ONE-WAY CARSHARING AS A FIRST AND LAST MILE SOLUTION FOR TRANSIT

Lessons from BCAA Evo Carshare in Vancouver

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INTRODUCTION

Study Context

Vancouver, situated in the province of British Columbia, Canada, is among the leading carsharing cities in North America with two carshare operators servicing the Metro Vancouver region, and a fleet of over 2,100 vehicles (TransLink 2012) (BCAA 2019) (Modo 2020). Vancouver also consistently ranks as one of the most livable cities, and its efficient and integrated transportation network is often cited as a key contributor (APTA 2019). Metro Vancouver's long-term vision is to meet the region's transportation needs to simultaneously improve the health of the region's people, communities, economy and the environment through investments, better management and partnerships (Mayors' Council on Regional Transportation 2015). One of the biggest challenges in attracting transit ridership in the region has been the first and last mile problem (Box 1). The fixed stops at which most public transit halts to pick and drop passengers are rarely, if ever, the same as the ultimate origin and destination of an individual passenger's journeys. When the distance from a passenger's point of origin or destination to the public transit stop is long, they are less likely to utilize public transit: research indicates that public transit usage declines by up to 90% when passengers need to walk more than half a mile to access the nearest transit stop (Transportation Research Board 2015) (Canales et al. n.d.). While transit can provide an efficient, cost-effective and quick journey for heavily traversed routes, the low density first and last mile trip poses challenges (Figure 1). To encourage the use of public transport, cities have long sought ways to shorten the distance between riders and public transport stops, experimenting with bike-sharing systems and longer bus routes, among other approaches. Contemporary private and shared mobility options can complement transit service by bringing people to transit in a more efficient, convenient and timely manner. This study seeks to investigate the role of one such shared mobility alternative - one-way carsharing - in serving the first and last mile connections from transit hubs to homes and workplaces. The key research question for the study is: how does one-way carsharing support first and last mile connections to transit? This question is explored through an analysis of data on one-way carsharing trips within the study's geographical region.

Carsharing and Transit

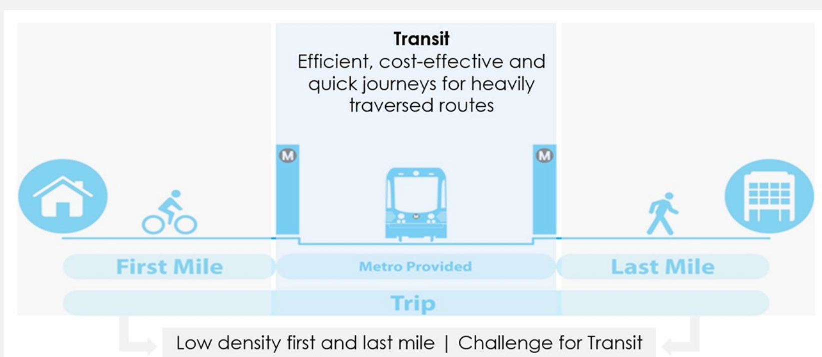
Integration and partnership of carsharing and transit modes has received close attention from transit agencies and researchers in recent years. Carsharing, within the larger gamut of shared mobility, directly impacts and is impacted by most facets of urban and transportation planning (Cohen and Shaheen 2016). For instance, it directly impacts modal choice, travel patterns, vehicle occupancy, vehicle kilometers travelled (VKT), and zoning requirements regarding parking directly (Cohen and Shaheen 2016). Indirectly, carsharing can influence environmental policies and climate action through it's potential to reduce greenhouse gas (GHG) emissions, economic development by way of increased employment opportunities (Cohen and Shaheen 2016).

BOX 1: 'FIRST AND LAST MILE PROBLEM' IN TRANSIT

First and last mile problem in transit describes the 'challenge of moving people between transit stations, mobility hubs, or fixed-route transit services and their home, workplace or other major destination' (Metrolinx 2018). The high density travelled part of the route is often provided efficiently by public transit. However, the low density first and last mile trips pose a challenge to public transit in sustaining ridership. First and last mile connection defines the beginning or end of an individual trip made primarily by public transit (TransitWiki 2019). In most cases, people will walk to transit if it is close enough. However, on either end of a public transit trip, the origin or destination may be difficult or impossible to access by a short walk. This gap from public transit to destination is termed a last mile connection. Broadly, the concept is applicable to making public transit more accessible for all people seeking to reach transit, regardless of whether they live within a mile of a transit station.

Solving the first and last mile connectivity problem requires a *different and additional* mode of transportation from public transit used for majority of the journey. This is critical since the need for this additional journey, and the inconvenience it represents, often discourages use of transit and induces an increase in personal automobile usage. There could be a range of viable solutions to resolve the first and last mile challenge through multimodal trips facilitated by conventional or new and shared mobility solutions such as walking, conventional and micro transit, carpooling, cycling, bike rentals, bikesharing, on-demand shuttle services, ride hailing, ridesourcing, carsharing (one-way or two-way/roundtrip); or through the larger conceptual ideas such as transit oriented development and mobility as a service.

Figure 1: Illustration depicting the first or last mile challenge for transit



Source: Adapted from illustration in King 2016

Context to the 'first and last mile problem': The first and last mile problem is drawn originally from telecommunications and supply chain management (goods movement). For telecommunications, first and last mile is the final leg (or first leg) to the consumer, since with physical infrastructure, it is expensive to match high capacity hubs to individual units. The concept was then used by logistics companies such as FedEx, UPS to describe their end point deliveries from centralized warehouses. These deliveries or trips were complex chains to optimize and the goal was to lower the overall cost of shipping the parcels between two points (King 2016).

Carsharing | Definitions and Benefits

Carsharing is a form of shared mobility that offers access to a fleet of shared vehicles that are available on-demand to registered members at different locations within a city (TransLink 2012) (Metrolinx 2018). Carsharing operators allow for flexible rental periods and payment structures such as, single-use or as part of a subscription. Members may be charged based on usage per kilometer or per hour, in addition to a nominal monthly administrative fee to cover part of the fixed costs.

Carsharing members can receive the benefits of using a private vehicle without the costs and responsibilities of ownership (fuel, maintenance, insurance), making it easier to go car-lite or car-free and having access to a fleet of shared vehicles on an as-needed basis (TransLink 2012) (Shaheen et al. 2020) (Shaheen and Chan 2016). Temporary vehicle access on an as-needed basis changes the cost structure of private vehicle usage for carsharing members by flipping the fixed costs of private vehicle use to variable costs that the members pay upon usage (Martin and Shaheen 2011). Carsharing also provides flexibility to members as they can access different types of vehicles depending on need (TransLink 2012).

Despite many successful one-way carsharing operations that were well received, many carsharing services shut down (See Annexure I for a discussion on cases of jurisdictions where one-way carsharing played a role in providing the first and last mile connectivity to transit). Primary causes of closing operation were economic unviability, underutilized services, deficient technology for successful operation. Nonetheless, initial one-way carsharing ventures laid the foundation for existing carsharing services today. However, with the ubiquity of mobile internet connectivity and GPS access through smartphones and the explosion of mobile applications, the technological advances in the last decade have unlocked the potential of one-way carsharing.

Carsharing could potentially enable both, a rise or decline in private vehicle usage in cities. Households without car ownership gain access to private vehicles and thus drive more. Correspondingly, carsharing may decrease car usage by car-owning households by way of easy access to shared vehicles and a possible shift to transit or non-motorized modes of transport (Martin and Shaheen 2011). Some research studies evaluating the net effect of carsharing on VKT and vehicle ownership have indicated that carsharing reduces personal vehicle ownership, thus freeing up road space for other uses and leading to net VKT declines: that in turn helps in lowering new GHG emissions (TransLink Strategic Planning and Policy 2012) (Martin and Shaheen 2011) (Shaheen et al. 2020). Within Metro Vancouver, carsharing vehicles are impacting private vehicle ownership and thus VKT and GHG emissions. Evidence on whether carsharing causes a net increase or decrease in VKT however is inconclusive (Metro Vancouver 2014). Prior research based on surveys indicates that more than one in five carshare members give up a car, more than three in ten avoid buying a car altogether; whereas one carshare vehicle replaces up to 20 privately owned vehicles (TransLink Strategic Planning and Policy 2012).

Transit agencies and governments have been supportive of new mobility alternatives such as carsharing considering the benefits of carsharing that mitigate private vehicle ownership and VKT. In contrast to private vehicle ownership, that causes higher traffic congestion, GHG emissions, air pollution, urban sprawl and modal shifts away from transit; carsharing has been considered a more sustainable alternative. Additionally, carsharing may provide some social benefit in form of access to private vehicle trips to lower income households on account of lower cost barriers to access carshare vehicles than owning a private vehicle. However, carsharing may act as a catalyst to car ownership for carless households, or may induce a form of suburban growth as more people migrate away from city centres to suburban areas with an easier access to carsharing vehicle rides. Within a city centre, the propensity of one-way carsharing vehicles to cluster around popular destinations and hubs may result in occupation of parking space on the roads for extended time periods blocking road space (Lempert 2019). Further research on carsharing to inform partnerships with transit must evaluate the pros and cons of carsharing with regards to transit, sustainability and equity goals.

Different carsharing models that exist are- two-way carsharing, one-way carsharing and personal vehicle sharing. Two-way carshare services, also known as roundtrip carshare, require members to pick up and drop off the vehicle to the same location (Metrolinx 2018). One-way carshare services, also known as free-floating or point-to-point carshare, allow customers to borrow and return vehicles at different locations within a designated service area. Personal vehicle sharing is another carsharing service model that is characterized by short-term access to privately owned vehicles, as against operator-owned vehicle fleet. Though each carsharing operation model can potentially provide first and last mile linkages to transit, one-way carsharing grants the highest level of flexibility to provide connectivity to transit (Shaheen and Chan 2016). This research study is restricted to one-way carsharing services.

One-way Carsharing | Trends

One-way carsharing has rapidly expanded since 2012, growing from services in 7 countries to 26 countries by 2016 (Shaheen and Cohen 2012) (Shaheen, Cohen, and Jaffee 2018). Worldwide, there were approximately 4.7 million one-way carsharing members in the year 2016: 2.9 million in Europe and 0.8 million in North America (Shaheen et al. 2018). One-way carsharing continues to expand, largely due to the current advanced technological backdrop comprising widespread mobile internet and GPS access at easy disposal through smartphones, mobile applications, vehicle access technologies and smartcards, and adoption of public policies that have facilitated private firms to reserve on-street parking (Shaheen, Chan, and Micheaux 2015). Experts in the field anticipate growth in one-way carsharing to continue (Shaheen et al. 2015).

Additionally, one-way carsharing has been thriving in cities worldwide not only as a new shared mobility mode augmenting urban mobility, but also as a probable solution to deal with the first and last mile challenge for transit (Shaheen and Chan 2016). Carsharing has the potential to expand the transit catchment area with the potential to perform a critical function of plugging gaps in current transportation networks through promoting reliance on multimodality with transit usage rather than driving in privately owned vehicles (Shaheen and Chan 2016). Convenient access to carsharing vehicles near an individual's home may mitigate the need for owning a vehicle, and carsharing vehicles accessible near an individual's workplace or school may allow them to commute by transit or other means, in the knowledge that a carshare vehicle will be accessible if required for business or personal trips in the day (TransLink Strategic Planning and Policy 2012). Bikesharing, ridesourcing or other new mobility alternatives also present a similar potential to serve the first and last mile for commuters; however, this study focusses on examining the role of one-way carsharing within the larger gamut of new mobility alternatives. Survey based research in the region suggests that carsharing could likely be a 'latent competitor' to transit and other transportation modes (Metro Vancouver 2014). Some of the studies that explore the complex role of carsharing with respect to complementarity with transit are discussed in the next section. Nonetheless, city and transit authorities worldwide have been building partnerships with several new mobility service providers in order to resolve transit's first and last mile challenge.

