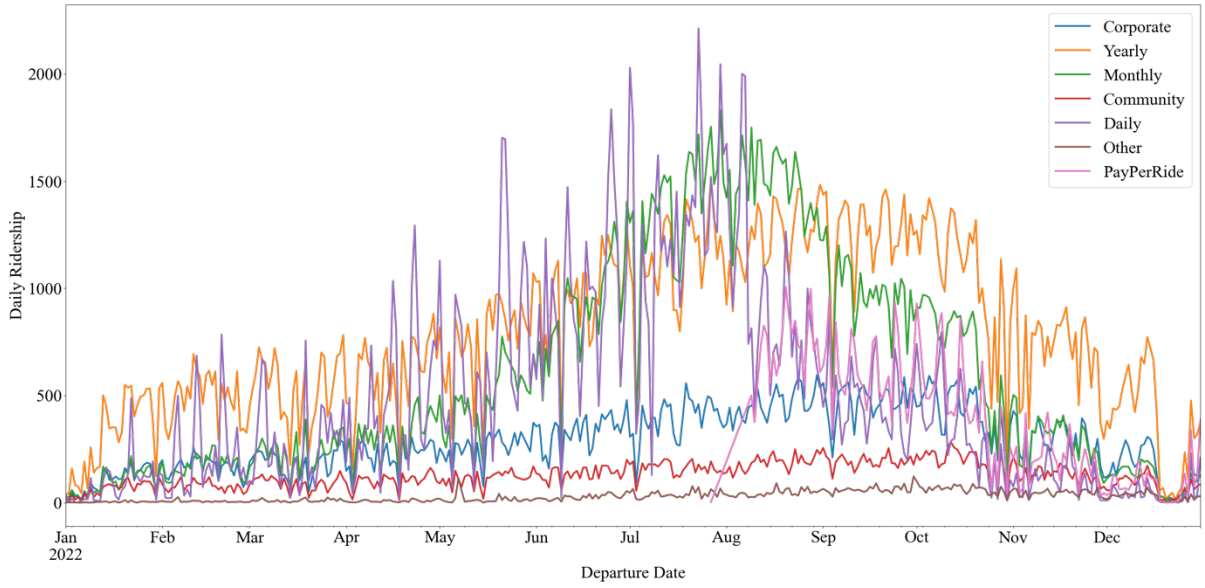

Figure 9 Total daily ridership from January to December 2022. Each line represents a pass membership type.

Key Takeaway #4: Single ride, daily, and monthly membership pass riders have fluctuating ridership values over the year, while community, corporate, and yearly pass riders are more consistent.

It has been a year since the introduction of e-bikes into the system in August 2022, with full deployment of ~500 e-bikes in September 2022. Since then, we have seen similar, but slightly different patterns of rides for their use compared to the classic bikes (**Figure 10**). The classic bikes have more rides around Stanley Park and along the waterfront areas of the peninsula, while the e-bikes have more riders concentrated in the Downtown core, around the 10th Ave bikeway, and east of the Downtown. Additionally, e-bike riders are traveling more up or down the hill on Ontario St.

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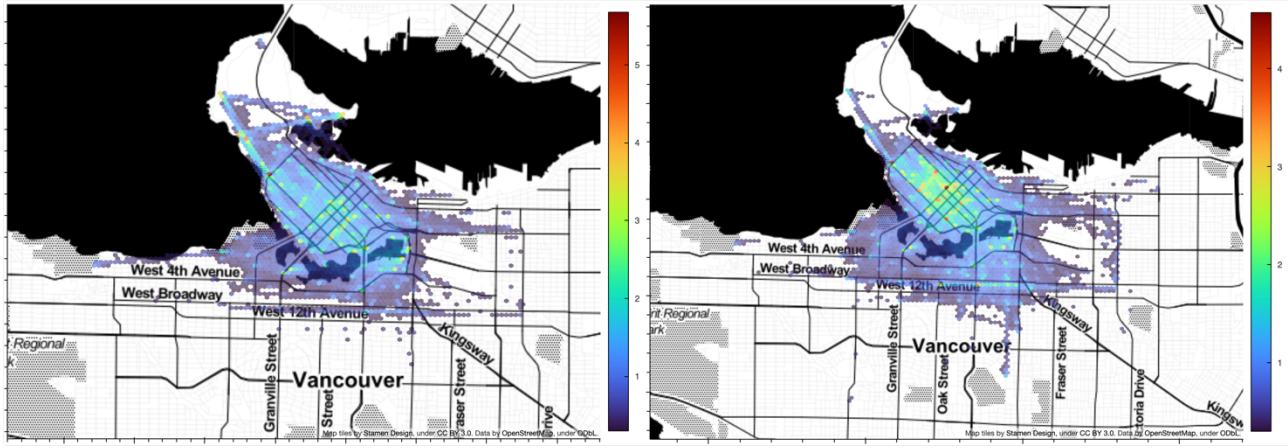

