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Ethics Statement

The author, whose name appears on the title page of this work, has obtained, for the research described in this work, either:

a. human research ethics approval from the Simon Fraser University Office of Research Ethics

or

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Abstract

Public bicycle share programs have the potential for positive health and environmental benefits. In order for these benefits to be realized, the programs need to be well used at the population level and contribute to increases in bicycling. This thesis aimed to understand demand for the Vancouver public bicycle share program among residents and the impact of the program on bicycling. We used data from a public bicycle share member survey and a repeat cross-sectional survey of Vancouver residents. As of Fall 2017, approximately 6.2% of Vancouver residents have used the public bicycle share program, and amongst non-users, nearly 1 in 4 indicate they are likely to use the program. However, we did not observe an increase in bicycling for those living and/or working inside the bicycle share service area relative to those outside the service area in the second season of program operation.

Keywords: public bicycle share program; bicycling; active transportation; natural experiment; population level impacts
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Chapter 1.

Introduction

Public bicycle share programs are at a time of rapid growth and expansion; increasing from ~90 programs in 2008 to ~1700 in 2018.\(^1,2\) These programs have the potential for positive health and environmental benefits through increases in population physical activity and decreases in air pollution and traffic congestion. However, in order for these benefits to be realized, the programs need to be well used at the population level and contribute to increases in bicycling. Two important questions are: Who does public bicycle share appeal to? And does public bicycle share contribute to changes in population bicycling? In 2016, Vancouver implemented a public bicycle share program as part of their commitment to make bicycling more accessible to Vancouver residents. This thesis aimed to understand demand for the public bicycle share program among Vancouver residents as well as the impact of the program on bicycling in the general population.

1.1. Literature Review

1.1.1. The link between active transportation, health, and the environment

Active transportation, defined as any form of human powered transportation,\(^3\) is a healthy and sustainable way to get around a city. Bicycling, walking, rollerblading, and skateboarding are all forms of active transportation.\(^3\) Incorporating these modes into daily travel routines is one way to increase physical activity levels. Despite this benefit, private motor vehicle use is by far the most common mode of transportation in North America. Specifically in Canada, 4 in 5 commuters use a private motor vehicle to get to work.\(^4\) Private motor vehicle use is associated with a number of negative health and environmental outcomes including physical inactivity, obesity, traffic congestion, and increases in air pollution and greenhouse gas emissions.\(^5–7\) Shifting trips made by private motor vehicles to active modes of transportation can help mitigate these effects.\(^8\)
There is evidence to support the link between active transportation, physical activity, positive health outcomes, and environmental benefits. Physical activity is a modifiable risk factor for a number of chronic diseases including cardiovascular disease, diabetes, obesity, hypertension, osteoarthritis, and depression. Studies specific to active transportation report that those who primarily walk or bicycle for transportation are more physically active and less likely to be overweight or obese compared to those who use private motor vehicles, and have reduced cardiovascular disease risk. Increased active transportation can also reduce air pollution and greenhouse gas emissions if trips made by active modes substitute for a significant proportion of trips previously made by private motor vehicles.

At a population level, the health benefits gained from increased transportation related physical activity outweigh the negative consequences from injuries and fatalities from collisions and individual exposure to air pollution. For example, Grabow et al. estimate that replacing 50% of short car trips (≤ 4km) with travel by bicycle in 11 of the largest mid-western metropolitan areas in the US (population: 31.3 million) would result in a net benefit of $8.7 billion per year from improved air quality and physical fitness and 1,295 fewer deaths per year. In a similar study, Rojas-Rueda et al. estimate that replacing 40% of car trips with bicycling in Barcelona (population: 1.6 million) would result in 67 fewer deaths and a reduction in CO₂ emissions of 42,783 tones per year. These studies provide support for developing interventions that encourage active transportation.

One way to shift a population towards using active modes of transportation is through modifying the built environment. Built environment features, such as buildings, footpaths, bicycle lanes, parks, trails, and transportation networks are key barriers or facilitators to engaging in active transportation. Modifying the built environment to support active modes of transportation has the potential for long term population wide health benefits because these interventions can impact a large number of people over a sustained period of time.