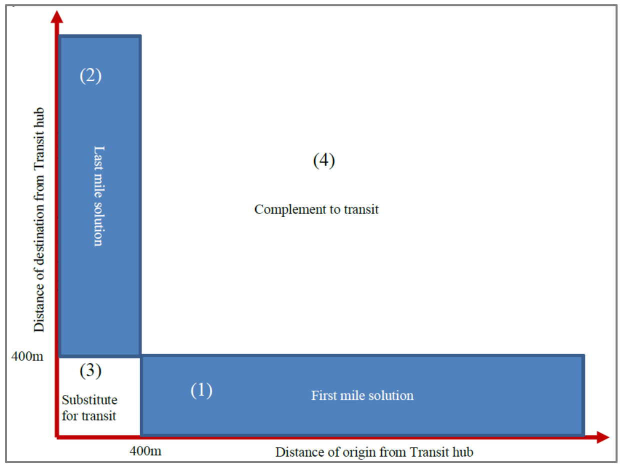
Literature Review | One-way Carsharing and First and Last Mile to Transit

Research on one-way carsharing in context of transit's first and last mile connectivity is in it's nascency, since the widespread proliferation of such services is a relatively recent phenomenon. Primary usage of carsharing has historically not been for commuting, but as a supplement to other modes of transport (Lempert 2019). Consequently, there has been a correspondence between the level of transit in a region and the level of carsharing services proliferation: carsharing is normally more successful in regions with robust public transportation networks (Shared-Use Mobility Center 2016). Carsharing was commonly used for moderate length trips that demanded higher levels of flexibility not conveniently provided by transit such as making multiple stops or trips to transport heavy goods (Lempert 2019). Recent research studies however, suggest that one-way carsharing may be increasingly used during commuting times, attributable either as a substitute for transit or a first and last mile complement to transit (Alencar et al. 2019) (Sprei et al. 2019) (Wang, MacKenzie, and Cui 2017) (Lempert 2019). Unlike the previous set of research studies embedded in a survey-based methodology to examine the role of carsharing, these studies have rooted their results in data analysis from the trips made by carsharing members in different North American and European cities. Analysis of carsharing trips data in all these studies illustrates certain characteristics in service utilization patterns: the highest volume of weekday one-way carsharing trips are clustered around the morning and evening peak commuting hours. Two comparative studies of one-way and two-way carsharing trips concluded that two-way carsharing trips do not exhibit those commute peaks (Lempert 2019) (Alencar et al. 2019). One-way carsharing trips offered travel-time savings versus similar trips on transit, albeit at a higher cost (carsharing trips were about $5 costlier on an average than a similar trip on transit, resulting in a travel-time reduction of 31 minutes). Despite the cost-effectiveness of travel time reduction, one-way carshare service was not being used disproportionately for trips that resulted in higher than average travel-time savings: suggesting that one-way carsharing may have been used more as a substitute to transit than a complement (Wang et al. 2017).

Research thus far establishes an evident association between one-way carsharing usage and work commute but does not answer whether these trips are used as a first and last mile complement to transit or a replacement for transit. One such attempt was inconclusive in determining the proportion of carshare trips that were first and last mile complements to transit (Lempert 2019). Nonetheless, the study provided an analytical structure as a guidepost for further research through a preliminary geo-spatial analysis of trips to be categorized as first and last mile. Analytical framework in their study is based on the hypothesis that trips that start within the 400 meters circular zone of a transit hub and end outside of 400 meters of a transit hub are last mile solutions; and trips that start outside of 400 meters and end inside 400 meters of a transit hub are first mile solutions (Figure 2). In addition to the schema presented in Figure 2, this study derives loosely from the circular buffer approach for planning the catchment areas for public transit (Andersen and Landex 2008) through creation of a circular buffer around a transit hub location to examine and optimise transit stops locations.

Building on the growing body of research, this research study investigates the role of one-way carsharing in serving the first and last mile to transit. This research study examines the case of BCAA Evo – a one-way carsharing platform based in Vancouver – to investigate the role it plays in solving the first and last mile problem for the Metro Vancouver region's transit service – TransLink. The research question is explored through analysis of data on one-way carsharing trips made within a

Figure 2: Schema for categorising carsharing trips as first or last mile connections to transit



Source: (Lempert 2019)

400 m circular zone of certain transit hubs within the study region. Project scope and the analytical framework deployed in the study are described in the following sections.

PROJECT SCOPE

Scope Definition

This section begins with a broad scope delineation for the study: in terms of the geographic scope and focus of the study on Evo and TransLink.

Geographical Scope of the Study

Geographical scope for this study is Metro Vancouver region of British Columbia, Canada (Figure 3). Jurisdictionally, Metro Vancouver is a federation of 21 municipalities, one Electoral Area and

Figure 3: Map of Metro Vancouver Region

Source: Google Maps, 2020

one Treaty First Nation. Within the region, this research study is limited to analyzing ten rapid transit hubs located within the City of Vancouver, New Westminster and North Vancouver (areas where the one-way carsharing operator Evo provides services).

Transit in the Metro Vancouver Region | TransLink

Metro Vancouver's transportation network is provided by TransLink through the bus system, SkyTrain rapid transit, SeaBus passenger ferries, West Coast Express commuter rail, and HandyDART for passengers who are unable to use conventional transit (Box 2). Through these services, TransLink serves over 1,800 square kilometers of service area in Metro Vancouver for a population of 2.5 million people (TransLink 2018b)

Box 2: Public Transportation Network in Metro Vancouver | TransLink

- *A bus system* | with 245+ routes and 1630+ fleet size
- *SkyTrain rapid transit* | 79 kilometers of rapid transit and 53 stations on three lines – Expo, Millennium and Canada Lines
- *SeaBus passenger ferries* | three passenger-only ferries linking downtown Vancouver and North Vancouver
- *West Coast Express commuter rail* | eight stations along 69 kilometers between downtown Vancouver and Mission
- *HandyDART* | a door-to-door shared ride service for passengers unable to access conventional public transit

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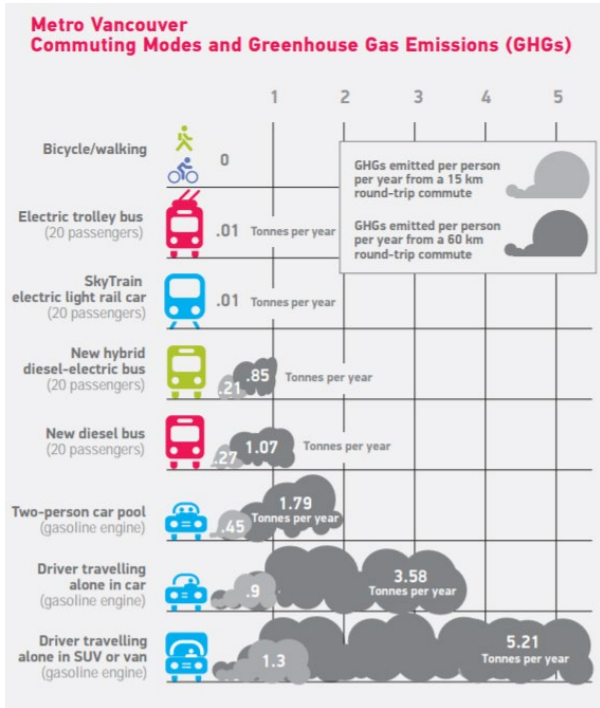
In Metro Vancouver region, transportation contributes more than a third of all GHG emissions (TransLink 2008). Figure 4 depicts the transportation modes and the corresponding GHG emissions in Metro Vancouver. It illustrates that the choice of transportation mode and the distance travelled has a large impact on the annual GHG emissions, with rapid transit (SkyTrain) being the least polluting, after walking and bicycling. The region is committed to increasing transit ridership, reducing automobile usage and VKT, adopting energy efficient vehicle technologies and low carbon transportation fuel choices. In 2018, TransLink adopted two environmental sustainability targets of an 80% GHG emissions reduction and 100 % renewable energy in all operations by 2050 (Lowell, Seamonds, and Hellgren 2020).

Metro Vancouver (Metro Vancouver n.d.) and TransLink (TransLink 2013) (TransLink 2012) have adopted polices to encourage expansion of car sharing programs, where feasible, to reduce vehicle ownership in the region to meet the sustainability targets. Figure 5 presents a snapshot of the policy directions within the long-term vision for TransLink with respect to carsharing. Carsharing aligns with two of the City of Vancouver's six Big Moves of the Climate Emergency Response: Big Move #2 that has set a target of two-thirds of trips in Vancouver by active transportation and transit by 2030 and Big Move #3 targeting 50% of kilometres driven on Vancouver's roads to be by zero emission vehicles (City of Vancouver 2018).

Figure 4: Modes of transit and GHG emissions in Metro Vancouver



Source: (TransLink 2008)

Figure 5: Policy directions for TransLink with respect to Carsharing, as depicted in Transportation 2040 document

TALKVANCOUVER.com
Transportation 2040

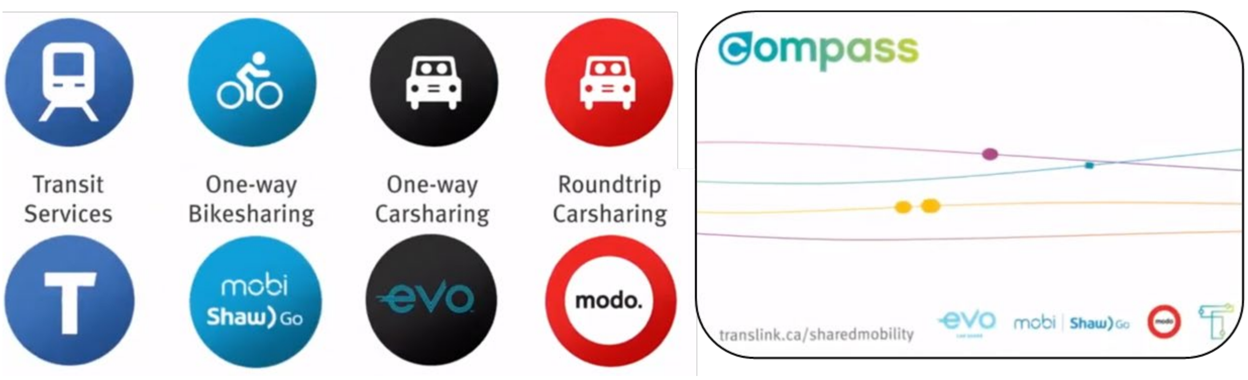
Number	Policy or Action
M	MOTOR VEHICLES
M 2	PARKING
M 2.9	Support cycling, low-carbon vehicles, and car-sharing
M 3	CAR-SHARING
M 3.1	Support increased car-sharing
M 3.1.1	Expand requirements and incentives for car-sharing in new developments.
M 3.1.2	Continue to make priority on-street locations available for car-sharing.
M 3.1.3	Adopt parking design guidelines for larger developments that enable non-residents to access on-site car-sharing vehicles.
M 3.1.4	Support legislative and technological advances that facilitate peer-to-peer car-sharing.
M 5	LOW-CARBON VEHICLES
M 5.2	Support early deployment of low-carbon and electric vehicles
M 5.2.1	Support the adoption of low-carbon and electric vehicle technology for car-sharing vehicles.
T	TRANSIT
T 6.2	Support effective fares that encourage transit use
T 6.2.4	Support integrating the Compass Card system with other forms of transportation, including bike- and carsharing, parking payment, private ferry services, and taxis.

Timing: Implementation Strategy; Short (2012-14); Medium (2015-17); Long (2018+); Ongoing

Source: Adapted from (TransLink 2012)

Consequent to the larger goals discussed thus far, TransLink has been collaborating with several private sector players in shared mobility space in the region. Within Metro Vancouver's home zone of the carshare operators, their vehicles can be parked free of charge in any available permit only on-street parking spot in residential neighborhoods. TransLink has partnered with the carsharing service operators previously through dedicated parking spots at select SkyTrain stations for carshare members in the region: Seven Metro Vancouver transit stations in five cities now have a combined ten Modo carshare parking spots, and two transit stations in New Westminster have four parking stalls each for Evo carshare vehicles. TransLink has also partnered with three shared mobility providers in the region to conduct a shared mobility and transit pilot project. The project aims to assess and explore how these collaborations can provide the passengers a higher convenience of bundled mobility services. In this pilot, TransLink has collaborated with: the one-way carsharing operator – Evo, two-way carsharing operator – Modo, and the bikesharing services operator Mobi by Shaw Go (TransLink 2019). This pilot project would be conducted between October 2019 and August 2020. Under the pilot, approximately 200 employees of 14 Vancouver-based organizations can access transit, carshare, and bikeshare services for work-related travel using a special Compass Card (Compass Card is TransLink's reloadable fare card that works on all transit in Metro Vancouver). The co-branded compass card (Figure 6) would allow the pilot users to unlock travel, pay for and view an integrated expense report with the four transportation providers in the region. The pilot would test the user experience and technical integration of tying multimodal journeys together with a Shared Mobility compass card.

Figure 6: Depictions from Shared Mobility Compass Cards Pilot Project between TransLink, Mobi, Evo and Modo



Source: (TransLink 2019)

Note: Collaborators on Shared Mobility Pilot (on the left) and Shared Mobility Compass Card (on the right)

Carsharing in the Region | Evo Carshare

Within the region, city of Vancouver is the most populous and dense municipality, with a population of 631,486 [Statistics Canada, 2019]. Vancouver has more carsharing vehicles per capita than any other city in North America, with 47.5 vehicles per 10,000 people (Lempert, Zhao, and Dowlatabadi 2019). The percentage of Vancouver residents over 18 with at least one carshare membership has grown steadily, from 13% in 2013 to 29% in 2016, the last year data was available (Lempert et al. 2019).