Figure 10 Spatial patterns for classic bikes (left) and e-bikes (right) for July 2022-June 2023.

Key Takeaway #5: E-bike usage is less concentrated in Stanley Park than standard bike usage, but more concentrated in the downtown core and in the Broadway Plan area. E-bike charging operations will be a major factor in the concentrations of e-bikes. Mount Pleasant, Downtown and West End are the home to the bulk of the charging stations. A higher percentage of e-bikes trips are traveling north-south on Ontario St compared to classic bike trips.

Looking at rides from July 2022 through June 2023, we can determine where one might be most likely to find a bike throughout the day, represented as the critical mass of classic bikes or e-bikes available to ride (**Figure 11**). Here, a higher ranking means more bikes are available to ride in that neighborhood for that hour. Throughout the day, the most likely neighborhood to find a classic bike is Downtown, while for e-bikes it is either Downtown or Mount Pleasant. The morning has a high amount of classic bikes and e-bikes available in the West End, but these are ridden to other neighborhoods for 9am-5pm before returning to West End for the evening and night.

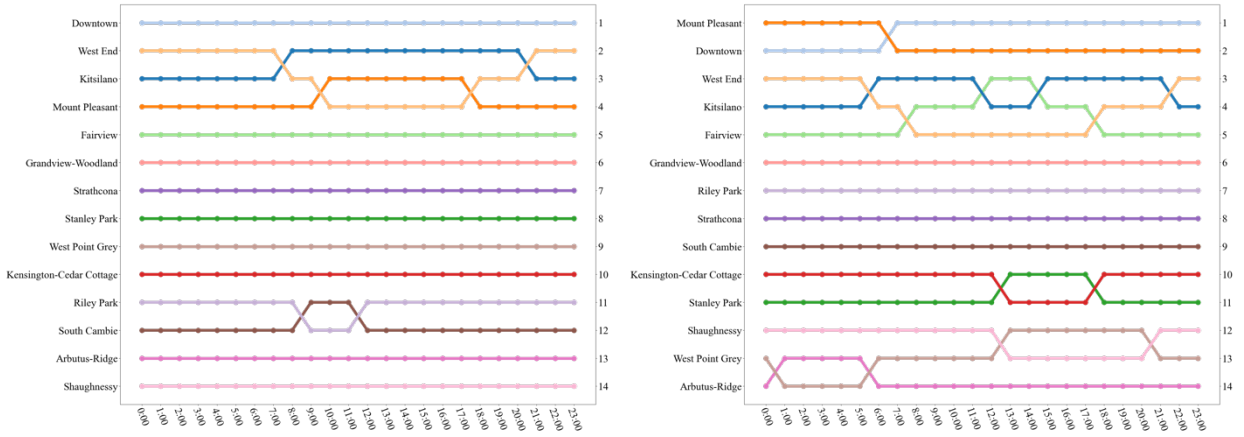

Figure 11 Classic bikes (left) and e-bikes (right) critical mass of bikes available by neighborhood and time of day.

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Finally, the breakdown of pass types for classic bikes and e-bikes are fairly consistent (Table 4). Yearly, monthly, corporate, and community pass members make up comparable percentages of the rides for each of the bike types. Daily and pay per ride percentages vary the most but this likely has to do with the way users are charged for e-bikes. For daily rides, classic bikes are not charged a per-minute rate for the first 30 minutes while e-bikes are. Unless a user takes over 10 distinct 30-minute trips in one day, the pay per ride pass is the more economical option for e-bike riding over the daily pass.

Table 4 Percentage of trips taken by each pass membership type for classic bikes and e-bikes.