1.1.2. Bicycle sharing: a new form of active transportation

Public bicycle share programs are an example of a built environment intervention with potential to shift populations towards active transportation. Over the past decade,
there has been an increase in the popularity and number of public bicycle share programs operating globally.\textsuperscript{1} These programs increase access to active transportation by providing a network of shared bicycles throughout a city.\textsuperscript{2} There are three main types of systems: station-based, flexible, and hybrid. Station-based systems require users to rent and return bicycles at designated stations throughout a city, flexible systems allow users to unlock and lock bicycles anywhere within the service area – similar to car share programs, and hybrid systems allow users to rent and return bicycles either at a station or non-station location.

Public bicycle share is often promoted as facilitating the first and last miles of trips, connecting users from transportation hubs to their destination. Typically, a user purchases a pass, which are commonly available for single trips, daily use, or longer-term memberships. In most programs, the first 30 minutes of a trip are included in the pass, and overage charges are applied after the first 30 minutes. Smartphone technology is often required in the registration process, and in flexible systems, when unlocking and locking a bicycle.

Public bicycle share system datum has been used to characterize bicycle share usage. Across programs, weekday usage tends to peak during commute times (7-9 am and 4-6 pm), while weekend usage peaks mid-day.\textsuperscript{25} Annual and monthly members tend to make shorter trips compared to casual users (i.e. day pass users). For example, in Washington DC, the mean trip duration and distance was 13 minutes and 1.6 miles for annual and monthly bicycle share members compared to 40 minutes and 3.1 miles for casual users.\textsuperscript{26} This is likely because annual and monthly members are more likely to use public bicycle share for commuting, whereas, casual users are more likely to use the program for leisure or sightseeing.\textsuperscript{25}

In recent years, equity in program access and uptake has become a key consideration for public bicycle share programs. Trends across several studies indicate that public bicycle share users are predominantly Caucasian, employed, and have higher incomes and educations, as compared to the general population.\textsuperscript{27} For station-based systems, the socioeconomic disparity in ridership is partly attributed to the location of docking stations, which in many cities are disproportionately located in higher socioeconomic status neighbourhoods.\textsuperscript{28–30} Other barriers to public bicycle share use include the cost and pricing structure, credit card ownership, limited access to a
computer or smartphone to sign up for bicycle share, and a lack of awareness about how bicycle share works. A number of programs are implementing initiatives to address these barriers. For example, the bicycle share program in Hamilton, Ontario rolled out their “Everyone Rides Initiative” in 2016, which includes subsidized memberships for low income residents, education and outreach initiatives, and the addition of new docking stations in low income neighbourhoods.

1.1.3. Bicycle sharing and health

Figure 1 shows a conceptual framework of the major pathways through which a public bicycle share program could affect health outcomes in the general population. Public bicycle share programs can directly increase population bicycling from the use of the program itself, and also indirectly, through increases from personal bicycle use. The second pathway, increases from personal bicycle use, can arise if the use of public bicycle share motivates users to also ride their personal bicycles more frequently, or if having a public bicycle share program as part of the city normalizes bicycling and influences non-users to bicycle more frequently. As described in section 1.1.1, increased physical activity from bicycling is the main pathway to positive health outcomes, and outweighs the risks of collisions and exposure to air pollution. This was also demonstrated in a health impact modelling study specific to bicycle share use, which found that Bicing users in Barcelona had greater benefits from physical activity than risks from collisions and exposure to air pollution.
Figure 1.1 Conceptual framework of the potential impacts of a public bicycle share program on health.