Metro Vancouver is currently served by two carshare operators: Modo provides two-way carsharing services; and Evo provides one-way carsharing services to their members in the region. Until recently, there were two more operators in the carsharing market in the region: Zipcar that offered two-way carsharing and Car2Go that offered one-way carshare services; and both have exited the market recently.

This research study is limited to the analysis of carsharing service provided by Evo, a service provided by British Columbia Automobile Association (BCAA). Evo was launched by BCAA in 2015 with a fleet of 250 hybrid vehicles. Evo is now the region's largest car share provider at about 1,500 vehicles, with 130,000+ members, who have made a collective 8.7 million+ trips (BCAA 2019).

Scope of this study is restricted to the analysis to the Metro Vancouver region's overlap with the Evo 'home zones' (the service area where members can start and end their trips) since the basis of analysis is the ridership data from Evo . It consists of the City of Vancouver, and parts of North Vancouver and New Westminster; and certain satellite parking zones as illustrated in Figure 7. Evo has satellite parking locations outside the City of Vancouver: these are designated parking areas where members can start and end their Evo trips. Evo's Home Zone also includes these satellite parking zones, currently situated at YVR Airport, Grouse Mountain and University campuses such as UBC, SFU, BCIT, and Capilano University. Evo members can park without a charge in: 'Evo only' parking spots on the street, or within designated parking lots, or in residential and permit only areas within the Evo home zone, non time restricted meter spots in the City of Vancouver; and with restrictions on time and cost in the remaining cases.

Figure 7: Map of Evo's Zone of Operation: Figure depicts the home zone areas in blue and the satellite parking locations depicted with blue circles marked with 'P'

Source: Retrieved from Evo's website, Jan 2020

Data

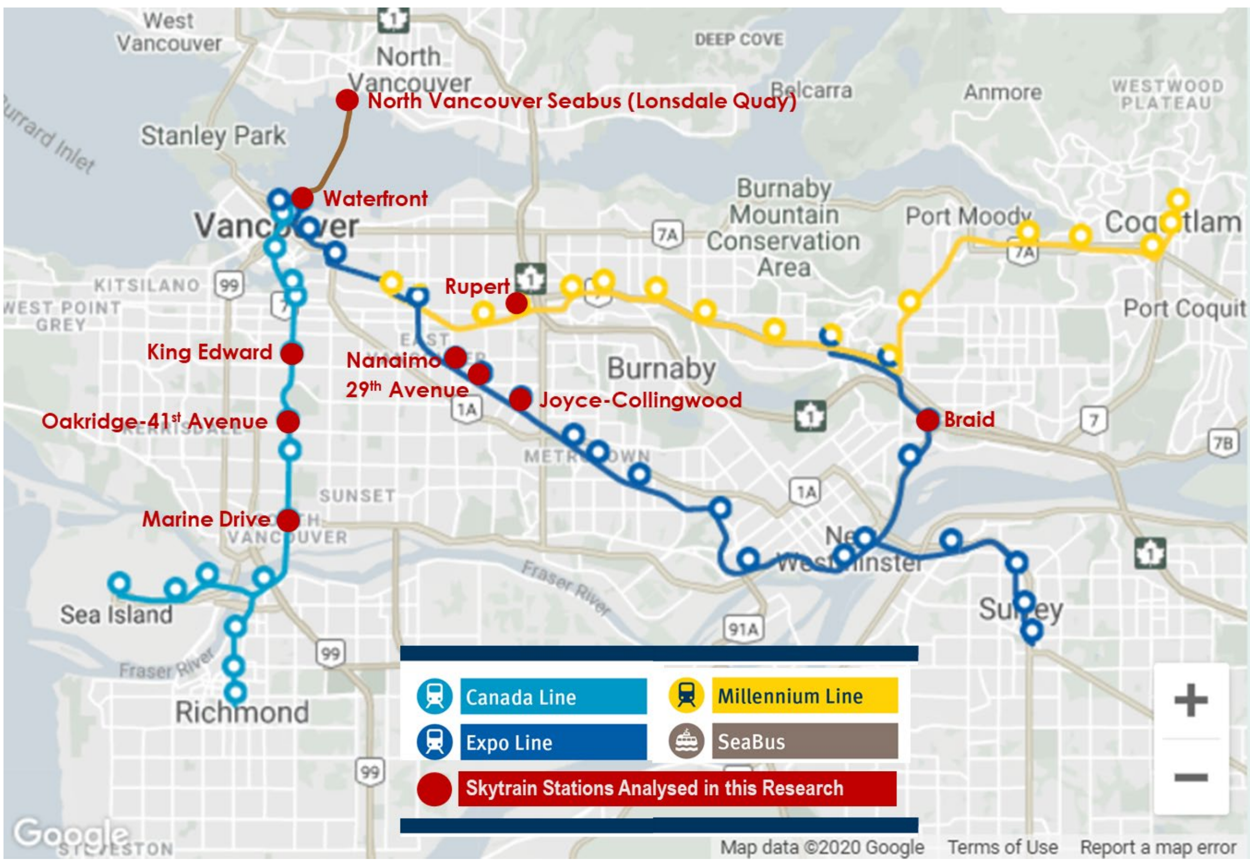
Trips Data | BCAA Evo Trips. BCAA Evo provided ridership data for analysis pertaining to trips undertaken by Evo members that originate or terminate within 400 m radius circular zones circumscribing ten rapid-transit system stations in the region (this circular periphery is also referred to as the zone of influence in the study). Data contains the trips' geographical and spatial parameters, and aggregate level non-identifiable data on members' demographic data on gender and age group. Data pertains to trips that were undertaken in the year 2019 – from January

1, 2019 to December 31, 2019. It is important to note that all analyses in this study are performed basis a subset of Evo trips in the year 2019. This subset is restricted basis the following criterion: data contains trips that originate and terminate within the 400 m radius circular zone surrounding the ten SkyTrain stations, and not the entire set of Evo's members' trips across their Metro Vancouver home zones in the year.

Transit Data Overlay | Skytrain Stations. Data on Evo trips is restricted to trips surrounding ten SkyTrain stations in the region (Figure 8):

1. Braid
2. Joyce-Collingwood
3. King Edward
4. Marine Drive
5. Nanaimo
6. Oakridge-41st Avenue
7. Rupert
8. Waterfront
9. 29th Avenue
10. North Vancouver SeaBus station (Lonsdale Quay SeaBus)

Figure 8: Map of SkyTrain stations incorporated in the study analysis



Source: Constructed upon the base map from TransLink [https://www.translink.ca/Schedules-and-Maps/SkyTrain/SkyTrain-Schedules.aspx]

Note: Map represents the three Skytrain lines in the region, with a constructed overlay of the ten stations that are considered for analysis in this research study (depicted in red)

These stations cut across the three SkyTrain Lines that TransLink operates in the region and were chosen to represent a combination of high and medium commercial activity areas:

- Braid, Joyce-Collingwood, Nanaimo, and 29th Avenue are stations on the SkyTrain Expo Line, a line that connects Vancouver with the cities of Burnaby, New Westminster and Surrey.
- Marine Drive, Oakridge-41st, and King Edward are stations on the SkyTrain Canada Line, a line that connects downtown Vancouver to the Vancouver International Airport (YVR) and the City of Richmond.
- North Vancouver SeaBus station (Lonsdale Quay SeaBus station) from the SeaBus service that is a passenger-only ferry that crosses the Burrard Inlet, connecting Downtown Vancouver with the North Shore of Vancouver.
- Waterfront station is the northern terminus station of Canada Line as well as of the West Coast Express, Expo Line and SeaBus.
- Rupert is on the Millennium Line that travels from Vancouver through Burnaby into Port Moody and Coquitlam.

Study Objective

The purpose of this study is to identify which one-way carsharing trips are serving the first and last mile to transit from the data on one-way carsharing trips undertaken in the region. It would seek to develop a methodology to discern which trips could be categorized as first and last mile trips.

RESEARCH METHODOLOGY

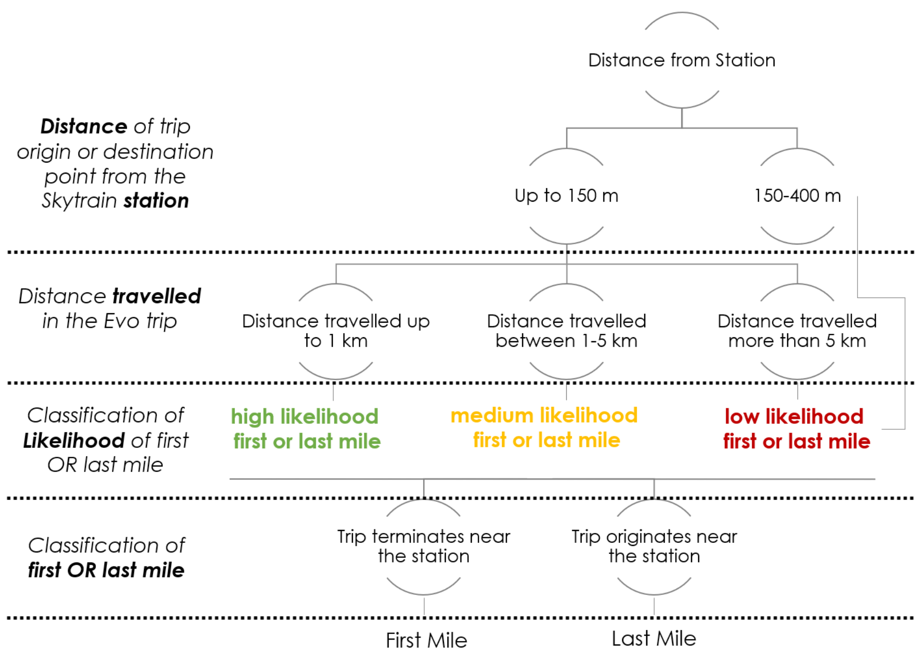
Analytical Framework

While the base dataset used for analysis has detailed information about the trip coordinates and time taken, it lacks any data or information on the members' perspective or intent of trip, thereby limiting the nature of questions that can answered through the analysis. For the data captured from Evo trips, there is no variable in the dataset to provide linkage of each carshare trip to transit use (through fare-cards or otherwise) to conclusively evaluate whether a certain trip initiated or culminated in a rapid-transit mode pre/ post the Evo carshare trip. *In the absence of such a linkage, a proxy measure of trip-takers' intent of trip could guide the investigation in future studies. Such a measure could be developed through a trip-diary type survey for the carshare users*. In cognizance of this, the study does not directly classify trips as 'first or last mile trips' or not; and follows a non-dichotomous classification of trips based on certain assumptions. Guidelines from the existing literature and a preliminary spatio-temporal analysis on trips data serves as a basis for formulating this set of assumptions that would help develop a framework for analysis.

A non-dichotomous ordinal scale is adopted in this study to represent the spectrum of likelihoods that a trip could be first or last mile (FMLM) rather than classifying the trips into dichotomous categories of 'first or last mile' or non-'first or last mile'. Trips from/ to each station were analysed individually to create an ordinal continuum of trips' likelihoods to be a 'first mile (FM)' or 'last mile

(LM)' based on the two criterion: the distance of the carshare trip's start or end geospatial coordinates from the station; and the distance travelled in the carshare vehicle.

Figure 9: Analytical Framework deployed for this research



Classification coding adopted for the trips is as follows (represented in the schematic in Figure 9):

Trips that originate within 150 meters of the rapid-transit station and have a trip travel distance of less than 1 kilometer are graded as 'High Likelihood last mile trips'. Trips that terminate within 150 meters of the rapid-transit station and have a trip travel distance of less than 1 kilometer are graded as 'High Likelihood first mile trips'. Trips that originate within 150 meters of the rapid-transit station and have a trip travel distance of between 1-5 km are graded as 'Medium Likelihood last mile trips'. Trips that terminate within 150 meters of the rapid-transit station and have a trip travel distance of between 1-5 km are graded as 'Medium Likelihood first mile trips'. Trips that originate between 150-400 meters of the rapid-transit station or have a trip travel distance of greater than 5 km are graded as 'Low Likelihood last mile trips'. Trips that terminate between 150-400 meters of the rapid-transit station or have a trip travel distance of greater than 5 km are graded as 'Low Likelihood first mile trips'.