Pass Type	Classic bikes (Percent of trips)	E-bikes (Percent of trips)
yearly	26%	30%
monthly	24%	21%
pay per ride	5%	15%
corporate	11%	13%
other	10%	10%
community	5%	6%
daily	19%	5%

Extreme Temperatures

Each bike is equipped with a temperature sensor that records the temperature at the check-out (departure) and check-in (return) of the bike. Aggregating across all of the bikes can give an on the ground temperature reading. We can compare this to the temperature sensor at the Vancouver International Airport. This is shown in Figure 12, where the average temperature from the airport sensor is shown in blue, with minimum and maximum readings creating error bars around it (light red and blue shading). Similarly, the average reading from the bike sensors for that day is shown in red, with light red error bounds[3]. Throughout the year, the average temperature from the on-bike sensors is higher than that from the airport sensor. The difference is greater as the temperature increases.

[3] For the bike sensors, the minimum and maximum are represented by the 10th and 90th percentile temperature for that day to remove outliers from faulty sensors.

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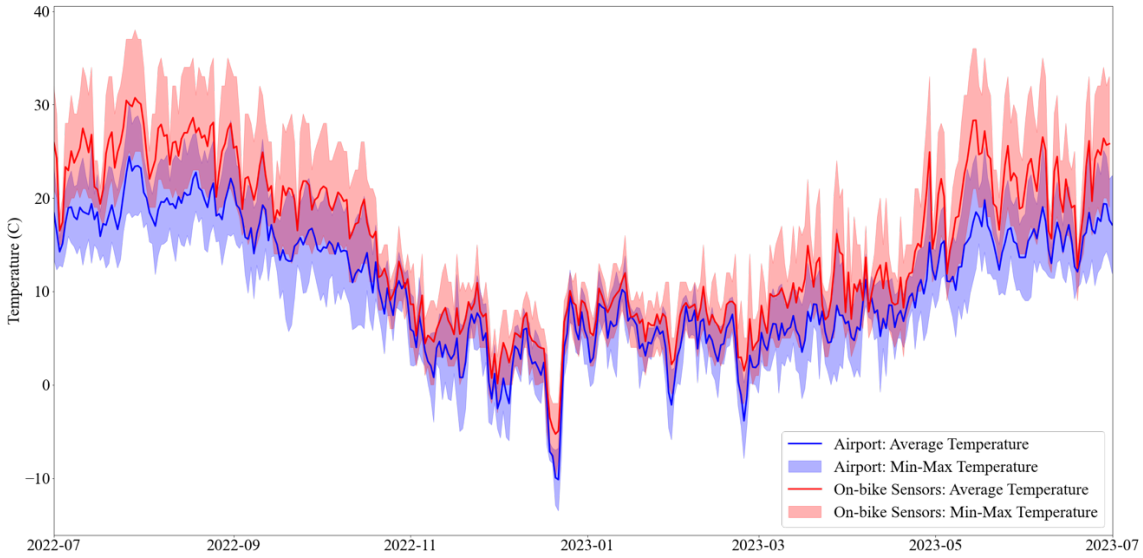

Figure 12 Temperature readings from July 2022 through June 2023 from the Vancouver International Airport sensor and the average of the on-bike sensors.

Key Takeaway #6: On-bike temperature sensors consistently register temperatures above those collected by the Vancouver Airport (YVR) sensor, on some days registering readings as high as 38°C even when the YVR sensor reads below 30°C.

Of particular importance are the days and readings at extreme temperatures—both below 2°C and above 30°C. We can examine the spatial patterns on rides that register readings in these ranges in 2022 (Figure 13). For extreme cold (below 2°C), the rides are mostly concentrated in the downtown core and near Olympic Village. A corridor extends east to and from the downtown area as well. This may be reflective of the fact that days below 2°C in 2022 were also accompanied by snow and the areas with high ridership are also those that are primarily plowed or salted. Regions outside of this area might not have seen road or bike path plowing and thus potentially reduced ridership. On the contrary, for extreme heat (above 30°C) the rides are heavily concentrated around Stanley Park and along the waterfront areas of the city.