1.1.4. Existing research on public bicycle share programs

Literature evaluating public bicycle share schemes has grown rapidly in recent years. Public bicycle share studies typically include surveys with users and/or analysis of system data. In a review of public bicycle share literature, Ricci (2015) categorized bicycle share research into three broad areas: 1) public bicycle share users and system usage, 2) impacts of public bicycle share programs, and 3) the implementation and operation of bicycle share programs.
1. Public bicycle share users and system usage. Research in this area includes evidence on who uses public bicycle share, program perceptions and attitudes, motivators and barriers to public bicycle share use, and usage patterns.

2. Impacts of public bicycle sharing. This area includes research on the impacts of public bicycle share programs on outcomes related to health, transportation, safety, and the environment.

3. Implementation and operation of bicycle share programs. A third body of research investigates the operational aspects of public bicycle share programs, such as optimizing station placement and the redistribution of bicycles.

The focus of this thesis is on perceptions and uptake of public bicycle share programs at a population level and the impact of these programs on bicycling. The following two sections provide an overview of literature in these areas.

1.1.5. Program perceptions and uptake

Public bicycle share programs have had variable success in attracting users. A standard metric to compare usage across bicycle share programs is the number of trips per bicycle per day. Worldwide, it is estimated that most programs have an average of 3 – 8 trips per bicycle per day. Barcelona and Dublin are two examples of cities with high performing programs, averaging ~8 trips per bicycle per day. In contrast, the public bicycle share programs in Melbourne and Brisbane average less than 1 trip per bicycle per day.

There are many factors that may influence public bicycle share uptake in a city including the size of the program, station placement, weather, and bicycling infrastructure and culture. Chardon et al. compared attributes of 75 public bicycle share programs, using trips per bicycle per day as a metric for performance. Attributes that had a negative impact on program performance were helmet law requirements and programs that were operated by non-profit organizations. Attributes associated with higher performing programs were higher in population size, bicycle infrastructure, station density, and warmer weather.
Public bicycle share users’ perceptions and attitudes towards bicycle sharing have generally been positive, but few studies evaluate perceptions and likelihood of use at the population level. Results from two population level studies found that most people are supportive of public bicycle share, but a much smaller segment are actually likely to use bicycle share. A survey of residents in Gothenburg, Sweden revealed that the majority of respondents (92.4%) thought that the program was good for Gothenburg, but less than 14% reported using the program at least once per month. Similar results were found in a survey conducted in 2012 in Vancouver, Canada, prior to the launch of the public bicycle share program, which found that 69% of respondents thought the program was a good idea, however, only 24% said they would likely use the program. The gap between the number of people that think bicycle share is a good idea and the number that report being likely to use the program suggests that there is potential for greater use of public bicycle share programs.

Further work assessing program perceptions and likelihood of use in the general population and in sub-groups of the population is needed to improve our understanding of the groups that do not use bicycle share. In particular, improved understanding of potential users of public bicycle share, those who have not used the program but are interested, can help inform targeted marketing and outreach efforts to increase public bicycle share uptake in the population.

1.1.6. Impacts on bicycling

Given that these programs increase access to bicycles, there is considerable interest in understanding how these programs influence bicycling behaviour. These programs have the potential to increase population-wide bicycling by increasing access to bicycling for those who do not own a personal bicycle, increasing the convenience of bicycling, and by normalizing bicycling as a form of transportation. A major advantage of bicycle sharing is the ability for users to unlock and lock bicycles at any one of the designated docking stations, and in the case of flexible systems, anywhere within the service area. This allows for one-way trips and eliminates the concern of bicycle theft that may arise from locking a personal bicycle in public spaces.

Studies suggest that public bicycle share programs increase bicycling for users, but less is known about the impact on bicycling at the population level. A standard
question asked in many bicycle share user surveys is, “As a result of your use of bicycle share, do you bicycle more often, about the same, or less often?” The majority of users report bicycling more often as a result of joining the bicycle share program. As examples, 72% of public bicycle share users surveyed in four North American cities reported bicycling more, and similarly, 78% of public bicycle share users surveyed in London reported bicycling more. This indicates an overall increase in bicycling for users of the program, but does not provide information on the magnitude and extent that bicycle share increases bicycling (i.e., how many additional trips are made by bicycle because of the program). At the population level, grey literature reports suggest growth in bicycling mode share concurrent with the roll out of bicycle share programs. For example, in Paris, the percentage of trips made by bicycle increased from 1.0% to 2.5% (2001-2005) and in Barcelona, from 0.75% to 1.76% (2005-2007), however, these reports do not account for other changes to bicycling infrastructure that were implemented at the same time.