Assumptions

Assumptions that underlie the analytical framework are outlined below:

Circular Zone Radius

While a typical pedestrian walking distance to transit is assumed to be 400 meters (TransLink Strategic Planning and Policy 2012), this study redefines that walking to transit to be more restrictive. This redefinition of the zone of influence is grounded in the distribution of trips across the 50 meter incremental catchment zones from the 10 rapid-transit stations (Annexure II); in conjunction with satellite images of the catchment area around each of the 10 transit stations

(Annexure III). Concentric circular zones of influence are created around the ten transit hubs with iteratively decreasing distance by 50 m to define the clusters of trips that could be first mile fillers or the last mile connectors. This was intended to include only the trips that originated/ terminated in the closest feasible (in terms of parking availability) vicinity of the rapid-transit stations. Underlying assumption for this hypothesis is that if parking is available, a carshare user would park the vehicle closest to the station if the intent is to egress/ access rapid-transit: attempted to be verified through satellite map images of the stations' vicinity. Given that each of the rapid-transit stations has a considerable number of commercial establishments within the vicinity, one would assume that a wider encircling of the catchment area may include trips with a lower likelihood of being a first and last mile complement to transit.

400 meter circular zone in the Evo trips data is also revised downwards since the actual walking distance from and to a transit hub would be longer than the Euclidean distance captured in the data because of structural or natural barriers. Additionally, there is an implicit assumption that the carshare member may be inclined to walk lesser than this conventional 400 meter distance given the additional time and effort spent in locating the car/ parking and entering/ leaving the carshare vehicle.

Overlaying precise data on parking availability within these circular zones could contribute to a more accurate demarcation in subsequent studies. Additionally, the zone of influence definition for each station could be modified basis the characteristics of the station and the zone of influence around it and the next closest transit hub station.

Distance travelled

While there are existing benchmarks for the conventional distance walked to access/ egress transit hubs (TransLink Strategic Planning and Policy 2012), there are no corresponding benchmarks in literature, to the best of our knowledge, for the typical distance travelled in motorised vehicles to access/ egress transit hubs. Basis the distribution of trips by the distance travelled per trip [Annexure IV], a cut-off of up to 1 km distance travelled in the carshare vehicle is applied to classify trips as high likelihood first or last mile; and between 1 and 5 km distance travelled to classify trips as medium likelihood first or last mile. If the trip's travel distance has been higher than 5 km, it is classified as low likelihood first or last mile. Given that Vancouver is a grid-style city with an average distance between SkyTrain stations of approximately 1 km (across all three SkyTrain lines) (Kalyta 2017), trips within the 1 km range could be trips from/ to the SkyTrain stations to/ from user's home or workplace, especially since they end within the 150 m circular zone: and thus, are most likely first or last mile trips.

A qualification for this categorisation is that even a trip with less than 1 km distance travelled could be a complete single mode trip and not necessarily a first or last mile complement to transit. Similarly, trips that are within the 1-5 km or more than 5 km distance travelled category too could still be trips that connect to transit for a variety of reasons such as travelling a long distance from a non-rapid-transit area, or convenience of travelling from a certain station, or a trip that demands multiple line changes. Thus, these categorisations would need to be analysed keeping the unresolved nature of the trip connection to transit in mind. Nonetheless, these categorisations would provide some direction, if not an accurate magnitude, on the possibility of certain carshare trips being attributed to first or last mile to transit.

Multi-modal trips

This study defines the first mile as the distance traveled before boarding transit and last mile as the distance travelled after alighting transit. There could be a diverse range of multi-modal trips using transit and carsharing; but given the complexity of assigning them as first or last mile in the absence of transit-linkage data, we make further assessments from the data to create the classification.

Limitations

Despite a tighter encircling of a station's zone of influence, the trips initiating or terminating within the 150 m circular zone could still be trips that did not link to transit where the origin or destination was only incidentally very close to the transit station. The proposed framework may have some inclusion and exclusion errors. For instance, someone taking a 'high likelihood first mile' trip might end her trip at the carshare destination without proceeding to access public transit; or a 'low likelihood first or last mile' trip may not necessarily be a substitute for transit if the user's journey by transit necessitates multiple line changes.

Skytrain stations are preferentially located in business-oriented or high commercial density neighborhoods. Many of the trips that are categorized as first mile/ last mile could as likely be trips to businesses located around the station. These errors, with varying degrees would continue to exist in the absence of data points to connect a carshare trip to eventual transit usage. Absence of this linking data could, in subsequent studies, be interpolated through data points from a survey on usage of carshare vehicles and transit complementarity as a weak substitute. Distinguishing between transit hubs and characterising hubs based on their neighbourhood demographics and adding additional layers of precise parking availability data could improve the classification of first and last mile trips from carshare trips.

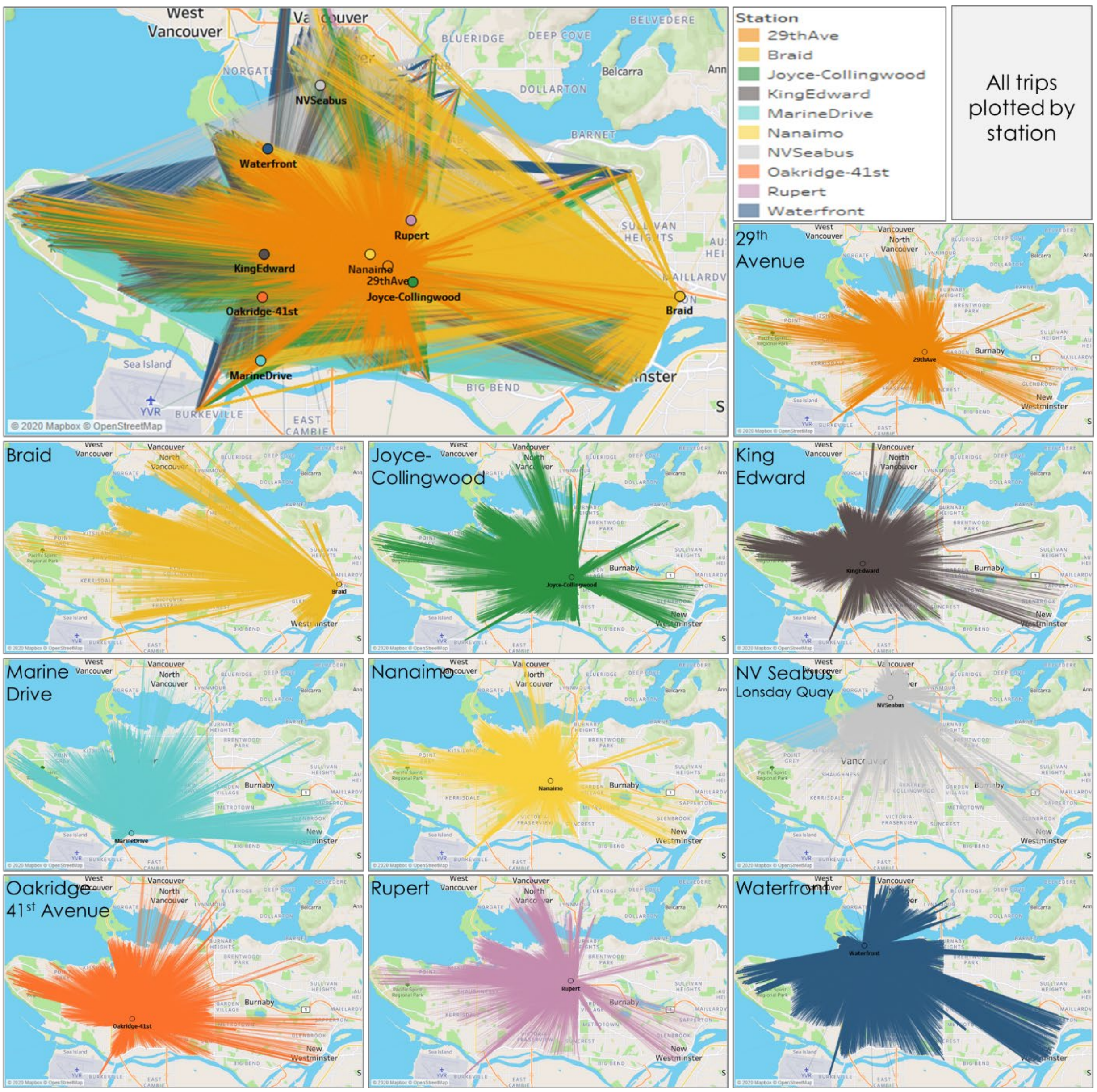
RESULTS

Geospatial Analysis

Figure 10 represents the geospatial depiction of the Evo trips that originated and terminated within 400 meters of the ten SkyTrain stations. These trips were classified as first or last mile trips as per the analytical framework described in the previous sections.

For all stations in aggregate, 4% of the trips analyzed were classified to be 'high likelihood first or last mile' (Table 1), 17% of the trips were classified as 'medium likelihood first or last mile'; and 79% were classified as 'low likelihood first or last mile'. 'High likelihood first or last mile' trips constituted 0.4% of the total vehicle kilometers travelled (VKT), 'medium likelihood first or last mile' trips accounted for 12% of the total VKT and the 'low likelihood first or last mile' trips represented 88% of the total VKT. VKT data depicts not just the volume of trips, but also the inherent nature of the classification categories: where the 'high likelihood' and 'medium likelihood' categories contain trips that are within 1 km or between 1-5 km of distance travelled. The average distance travelled in the carsharing vehicle in the 'high likelihood first or last mile' category is 0.42 km. Trips in the 'medium likelihood first or last mile' had an average distance travelled of 2.77 km. Average distance travelled in the 'low likelihood first or last mile' category was 4.4 km. It is lesser than 4, given that it also includes trips in the 150-400 meter periphery of the stations that were less than 5 km. Duration of the trip was not always representative of the distance travelled as per the data; as is illustrated in the average trip duration of an hour for trips that are within 1 km travel distance.

Figure 10: Spatial distribution of Evo trip-lines: pertaining to trips originating and terminating within 400 m radius circular zone of each of the ten SkyTrain analysed in the study



Tables 2 and 3 depict the distribution of classified trips for the ten stations separately for trips classified 'first mile' complements to transit (Table 2); and 'last mile' complement to transit (Table 3). Within the stations, trips surrounding Rupert, Oakridge-41st Avenue and NV SeaBus stations have the lowest proportion of trips classified as 'high likelihood' to be first and last mile: Rupert at 1% and the other two stations at 2% for both first and last mile categorization. This could be explained in part by the nature of lower parking availability around these stations. Braid station stands out from the rest of the stations studied with 16% and 20% (compared to the 4% for the aggregate of all trips) of the trips categorized as high likelihood 'first mile' and 'last mile' respectively. Nanaimo and 29th Avenue have the next highest proportion of trips categorised as high likelihood first or last mile at 8% and 7% of station trips respectively.

Table 1: Characteristics of trips classified by likelihood of first or last mile complement to transit

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Likelihood of FMLM	*% of Trips*	*% of VKT*	*Average Distance Travelled(Km)*	*Average Duration (minutes)*
High Likelihood FMLM	4%	0.4%	0.42	61
Medium Likelihood FMLM	17%	12%	2.77	19
Low Likelihood FMLM	79%	88%	4.40	32
All Trips in Aggregate	100%	100%	3.96	31

Table 2: Proportion of trips classified by likelihood of first mile complement to transit for SkyTrain Stations

Table 2: Proportion of trips classified by likelihood of first mile complement to transit for SkyTrain stations

Likelihood of FM (First Mile Trips)	*Braid*	*Joyce-Collingwood*	*King Edward*	*Marine Drive*	*Nanaimo*	*NV Seabus*	*Oakridge-41st*	*Rupert*	*Waterfront*	*29thAve*	***Total FM Likelihood***
High Likelihood FM	16%	5%	5%	3%	8%	2%	2%	1%	3%	7%	**4%**
Medium Likelihood FM	24%	11%	27%	3%	31%	7%	10%	2%	19%	23%	**17%**
Low Likelihood FM	60%	84%	68%	94%	61%	91%	89%	97%	78%	70%	**79%**

Table 3: Proportion of trips classified by likelihood of first mile complement to transit for SkyTrain Stations

Table 3: Proportion of trips classified by likelihood of last mile complement to transit for SkyTrain stations

Likelihood of LM (Last Mile Trips)	*Braid*	*Joyce-Collingwood*	*King Edward*	*Marine Drive*	*Nanaimo*	*NV Seabus*	*Oakridge-41st*	*Rupert*	*Waterfront*	***Total LM Likelihood***
High Likelihood LM	20%	5%	5%	3%	8%	2%	2%	1%	3%	**4%**
Medium Likelihood LM	38%	9%	27%	3%	29%	7%	9%	2%	18%	**16%**
Low Likelihood LM	43%	86%	68%	94%	63%	91%	89%	97%	79%	**80%**

For the category of 'medium likelihood first or last mile': Nanaimo, King Edward and Braid stations have a substantially higher proportion of trips at 31% (first mile) & 29% (last mile), 27% (both) and 24% (first mile) & 38% (last mile) trips respectively in this category than the overall aggregate of 17% (first mile) & 16% (last mile) for all stations (Figure 11). In the 'medium likelihood' category: Rupert, Marine Drive and NV SeaBus stations are substantially lower than the aggregate stations' proportion for the 'medium likelihood first or last mile' category at 2%, 3% and 7% respectively (both for first and last mile).