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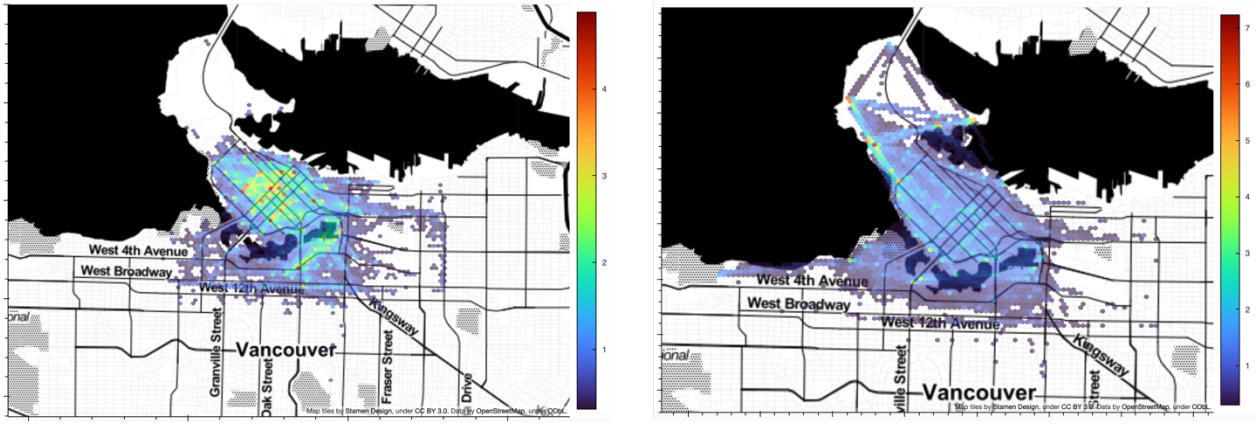

Figure 13 Spatial patterns of desire lines for below 2°C (left) and above 30°C (right). Lighter, more red color represents higher ridership.

Key Takeaway #7: Overall ridership changes in extreme temperature, concentrated in Stanley Park for days above 30C and in the downtown core on days below 2C

CO2 Reduction

The City continues to work internally and with researchers to consider and refine CO2 and GHG reduction models. In this model, each ride represents a sustainable way to move around the city, however it is noted that this model is not operable with other City models. We can calculate the amount of CO2 reduction by each trip being taken on a bike as opposed to a vehicle. To calculate this reduction we perform the following:

1. Collect vehicle distributions from ICBC across Vancouver [6]. This provides the amount of each make and model for vehicles registered in the city.
2. Match each make and model with an emissions profile from Environment Canada [7]. The emissions profile gives grams of CO2/km driven (g/km).
3. Calculate the driving distance (km) between each departure and return station pairing.[4,5]
4. Randomly assign a vehicle make and model with an emission profile to each bike share trip.
5. Now each trip has an associated driving distance (in km) and emission profile (in g/km). Multiply these values for the grams of CO2 reduction by each trip.
6. Calculate the sum over all the trips and convert to tonnes of CO2 (1,000,000 g in a tonne)

[4] This likely underestimates the distance traveled by the user in undertaking the trip because it does not account for walking to/from the stations from the true origin and to the intended destination. However, given the spatial extent of the bike system, we expect this added distance to be small.

[5] For rides that start and end at the same station, the driving distance will be 0km.

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7. Repeat steps 4-6 at least ten thousand times and compute the average CO2 reduction.[6]

This model shows that bikeshare trips in 2022 replaced the equivalent of over 1.8 million kms of driving [8]. The CO2 reduction for this period was 391 tonnes of CO2 which is an average of 32.6 tonnes per month. In comparison, the average vehicle emits 4.6 tonnes of CO2 each year [8].

Key Takeaway #8: Vancouver's public bikeshare system reduced 391 tonnes of CO2 in 2022 (on average 32.6 tonnes per month). 2023 is set to exceed this, with June 2023 reducing 58 tonnes of CO2.

Similarly, this model shows trips on e-bikes from their introduction in July 2022 through the end of June 2023 replaced the equivalent of 363,000 kms of driving [8]. The CO2 reduction for nearly one full year of e-bike ridership was 88 tonnes of CO2, for an average of 7.3 tonnes per month. For only 500 e-bikes, this is 176 kg of CO2 per e-bike across the year. In June 2023 alone, e-bikes reduced 16 tonnes of CO2. These values may grow as the system expands, ridership grows, and riders become more comfortable choosing e-bikes.

Key Takeaway #9: Mobi's e-bikes fleet reduced 88 tonnes of CO2 in the past year (on average 7.3 tonnes per month). In June 2023, the CO2 reduction from e-bike trips was 16 tonnes of CO2.