To date, there is one example of a natural experiment study of a public bicycle share program in Montréal. This study found increases in self-reported bicycling for those who lived close to a public bicycle share docking station at the end of the second season of BIXI Montréal relative to those who did not live near a docking station. This study suggests that public bicycle share programs have potential to increase bicycling in the population. However, public bicycle share programs are implemented at different scales and program uptake varies widely across cities. Assessing the impacts of public bicycle share in different cities can provide decision makers with evidence on potential changes in population bicycling associated with programs implemented at different scales and in different contexts.

1.1.7. Research gaps

In a recent narrative review of public bicycle share literature, Bauman et al. identify the lack of research on whether these programs can contribute to population physical activity through increases in bicycling as a key gap in the field. To better understand the impacts of bicycle sharing at the population level, three methodological gaps in bicycle share research need to be addressed:
1. Study population. Population-level data on demand for public bicycle share programs and impacts on transportation behavior are rarely incorporated into evaluations, but are necessary for understanding the potential impacts of these programs for both users and non-users.46

2. Study design. Natural experiment studies can be used to understand the effects of a population level intervention on a behaviour,47 such as the implementation of a public bicycle share program on bicycling. Studies using appropriate natural experiment study designs are needed to understand the population level impacts of these programs. To date, the evaluation in Montréal is the only study that uses a natural experiment study design to evaluate a public bicycle share program.

3. Intervention exposure. Evidence suggests that people who live or work close to docking stations are more likely to use public bicycle share.38,39 Additionally, any indirect impacts of public bicycle share programs on bicycling attitudes and behaviour will presumably be stronger for those who are exposed to the program on a regular basis. The evaluation in Montréal provided evidence on the impacts of a public bicycle share program on bicycling for those who live in close proximity to a docking station,45 however there is limited research on the impacts on bicycling for those who work close to a docking station.

1.2. Rationale

In 2017, the Canadian Institutes of Health Research Population & Public Health Institute identified research on the design of healthy cities as a strategic priority area.48 Public bicycle share programs are an urban intervention that have potential to contribute to healthier cities if they are well used at a population level and contribute to increases in bicycling. To advance research in this area and address the research gaps identified above, this thesis aimed to understand demand for the Vancouver public bicycle share program among Vancouver residents and the population level impact of the program on bicycling for those living and working in close proximity to the program.
1.2.1. Objectives

The specific objectives of my thesis were:

1. To examine the socio-demographic and transportation characteristics of current, potential, and unlikely users of a public bicycle share program and identify specific motivators and deterrents to public bicycle share use.

2. To estimate the population-level impact of a public bicycle share program on bicycling.

1.2.2. Data

My thesis is part of “Understanding a New Bike Share Program in Vancouver: Motivators, Deterrents, & Equity”, a study initiated in 2012, funded by CIHR and the City of Vancouver. This study aims to assess the impact of Vancouver’s public bicycle share program on transportation, health, and equity outcomes in the general population, in users of the program, and within key populations. This is a mixed-methods study that includes repeat cross-sectional surveys before and after the public bicycle share launch, bicycle share member surveys, and focus groups with target populations to identify barriers to program use. I was involved in all aspects of data collection from 2016 to 2018.

For my thesis, I used data from the repeat cross-sectional surveys with Vancouver residents and the 2017 Mobi member survey. Both surveys included questions on individual and household demographics, transportation access, transportation behavior, bicycle share use or likelihood of use, and motivators and deterrents to bicycle share use (refer to Appendix A and B for the complete list of survey questions). Details for each survey are described below.