Within the 'low likelihood first or last mile' categorization: Rupert, Marine Drive and NV SeaBus stations have a substantially higher proportion of trips at 97%, 94% and 91% trips respectively in this category than the overall aggregate of 89% for all stations. In the 'low likelihood' category: Braid, Nanaimo and King Edward stations are substantially lower than the aggregate stations' proportion (79%) for the 'low likelihood first or last mile' category at 60% (first mile) & 43% (last mile), 61% (first mile) & 68% (both) respectively.

Figure 11: Proportion of trips in the three likelihood of first or last mile categories for each of the SkyTrain stations

In the next section, two of the stations with the highest and lowest proportion of high likelihood trips are presented in greater detail.

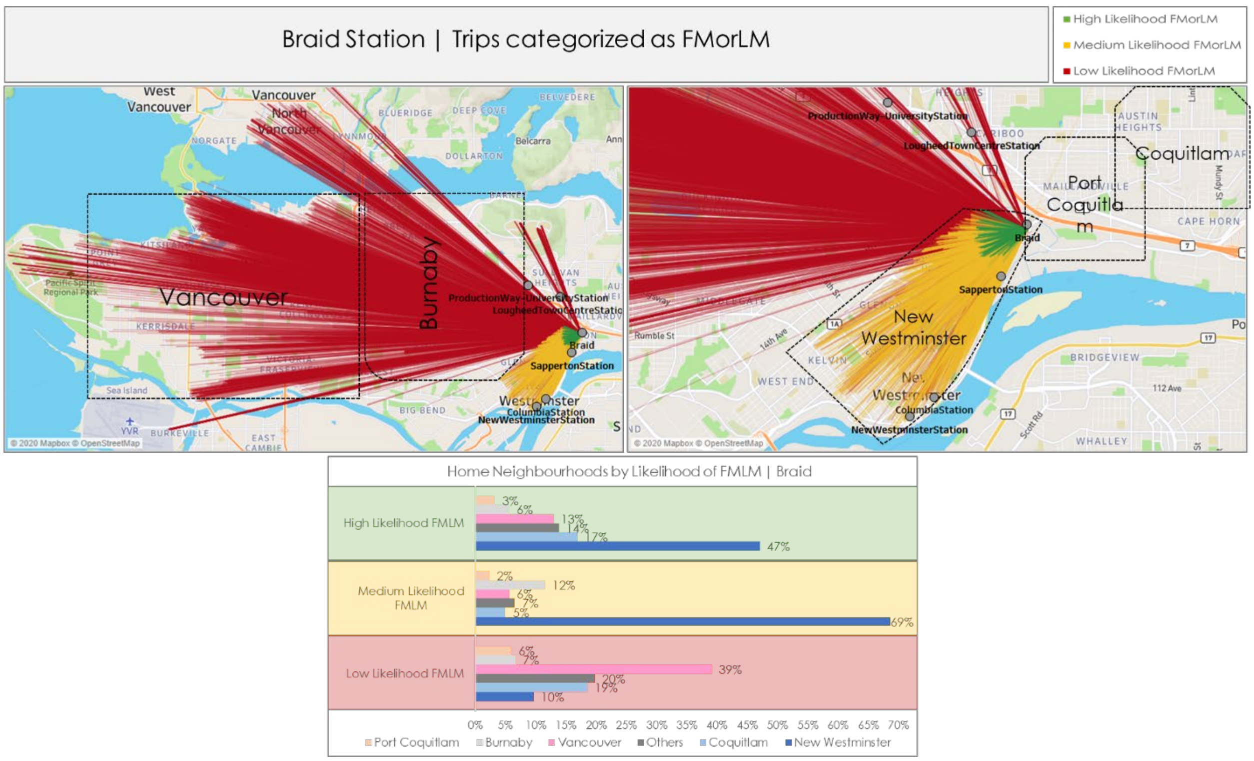
Geospatial & Temporal Analysis | By Station

Station Profile | Braid

Braid station is on the SkyTrain's Expo Line that connects Vancouver with the cities of Burnaby, New Westminster and Surrey. The station is located near the intersection of Braid Street and Brunette Avenue in the Brunette Creek neighbourhood of New Westminster, British Columbia. Braid station's buffer serves a population of 3000 with an employment figure of 1000 [buffer population and employment represent the number of people who live or work within the 800 m from the station, approximately 10 minute walk]. The average daily weekday boarding count for the station was

4,090 for the year 2018 (TransLink 2018a). Positioned near the Coquitlam border, the station is a major transfer point for bus routes serving the Tri-City area and provides connections to local bus services serving New Westminster and Coquitlam. Amazon Fulfillment Centre is located in the immediate vicinity of the station and Hume Park is nearby. There are four dedicated parking stalls for Evo carshare vehicles located in the parking lot across from the entrance at Braid station to facilitate transit use. Relatively higher volume of high likelihood of first or last mile trips around Braid could in part be attributed to the dedicated parking availability at transit, along with the characteristics of the station hub.

Figure 12: Braid Station | Geospatial mapping of trips by likelihood of first or last mile and home neighbourhood analysis

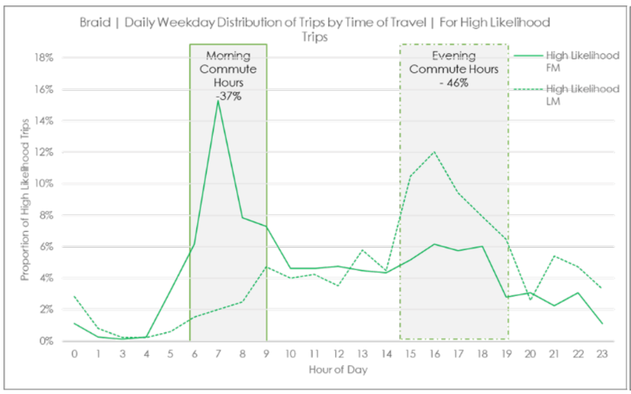


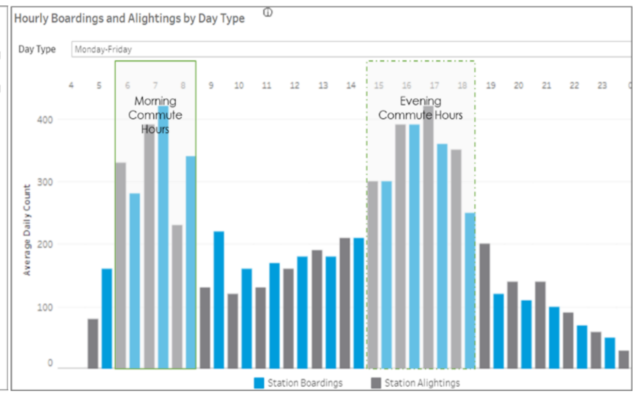
Of the trips analysed, trips around Braid station have the highest proportion of trips categorised in the 'high likelihood' and 'medium likelihood' to first or last mile (Figure 12). An in-depth analysis of users' neighbourhoods was conducted basis the home neighbourhood's first three digits of the postal code. Neighbourhoods were identified to depict the users' residence area in the region. Predominant neighbourhood of residence for users that undertook trips tagged as high likelihood and medium likelihood FMLM was New Westminster, the jurisdiction where Braid station is located (Figure 13). Whereas, for the trips tagged as 'low likelihood FMLM', the predominant neighbourhood of residence was Vancouver. Of all the trips categorised as 'high likelihood first or last mile' to Braid station: almost half (47%) were undertaken by users that lived in the New Westminster area. Similarly, more than two thirds (69%) of trips categorised as 'medium likelihood first or last mile' to Braid station were undertaken by users that lived in the New Westminster area.

High and medium likelihood trips from New Westminster, Burnaby and Coquitlam residents were potentially to egress or access transit. Two-fifth of the trips (low likelihood category at Braid) were largely from/ to different neighbourhoods in Vancouver, are attributed in the data as long trips. Given that these trips traverse the transit route, they are less likely to be first and last mile connections, and instead substitutes to transit.

Figure 13: [Left Panel] Daily hourly weekday distribution of high likelihood first and last mile Evo trips surrounding Braid Station

Figure 14: [Right Panel] Daily hourly average weekday distribution of boardings and alightings at Rupert Station for the year 2018





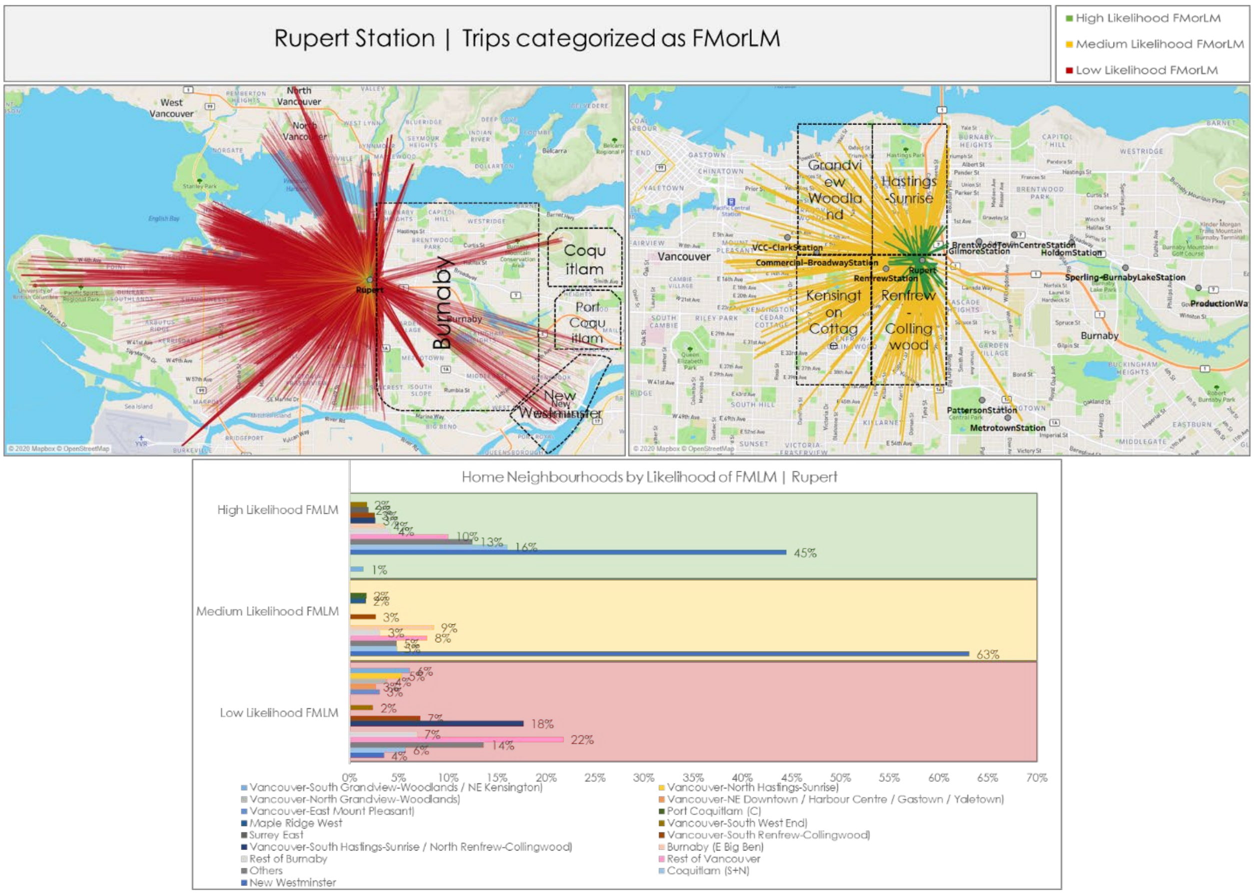
Source: Figure 13 created by author. Figure 14 sourced from TransLink dashboards

Figure 13 depicts the daily weekday distribution of high likelihood first and last mile Evo trips surrounding Braid station by hour of the day. Evo trips originating or terminating around Braid depict an evident morning and evening travel peaks (morning peak of 6-9 am and evening peak of 3-7 pm). These trips could be ascribed to work commute. Figure 14 shows the transit boarding and alighting numbers at Braid station by the hour of the day for weekdays. Transit displays the same commute hour peaks as the Evo trips for Braid station. Braid station's geo-spatial and temporal analysis confirms the previous research studies that found a correspondence between one-way carsharing and work commute. However, breakdown of trips by in a similar fashion for another station – Rupert – does not display the commute pattern convincingly.