Station Siting

The trip data, and more specifically the e-bike trip data, is used to potentially inform future station siting decisions such as which of the existing stations to add electrification for charging. When stations have electrification, e-bikes that are docked can charge while waiting for the next trip to begin. This reduces the need for bringing the bikes to a separate charging location throughout the day. In order for the stations to be most effective, when an e-bike is docked, it should stay docked for at least 30 minutes before being checked out again. This allows the bike to make significant gains in battery potential. Therefore, based on about one year of e-bike trips from July 2022 through June 2023, we estimate the average number of e-bikes that docked longer than 30 minutes in a day for each station. These represent the stations that will charge the greatest number of bikes across the system. Note that the decision to electrify a station involves many more variables than this, and this represents just one model for planning electrification prioritization.

[6] This is called a Monte Carlo simulation and it ensures a more accurate estimation since the random assignment of the vehicle make and model impacts the final value. For example, randomly assigning a heavy polluter for a long bikeshare trip will inflate the CO2 reduction more than randomly assigning an electric vehicle to the same trip. Through the Monte Carlo simulation, these effects will be attenuated.

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The top 10 stations, outside of existing charging stations, are shown in **Table 5** and visualized in **Figure 14**. In Figure 14, the existing charging infrastructure as of June 2023 is shown outlined in red.

Table 5 Top ten stations for number of bikes staying longer than 30 minutes each day.

Station	Average # of bikes staying longer than 30 min a day
Smithe & Burrard	6.80
Davie & Beach	6.79
10th & Cambie	6.04
Granville Island	5.31
Bute & Robson	5.27
Hornby & Pender	5.26
Canada Place	5.13
Richards & Davie	5.07
Bute & Davie	4.97
Anderson & 2nd	4.89

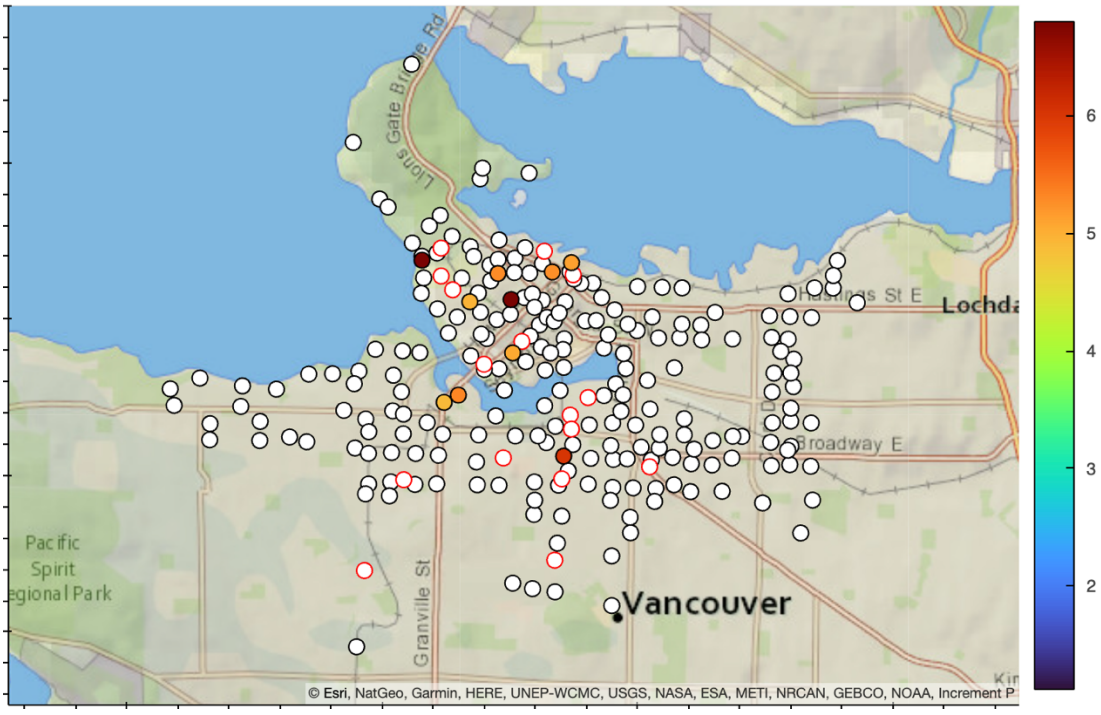

Figure 14 Location of top 10 stations for potential electrification. Darker red represents more e-bikes staying over 30 minutes each day. All stations are marked in white and existing charging infrastructure outlined in red (as of June 2023).

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The stations that see the highest number of e-bikes staying longer than 30 minutes each day are concentrated in the downtown region and just outside in Fairview and Kitsilano neighborhoods. It may be advantageous to understand which stations would be most effective for charging at different points of the day. See Appendix A for this breakdown.

However, if we assume that as e-bikes continue to be introduced into the system, rider patterns will start to mirror those of the classic bikes simply due to more e-bike availability, we can look to all of the rides on both classic bikes and e-bikes over the same time period to understand where might be the best stations for electrification based on the same criteria. This is shown below in Table 6 and Figure 15. Now, the top ten stations are near locations that heavily serve visitor and causal riders, such as around Stanley Park and at key recreational locations such as Science World and Canada Place.

Table 6 Top ten stations for number of classic bikes and e-bikes staying longer than 30 minutes each day.

Station	Average # of bikes staying longer than 30 min a day
Davie & Beach	39.00
Stanley Park – Third Beach	28.20
Stanley Park – Second Beach N	27.37
Cardero & Bayshore	27.35
Stanley Park – Information Booth	26.87
Science World	24.78
Canada Place	24.08
Stanley Park – Second Beach S	24.04
Ontario & Seawall	24.02
Anderson & 2nd	28.86

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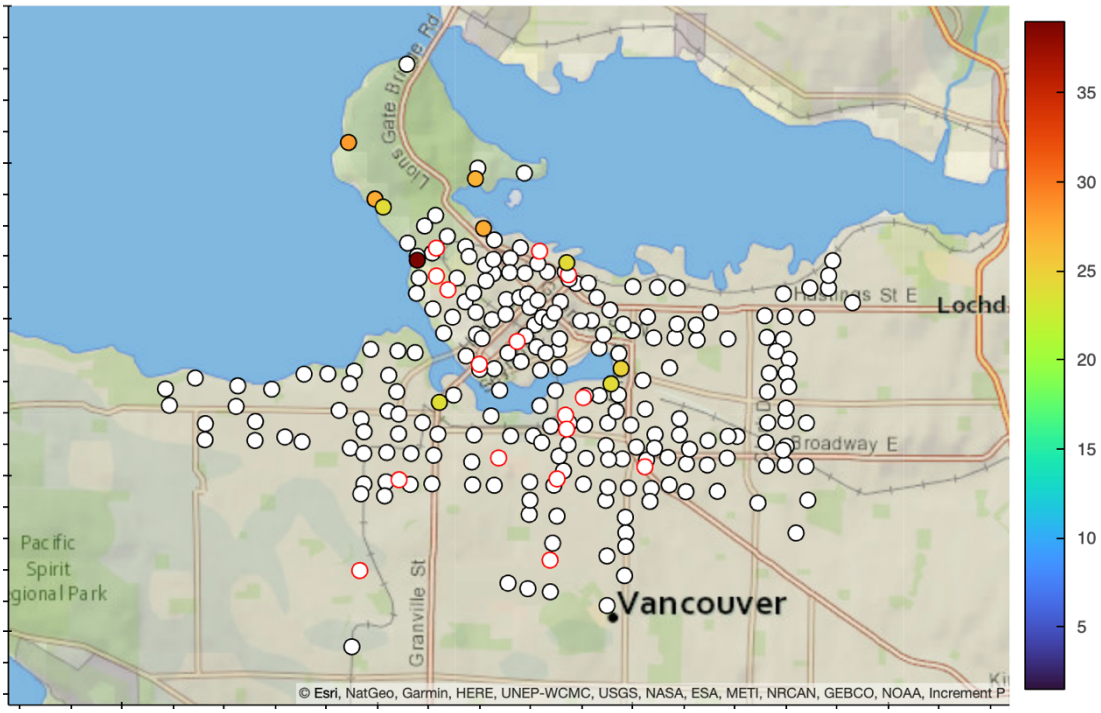

Figure 15 Location of top 10 stations for potential electrification from classic bikes and e-bikes. Darker red represents more e-bikes staying over 30 minutes each day. All stations are marked in white and existing charging infrastructure outlined in red (as of June 2023).