Station Profile | Rupert

Rupert station is on SkyTrain's Millennium Line that travels from Vancouver through Burnaby into Port Moody and Coquitlam. It is located along Rupert Street between East Broadway and Grandview Highway in Vancouver. Businesses situated near the station include BC Liquor Distribution Branch, Vancouver Film Studios, Canadian Tire and Walmart superstores to name a few. Falaise Park is also located south of Rupert station. The station serves the four surrounding neighbourhoods: Hastings-Sunrise, Renfrew-Collingwood, Kensington Cottage, Grandview Woodlands. It is the last station on the Millennium Line (moving towards east) in the City of Vancouver jurisdiction. Rupert station's buffer serves a population of 6000 with an employment figure of 8000. The average daily weekday boarding count for the station 1,007,900 for the year 2018 (TransLink 2018a).

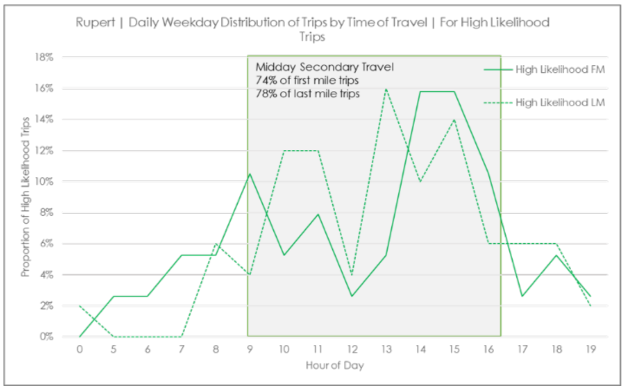
Figure 15: Rupert Station | Geospatial mapping of trips by likelihood of first or last mile and home neighbourhood analysis

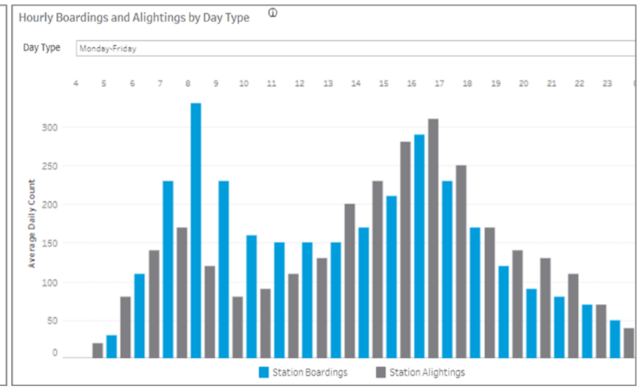


Out of the trips analysed, trips around Rupert station have the lowest proportion of trips categorised in the 'high likelihood' and 'medium likelihood' to first or last mile (Figure 15). An in-depth analysis of users' neighbourhoods was conducted basis the home neighbourhood's first three digits of the postal code. Neighbourhoods were identified to depict the users' residence area in the region. Predominant neighbourhood of residence for users that undertook trips tagged as high likelihood and medium likelihood FMLM was New Westminster (Figure 15). Whereas, for the trips tagged as 'low likelihood FMLM', the predominant neighbourhood of residence was Vancouver barring the immediate four neighbourhoods of Rupert. Of all the trips categorised as 'high likelihood first or last mile' to Rupert station: almost half (45%) were undertaken by users that lived in the New Westminster area. Similarly, almost two thirds (63%) of trips categorised as 'medium likelihood first or last mile' to Rupert station were undertaken by users that lived in the New Westminster area. High and medium likelihood trips from New Westminster residents were potentially to egress or access transit. 43% of the trips in the 'low likelihood FMLM' category at Rupert were from/ to the four immediate neighbourhoods of Rupert: Hastings-Sunrise, Renfrew-Collingwood, Kensington Cottage, Grandview Woodlands.

Figure 16: [Left Panel] Daily hourly weekday distribution of high likelihood first and last mile Evo trips surrounding Rupert Station

Figure 17: [Right Panel] Daily hourly average weekday distribution of boardings and alightings at Rupert Station for the year 2018





Source: Figure 16 created by author. Figure 17 sourced from TransLink dashboards

Figure 16 depicts the daily weekday distribution of high likelihood first and last mile Evo trips surrounding Rupert station by hour of the day. Unlike at Braid station, Evo trips originating or terminating around Rupert do not follow the morning and evening commute peaks. Trips show a spread out pattern of midday to early evening trips. Figure 17 shows the transit boarding and alighting numbers at Rupert station by the hour of the day for weekdays. Transit displays the commute peaks to a larger extent than the Evo trips for Rupert station.

Temporal Analysis

Travel patterns of all trips were analysed based on the day and time the trip was undertaken. On weekdays, within the 'high likelihood first mile' category, there were two peaks : 35% of all trips were made in the morning peak hours between 6-9am and 17% of the trips were between the evening peak hours 4-7pm; and remaining trips were spread through the rest of the day (Figure 18). Proportionally higher number of these trips correspond to the morning peak hours on weekdays signalling a possible usage of these vehicles for work commute. This outcome though is indicative but not proof that one-way trips correspond with commuting trips. A similar significant peak is not observed for the 'high likelihood last mile' trips and these more evenly distributed over the day.

Weekday trips in the 'medium likelihood first mile' category display a high morning peak of 42% trips undertaken between 6-9 am; and the 'medium likelihood last mile' category display an evening peak of 33% trips undertaken between 4-7 pm (Figure 19). Even within the low likelihood first or last mile, a similar pattern of morning and evening peak travel is observed. Weekend trips for all categories represent a stream of trips spread throughout the day instead of two clear peaks within the day. These travel patterns are to be expected and correspond to the transit temporal patterns that are depicted in Figure 15 and 18 for two stations.

Figure 18: Daily temporal distribution of Evo trips by likelihoods of first or last mile | For Weekdays (left panel) & Weekends (right panel)

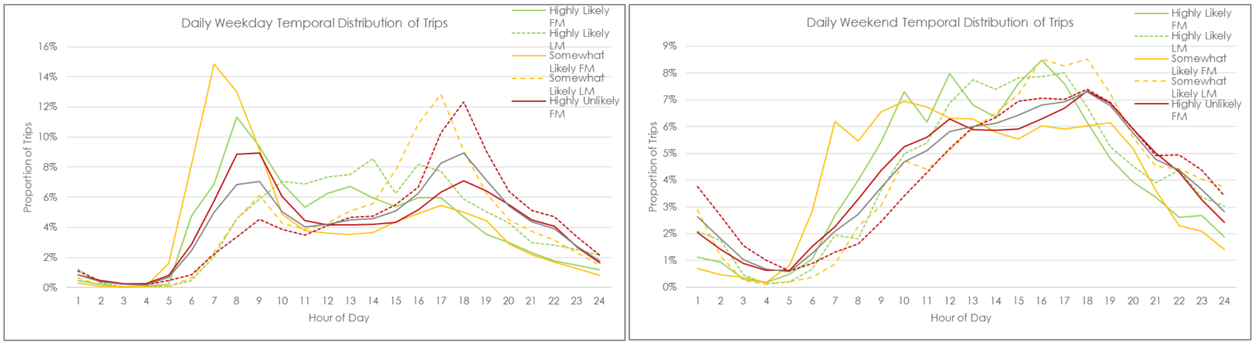


Figure 19: Daily temporal distribution of Evo trips by likelihoods of first and last mile | For Weekdays (top panel) & Weekends (bottom panel)

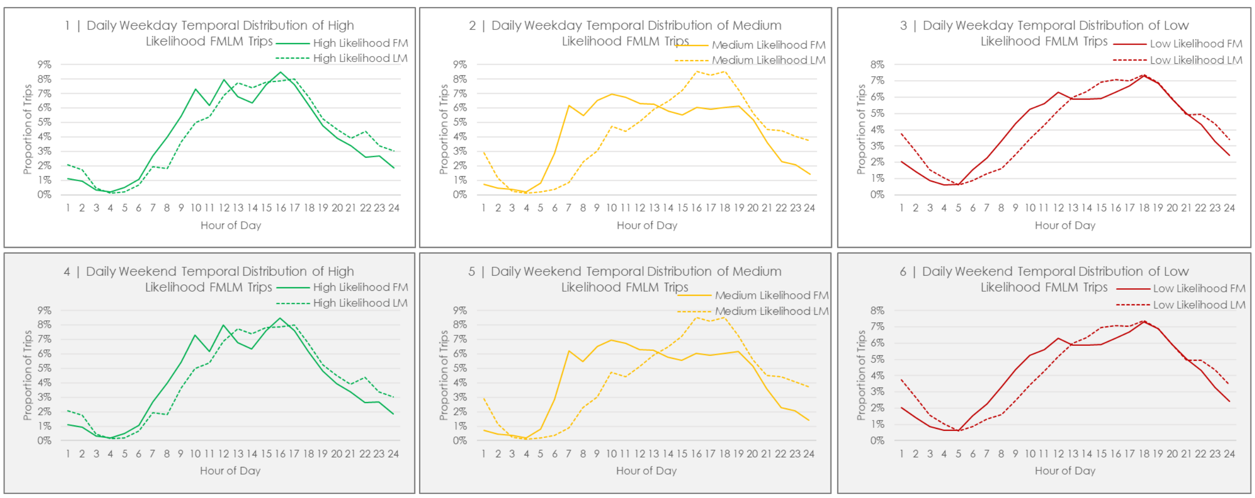
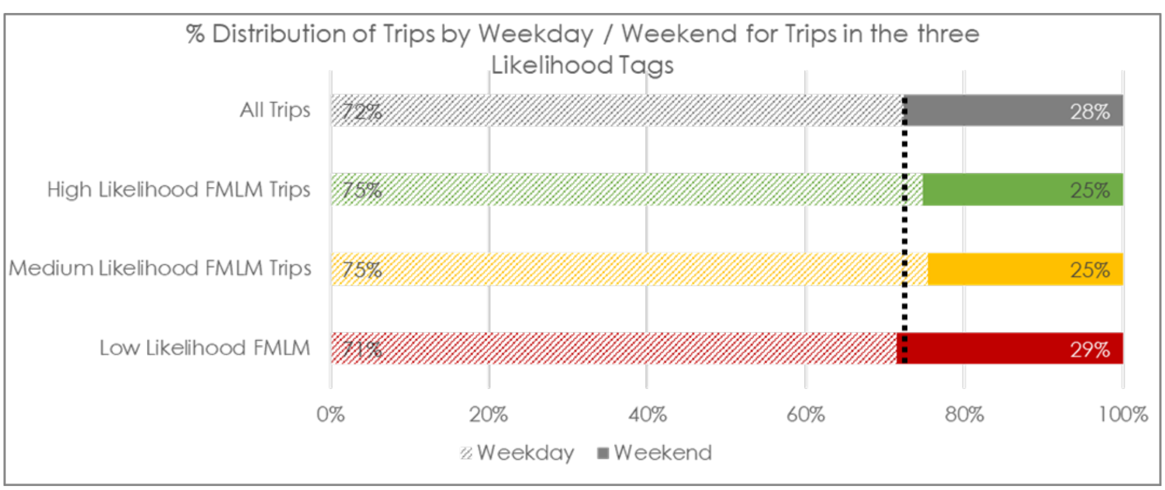


Figure 20: Distribution of Evo trips by weekday and weekend for trips in the likelihood of first or last mile categories



Annexure V represents the weekend/ weekday travel patterns for each of the categories of likelihood to be first or last mile trips for the ten stations in aggregate and individually for each station. Overall a higher proportion (29%) of trips within the 'low likelihood' category are weekend trips, compared to 25% each with the 'high likelihood' and 'medium likelihood' category (Figure 20).