Key Takeaway #10: Based on the average number of bikes staying docked longer than 30 minutes per day, there are 10 potential stations to prioritize electrification, with each seeing more than 5 bikes per day stay long enough (>30 minutes) to charge.

However, it is also possible to prioritize future electrification, according to this simplistic model, based on the needs of specific riders such as community pass holders. In this, we examine the same criteria but for stations that see the highest amount of community pass holders beginning their trip with an e-bike from July 2022 through June 2023. This prioritization model would work to ensure that when a community pass holder begins an e-bike trip, it has the best chance of being charged for the subsequent ride. The top ten stations are again shown in Table 7 and visualized in Figure 16.

Table 7 Top 10 stations for future electrification based on community pass member ridership.

Station	Average # of bikes staying longer than 30 min a day
Smithe & Burrard	1.74
Richards & Davie	1.70

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Helmcken & Burrard	1.69
Alexander & Railway	1.61
Balsam & Cornwall	1.39
Georgia & Thurlow	1.39
Harwood & Bute	1.38
Bute & Robson	1.35
Franklin & Nanaimo	1.35
Alexander & Dunlevy	1.34

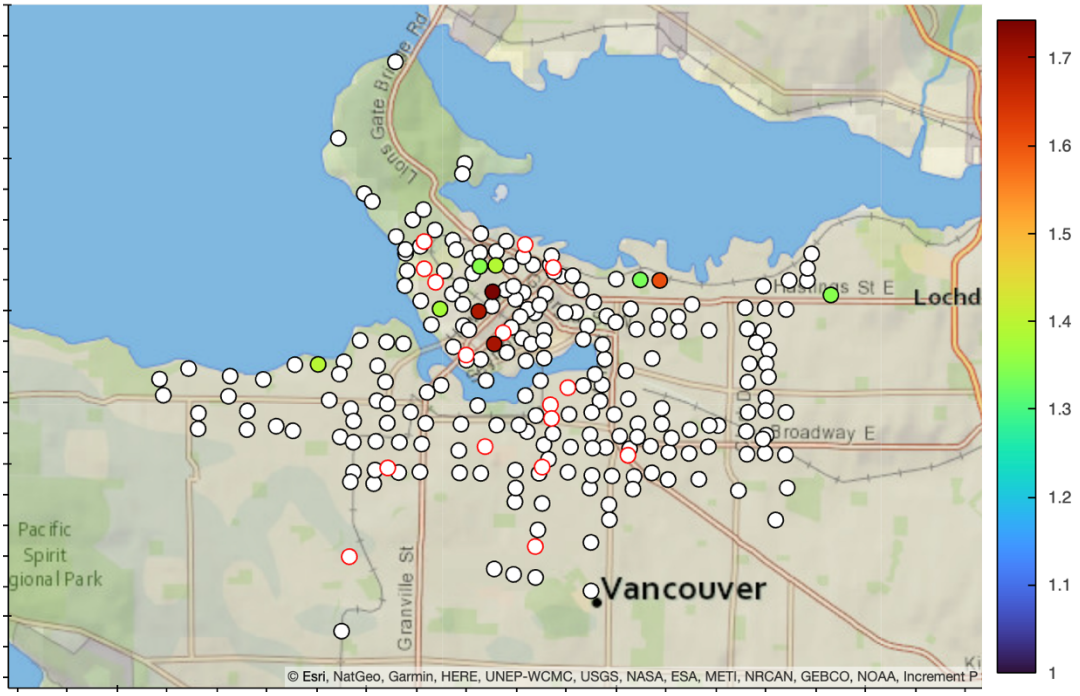

Figure 16 Location of top 10 stations for potential electrification to benefit community pass members. Darker red represents more e-bikes staying over 30 minutes each day. All stations are marked in white and existing charging infrastructure outlined in red (as of June 2023).

Now, the top ten stations in addition to the existing charging infrastructure are in both the downtown core as well as reaching out towards the edges of the network to the east and one station out along the waterfront to the west.

Key Takeaway #11: From an equity perspective, prioritizing electrification of stations for community pass members includes stations both in the downtown core as well as reaching out to the edges of the network.