Demographic Results

Annexure VI represents the demographic characteristics of users that have undertaken the trips under analysis. Variation in age profiles by the likelihood category of the trips is minimal. For the users in the high likelihood of first or last mile trips, 60% are in the 23-35 years age bracket, 22% are in the 36-45 years age bracket and 58% are males (these numbers exclude the trips with missing data on demographics) (Figure 21). However as is expected, demographic profile of all trip takers

Figure 21: Demographics for High Likelihood of first or last mile trip takers' | Age Distribution (left panel) and Gender Distribution (right panel)

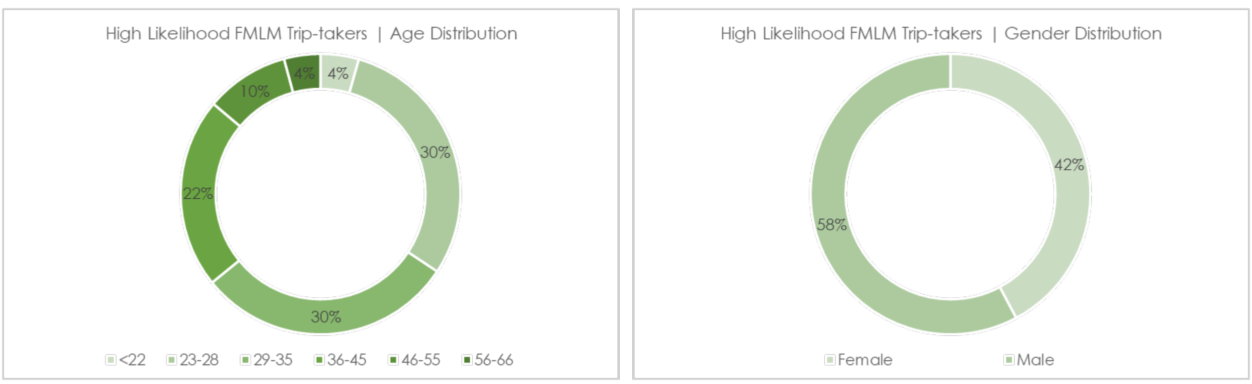
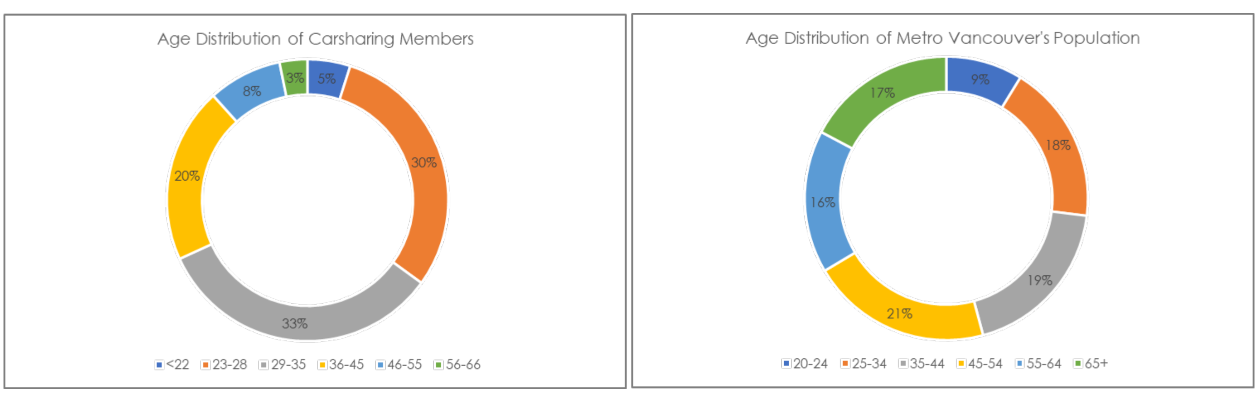


Figure 22: Age distribution comparison | Evo trip takers' (left panel) and Metro Vancouver's population (right panel)



Source: (Metro Vancouver)

is not representative of the demographic profile of the regional population. Compared to the regional population profile, Evo members' profile was generally overrepresented by 23-45 year olds with 83% of trips taken by members in this age group whereas Metro Vancouver's population constitutes 37% (out of the driving eligible age population, thus excluding 0-19 year old group) and no representation of 65+ years age group that comprises 17% of the region's population (Figure 22). These results have been similarly represented in the past survey research studies too.

RECOMMENDATIONS

This study, consistent with the previous studies analysing one-way carshare trips indicates a possibility of one-way carshare usage for commute trips. It also suggests that part of these trips can be attributed to first or last mile connections to public transit, on a spectrum of likelihoods. However, more research is warranted for assessing the nature of these first and last mile connection trips to understand the dynamics between one-way carsharing and transit. Recommendations in this section are vast subjects of research in themselves having far-reaching impacts wider than the scope of this study and should be considered in light of their overall impact.

Data sharing and security

Further collaborations between transit agencies and one-way carshare operators could be considered to facilitate data sharing. To enable such partnerships, it would be crucial to form data-driven policy decisions through access to anonymized data from one-way carshare operators without compromising user privacy or exposing data to competitors.

Parking – Carshare operators, Transit, and private parking providers

Advanced research on impact of one-way carsharing with regards parking in the region would also inform such policy for transit. TransLink, Evo and other carsharing operators have established a few dedicated parking spots at some of the SkyTrain stations in the Region. One-way carsharing operators could explore additional parking opportunities close to transit stations in conjunction with city authorities and private providers.

Alignment with carshare operators in the low-density areas

These collaborations between transit agencies and one-way carshare operators could be informed by identification of low transit connectivity neighbourhoods in the region that would possibly yield the highest first and last mile connectivity to transit users.

Integrated or dynamic ticketing

Data sharing protocols would also be facilitated by dynamic trip planning services allowing users to map out multi-modal journeys within a region, while providing greater convenience to them in accessing mobility as a service (MaaS) instead of accessing a particular mode of transport. Such services allow users to access transit and all other alternative and complementary modes available in a region and make it easier to manage connections between different transportation modes. Higher convenience to users with such services has been shown to increase overall transit use by about 2% as the riders evaluate the multiple transportation modes available to them with regards to the mode's economic, time, environmental and sometimes health impacts (Canales et al. n.d.). MaaS dynamic trip planning applications are already in place in several jurisdictions globally (Box 4). Public transit agencies would benefit from analysing the data such services collect about users' trips (in line with applicable data privacy laws) to identify potential service gaps and improvements. Such analyses would also inform the comparative role and impact of different modes of transportation on resolving the first and last mile challenge.

Box 4: Mobility as a Service

Examples of applications of MaaS with varying degrees of continuity and success so far include: Whim offering dynamic planning and ticketing for trips using public transit, carshare vehicles, bikeshare, and taxis in Helsinki, Finland and its environs. Other examples include: Moovel in Stutgart and Hamburg; Monpelier's EMMA (TaM); Foli in the city of Turku, Finland; the Hannovermobil in Hanover; the year-long Smile pilot in Vienna that was reinstated with the reasonably thriving WienMobil Lab; myCicero in Italy; UbiGo pilot project in Gothenburg that ceased to exist in 2014 despite its success, and as of 2019 had been relaunched in Stockholm; Scottish project NaviGoGo in North Fife and Dundee; and ALD Move in the Netherlands. TransLink's pilot project on Shared Mobility Compass card in the Metro Vancouver region is step in the similar direction within limits of the pilot exercise.

Targeted subsidies for access to the whole social gradient

Given the transit agency's larger goals of equity and accessibility, collaborations must also evaluate the impact of such services on transit access for low-income households. Affordability concerns may exclude such households from access to transit due to cost concerns despite the existence of one-way carshare availability. Transit agencies would need to incorporate targeted inclusion plans for low-income users or address their transit access through alternative options.

DIRECTIONS FOR FURTHER RESEARCH

Subsequent studies to explore this research question would benefit from incorporating data on parking availability around the transit hubs to modify the zone of influence around stations more accurately. Additionally, making distinctions between transit hubs and overlaying neighbourhood demographics data to characterise the nature of trips could help sharpen the results, with a specific emphasis on identification of neighbourhoods with low access to transit. Nonetheless, these would still be strategies to minimise the margin of error, and ideally such data analysis would be combined with user surveys, trip-diaries and in depth user-studies to better understand the motives behind the transportation choices. Such trip-diary style surveys and studies would inform the missing link in this study and provide a measure of proportion of one-way carshare usage in complement with transit. Questions in such surveys would address the travel patterns of users, how often they use one-way carsharing as a single mode and how often it is used as a connection to and from transit. Shared Mobility Compass Card pilot, along with the pre and post enrollment surveys would present such data, however it would be limited to work-related commute and thus not representative of the region as a whole.

SUMMARY

A non-dichotomous ordering of one-way carshare trips basis the distance from the transit hub and the distance travelled suggests some patterns of one-way carsharing usage that could be attributed with varying degrees of certainty as first or last mile complements to transit. This research corroborates some of the previous work that illustrated commute patterns in one-way carsharing usage (Lempert 2019) (Alencar et al. 2019) (Sprei et al. 2019) (Wang et al. 2017). Commute patterns in this study are exhibited by trips in all three categories of high/medium/low likelihood of first or last mile to transit. However, in the absence of data to establish a link between a carshare trip and actual transit use [by way of linkage to transit fare-cards/ ticketing or by way of representative data from surveys of carshare users that depict the proportions of users that use carshare trips as first or last mile], this study represents an exploration of the trips data in reference to the transit hubs. Conclusive assessment of the research question: 'is one-way carsharing a solution to the first and last mile problem in transit?' remains elusive with the existing data. Nonetheless, the results are indicative of at least one-fifth of the trips under analysis being first or last mile trips to transit in the Metro Vancouver region. The classification is still not ironclad and would err on both sides: including some possible 'non-first or last mile trips' as 'first or last mile trips' and vice versa. Transit stations depict divergent and specific patterns of travel from home neighbourhoods to transit hubs' periphery. This research provides a foundation to explore the data more in depth with additional and precise data points on parking availability, transit hubs and neighbourhood characteristics and surveys to link one-way carshare usage with transit.

This study was restricted in scope to answering the question of complementarity of one-way carsharing with transit and the recommendations provided for policy and research stem from that focus. One-way carsharing, however, is one aspect a large and emerging transport ecosystem in the region. It is imperative for city administrations and transit agencies to understand the big picture impacts of such services on the region's transportation landscape, environment and the society.

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ANNEXURES

Annexure I - Cases of jurisdictions where one-way carsharing played a role in providing the first and last mile connectivity to transit*

Carsharing has witnessed a long period of evolution since 1951, with paradigm-shifting developments in the last decade. Early decades of carsharing were dominated by two-way (roundtrip) carsharing operation models. One-way carsharing was operated in most jurisdictions by way of experimental programmes to serve the first and last mile connectivity to public transit, beginning in Europe in the 1970s, East Asia in the 1990s, and continuing in North America from the 1990s until today.

Procotip - was the first recorded one-way carsharing experiment, launched in August 1971 in Montpellier, France with thirty-five cars and nineteen stations. It closed in May 1973 due to technological and financial issues.

Liselec - launched in 1993 in La Rochelle, France with fifty electric vehicles (EVs) at seven stations. Liselec was successful and still exists today as Yelómobile. It is sponsored by Peugeot-Citroen and receives financial support from the government.

Praxitèle - European one-way carsharing schemes connected to public transit began with Praxitèle in 1997. 50 EVs were placed at a Paris suburb, allowing its 500 members to make one-way trips between fourteen stations located in neighbourhoods, near offices, and at public transit stations. By March 1999, 90% of total trips were one-way trips. Although Praxitèle succeeded in its technical implementation, the programme struggled with costs and ended in July 1999.

In Japan, automakers piloted mobility services with one-way carsharing at public transit stations. In 1998, Honda Motor Company deployed the Intelligent Community Vehicle System (ICVS) concept, which included both roundtrip and one-way carsharing with connections to public transit.

Similarly, in 1999, Toyota Motor Company launched the Crayon System in Toyota City, Japan. Fifty EVs were placed at public transit stations and other locations for its 700 members. Both Honda and Toyota employed advanced technologies including: smartcards, automatic vehicle location, vehicle information and communication systems, and a management system for reservations and recharging.

CarLink - One-way carsharing began in the US as pilot projects for public transit connectivity. In 1999, CarLink I launched at the Dublin/ Pleasanton Bay Area Rapid Transit (BART) station in the East Bay of the San Francisco Bay Area. Similarly, CarLink II was based at the Caltrain station in Palo Alto, California with twenty-seven Honda Civics and 100 users. The CarLink pilot programmes facilitated one-way trips between rail stations and home- and work trips. At the end of the CarLink II pilot, Flexcar took over the service in 2002. However, it ceased operations in 2003 due to concerns with cost recovery and its limited scale.

The University of California (UC) piloted several one-way carsharing projects with links to public transit. UC Irvine operates the Zero Emission Vehicle Network Enabled Transport (ZEV·NET) system. UCR Intellishare operated around the UC Riverside campus and the Downtown Riverside Metrolink station from 1999 to 2010."