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Summary

In total, this study has worked to understand the patterns of use of Vancouver's bike share system. Analysis of the system reveals varying spatial and temporal patterns of use across the day, week, and year for different pass membership types. Additionally, the introduction of e-bikes into the system has seen quick uptake by riders and shown that these riders exhibit slightly different patterns of use than the classic bikes riders. In extreme heat and extreme cold, the system is still being used, but in different ways. Extreme heat sees riders using the bikes to travel to cooler or more casual locations such as near the waterfront or around Stanley Park, while extreme cold sees use concentrated in the downtown core and along major plow corridors.

The bikeshare system also represents a sustainable mode of transport throughout the city, reducing nearly 400 tonnes of CO2 in 2022. Each year sees ridership increasing and thus CO2 reduction increasing as well, helping support the goals set out in the Climate Emergency Action Plan. E-bikes represent a good amount of that reduction, with 16 tonnes of CO2 reduced from e-bike trips in June 2023 alone. In order to continue supporting overall usage, but especially e-bike usage, of the system, further electrification of docking stations will help charge e-bikes in the on location as they sit before the next trip. Based on current and projected use of the system, a few of the existing stations are primed for electrification. Through an equity lens, electrifying some of these stations would also serve community pass members more completely, ensuring that e-bikes are charged to ride when these members are ready to depart.

Recommendations for Future Analysis

The trip data from Vancouver's public bikeshare represents a rich source of information for further analysis. Beyond repeating this analysis in the future for further year over year comparisons, the following are a few specific pieces of analysis that could be beneficial.

1. Extending the desire lines spatial analysis to predicting the actual routes taken for each trip. As each trip includes the distance traveled and total duration, further resolution can be predicted from the path through various methods including a particle filter.
2. Understanding if an alternative mode of transport is being replaced by the trip and if so, which kind. For example, understanding if the trip is replacing or extending transit rides, replacing or extending vehicle trips, etc.
3. Expanding the simplistic station siting model for future electrification to include other important variables and optimizing the choices based on their weights. For instance,

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including changes in battery levels for the e-bikes, weighing factors based on classic bikes against those on the current use of e-bikes given that e-bike usage will expand, etc.

4. Fusing the trip data with other sources, such as demographic information or ridership counts from other modes, to create a fuller picture of the mobility landscape in Vancouver.

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Appendix A- Time of Day Station Siting

By time of day, the average number of bikes staying longer than 30 minutes each day (top 5).

Morning		Day		Evening		Night	
Station	Avg # bikes staying longer than 30 min	Station	Avg # bikes staying longer than 30 min	Station	Avg # bikes staying longer than 30 min	Station	Avg # bikes staying longer than 30 min
0024 Hornby & Pender	3.50	0028 Davie & Beach	2.97	0028 Davie & Beach	3.58	0196 Hornby & Drake	1.99
0001 10th & Cambie	3.22	0103 Stanley Park- Third Beach Parking Lot	2.65	0217 Smithe & Burrard	3.22	0400 Jericho Beach	1.95
0012 Dunsmuir & Richards	2.82	0066 Anderson & 2nd	2.64	0103 Stanley Park- Third Beach Parking Lot	2.91	0028 Davie & Beach	1.91
0189 Granville Island	2.62	0189 Granville Island	2.48	0154 Kitsilano Beach Park	2.83	0082 Richards & Davie	1.80
0112 10th & Oak	2.57	0200 Cardero & Bayshore	2.46	0031 Morton & Denman	2.73	0187 Bute & Davie	1.80

Appendix B - Time of Day Station Siting for Community Pass Members

By time of day, the average number of bikes staying longer than 30 minutes each day (top 5).

Morning		Day		Evening		Night	
Station	Avg # bikes staying longer than 30 min	Station	Avg # bikes staying longer than 30 min	Station	Avg # bikes staying longer than 30 min	Station	Avg # bikes staying longer than 30 min
Smithe & Burrard	1.53	Alder & 11th	1.40	Woodland & 4th	1.40	Nelson & Mainland	1.5
Alexander & Railway	1.38	Lakewood & Oxford	1.33	Burrard Station (Melville & Dunsmuir)	1.33	Ontario & Seawall	1.333333
Balsam & Cornwall	1.25	1st & Manitoba	1.29	Nelson & Mainland	1.27	East Blvd & 37th	1.25
Cypress & 10th	1.25	Wallace & 4th	1.25	Bute & Davie	1.27	Alder & 11th	1.2
Richards & Cordova	1.24	Arbutus & 10th	1.25	Beatty & Nelson	1.25	Helmcken & Burrard	1.186047