* Excerpts from (Shaheen and Chan 2016)

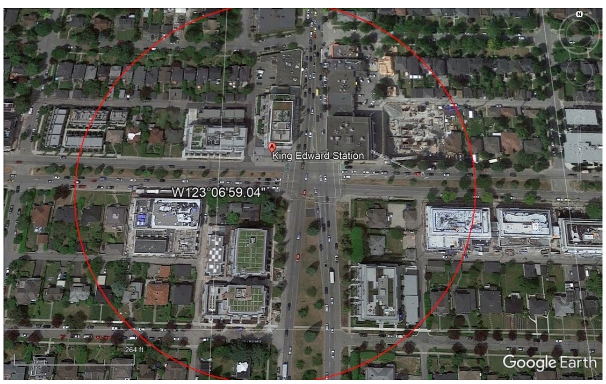
Annexure II - Distribution of Evo trips that originate or terminate within various radii of circular zones of influence from the selected 10 SkyTrain stations

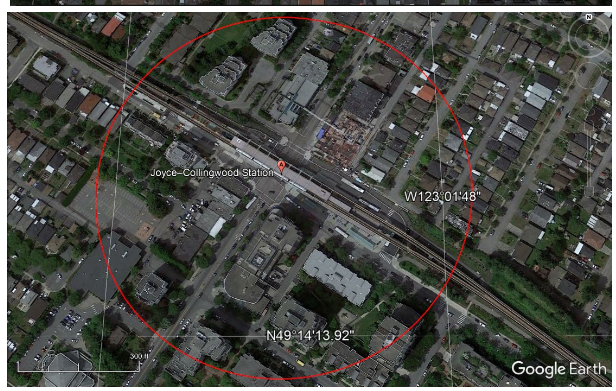
Distance Station Meters -Ranges	Braid	Nanaimo	King Edward	29thAve	Joyce-Collingwood	Oakridge-41st Ave	Rupert	Waterfront	MarineDrive	NV Seabus	All Stations
1. 50 m Radius	0%	0%	3%	0%	0%	0%	1%	0%	0%	0%	0%
2. 100 m Radius	10%	27%	14%	21%	5%	4%	1%	25%	0%	2%	16%
3. 150 m Radius	93%	47%	36%	37%	22%	17%	5%	28%	14%	11%	29%
4. 200 m Radius	93%	58%	53%	58%	47%	35%	17%	30%	20%	12%	37%
5. 250 m Radius	94%	66%	67%	68%	63%	49%	48%	37%	32%	18%	48%
6. 300 m Radius	95%	72%	79%	76%	79%	74%	70%	48%	48%	41%	61%
7. 350 m Radius	95%	88%	87%	90%	91%	88%	81%	73%	91%	65%	81%
8. 400 m Radius	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

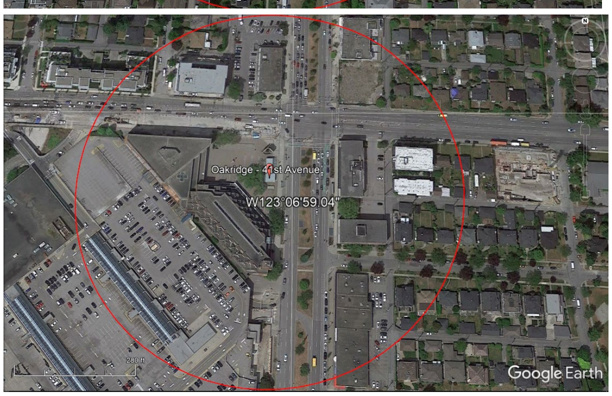
Note: Table presents the proportion of trips that originate or terminate within different circular zones surrounding the ten SkyTrain stations. All the trips in the dataset either started or ended within the 400 meters of the stations.

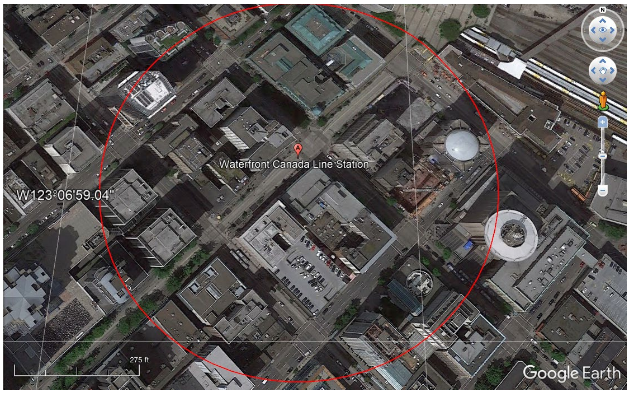
Annexure III - Satellite maps of SkyTrain stations with 150 m radius circular zones

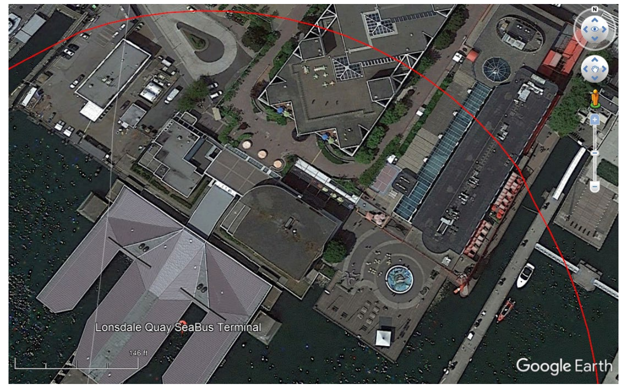
This annexure contains the maps of the 10 rapid-transit SkyTrain stations with the circular zones of 150 meters radius circular zone surrounding each station in red ink and the station name at the centre of the circular zone. Each of the map images are sourced from Google Earth [earth.google.com/web/].

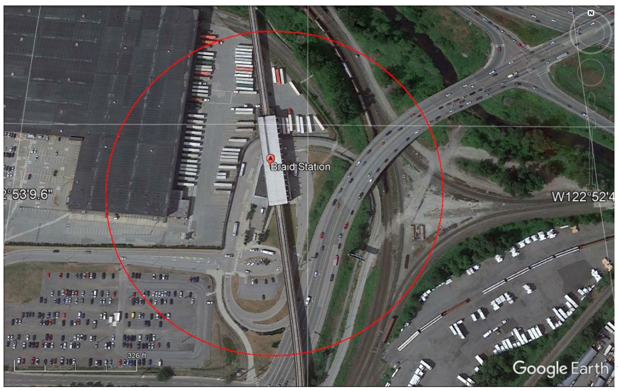


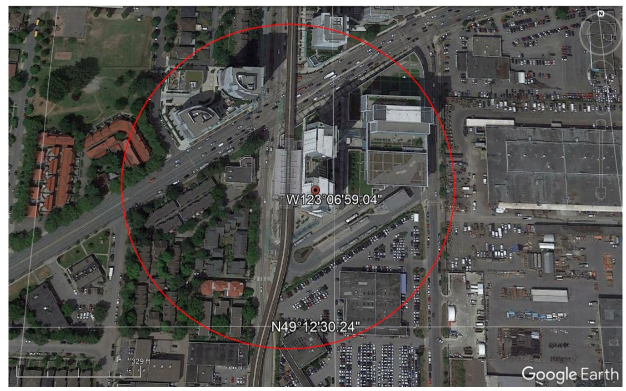





Waterfront Canada Line Station
W123°06'59.04"
275 ft
Google Earth


Lonsdale Quay SeaBus Terminal
Google Earth


Braid Station
Google Earth

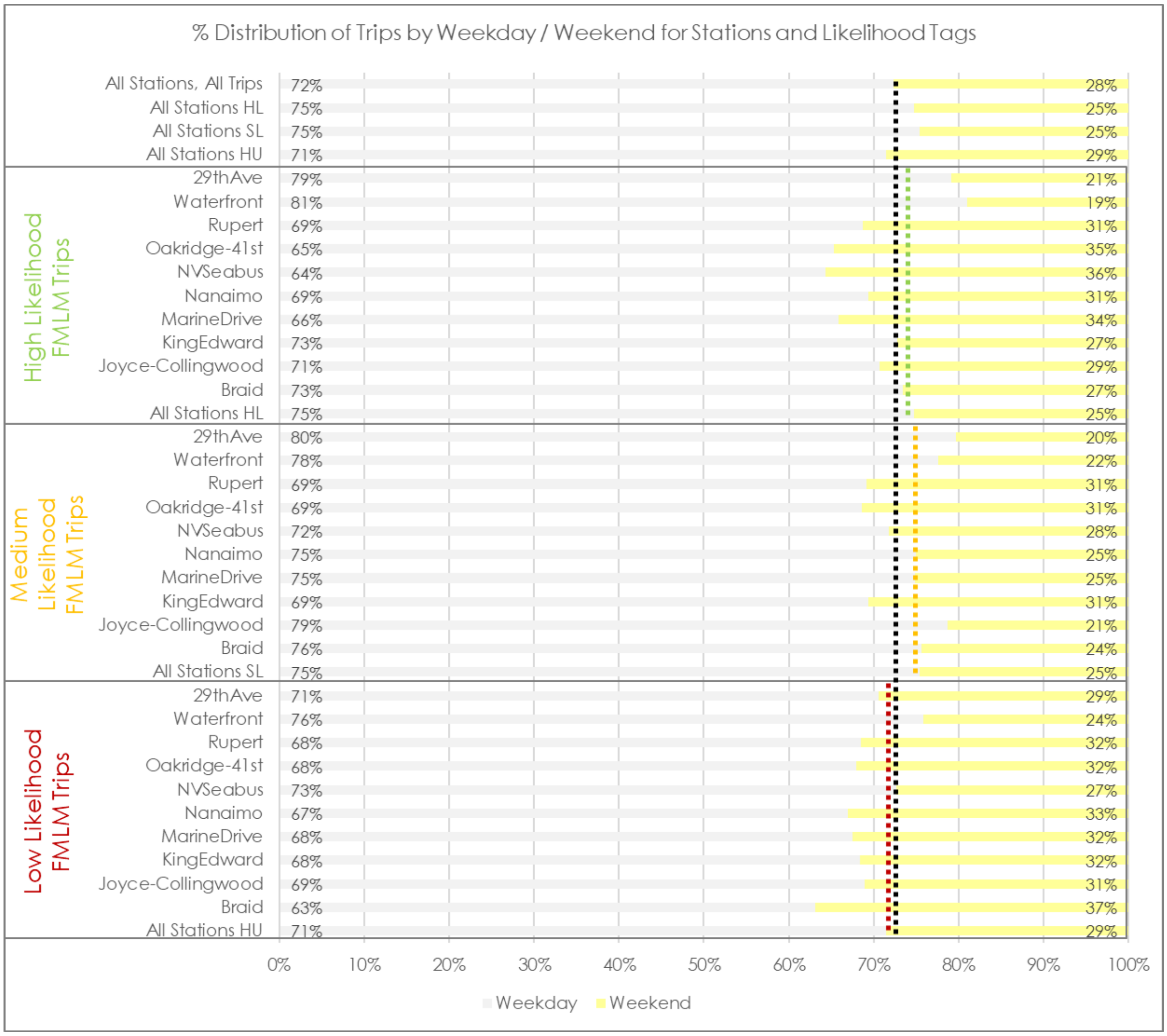

W123°06'59.04"
N49°12'30.24"
Google Earth

Annexure IV - Distribution of trips by SkyTrain station based on the distance travelled per trip

Trip Distance (upto x km)	*Braid*	*Nanaimo*	*King Edward*	*29th Ave*	*Joyce-Collingwood*	*Oakridge -41st Ave*	*Rupert*	*Waterfront*	*Marine Drive*	*NV Seabus*	*All Stations*
0	19%	17%	14%	18%	22%	13%	19%	14%	15%	20%	16%
1	35%	34%	36%	36%	33%	28%	35%	32%	26%	50%	33%
2	44%	49%	54%	50%	47%	44%	51%	48%	31%	57%	47%
3	50%	64%	75%	65%	56%	59%	61%	68%	37%	64%	63%
4	53%	78%	87%	75%	63%	70%	68%	79%	44%	76%	73%
5	55%	84%	92%	83%	71%	84%	75%	85%	56%	84%	80%
6	55%	91%	95%	88%	77%	92%	84%	90%	66%	90%	86%
7	55%	94%	96%	93%	83%	93%	91%	93%	78%	92%	90%
8	57%	95%	97%	95%	89%	94%	95%	95%	86%	94%	92%
9	57%	97%	99%	97%	94%	96%	97%	96%	89%	95%	94%
10	58%	98%	99%	98%	97%	98%	98%	98%	91%	95%	96%
11	60%	99%	99%	99%	98%	99%	99%	98%	93%	96%	96%
12	62%	99%	99%	99%	98%	99%	99%	98%	94%	96%	96%
13	64%	99%	99%	99%	98%	99%	99%	98%	95%	97%	97%
14	67%	100%	100%	100%	98%	99%	99%	98%	97%	98%	97%
15	69%	100%	100%	100%	99%	100%	100%	99%	98%	98%	98%
16	74%	100%	100%	100%	100%	100%	100%	99%	99%	99%	99%
17	82%	100%	100%	100%	100%	100%	100%	100%	100%	100%	99%
18	91%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
19+	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Note: Distribution contains cumulative percentages for each SkyTrain station

Annexure V - Distribution of Evo trips by weekday and weekend for trips in the likelihood of first or last mile categories | Overall and for each of the ten SkyTrain stations



Annexure VI - Demographics for Evo trip takers by Likelihoods of first or last mile trip takers' | Age Distribution (left panel) and Gender Distribution (right panel)