Repeat cross-sectional surveys:

- Online cross-sectional survey with Vancouver residents at three time points: pre-bicycle share launch (October 2015), early launch (October 2016), and 1-year post-launch (October 2017).
• Respondents were recruited using age and sex quotas via an online panel maintained by Léger Marketing.

• Sample sizes: 2015 (n=1111), 2016 (n=995), and 2017 (n=966)

2017 Mobi member survey:

• Online cross-sectional survey with annual and monthly public bicycle share members (September/October 2017).

• Sample includes 1400 bicycle share members

1.2.3. Context

Vancouver is home to 631,486 people and is the most densely populated city in Canada, with over 5,400 people per square kilometer. With an extensive bicycle network and a mild climate, Vancouver is ideal for bicycling year-round. Bicycling accounts for 6.1% of all trips made to work, which is higher than most other Canadian cities. The City of Vancouver is committed to making bicycling a viable and sustainable transportation option to meet the objectives of their Transportation 2040 Plan, which aims to have two-thirds of all trips be made on foot, bicycle, or transit by 2040. The implementation of the Mobi by Shaw Go public bicycle share program during the summer of 2016 was one of the key initiatives of Transportation 2040.

Mobi by Shaw Go is a station-based system, with 1,500 bicycles at 151 stations as of June 2018. The public bicycle share service area covers the downtown core, and is bounded by Stanley Park, Arbutus Street, 16th Avenue, and Commercial Street. Implementation of the program is ongoing with plans to expand to 200 stations and 2000 bicycles by the end of August 2018. For unlimited 30-minute trips, the cost to use Mobi by Shaw Go is $9.75 for a day pass, $75 for a 3-month pass, and $129 for an annual pass. “Plus” passes can be purchased at an additional cost for unlimited 60-minute trips. The rollout of Vancouver’s public bicycle share program presents an important opportunity to build on the work conducted in Montréal and contribute to research on the population level impacts of these programs.
1.2.4. Structure

This thesis consists of four chapters: an introductory chapter, two chapters that address the research objectives above, and a concluding chapter.

In Chapter 2, I examined the characteristics of current, potential, and unlikely users of the Vancouver public bicycle share program. I categorized non-users of bicycle share as either potential or unlikely users based on their stated interest in using bicycle share within the next year. The purpose of this chapter was to provide municipal decision makers and bicycle share operators with information about the populations segments that are currently using bicycle share, as well as those that are in the near market for bicycle share to help inform their marketing and outreach efforts.

In Chapter 3, I estimated the population-level impacts of Vancouver’s public bicycle program on bicycling. I measured self-reported bicycling of Vancouver residents at three times points: prior to the implementation of the program, in the early phase of...
implementation, and one-year post implementation. I assessed whether there was an increase in bicycling from pre to post bicycle share implementation amongst those living and/or working in close proximity (≤500 meters) to Vancouver’s public bicycle share program, compared to those living and working outside this area.

Lastly, in the concluding chapter, I integrated the findings from Chapter 2 and 3, discussed the contributions and limitations of this thesis, and identified areas for future work.
Chapter 2.

Who is in the near market for bicycle sharing? Identifying current, potential, and unlikely users of a public bicycle share program

2.1. Introduction

Cities often implement public bicycle share programs as a way to help shift populations towards active and sustainable modes of transportation. By making bicycles available at docking stations throughout a city, these programs increase access to bicycling, especially for those who do not own a bicycle. However, public bicycle share programs are not used equally by all segments of the population. In many cities, program members tend to be male, Caucasian, employed, and have higher educations and incomes compared to the general population. This has raised concerns that public bicycle share programs are further disadvantaging populations that may already experience inequitable access to transportation options. In addition, the majority of bicycle share trips replace trips previously made by walking or public transit, indicating that bicycle share appeals to people who already use active and sustainable modes of transportation. In order to meaningfully contribute to creating a population level mode shift towards active and sustainable transportation, and to do so equitably, public bicycle share programs need to appeal to a broader population.

Social marketing is one approach to increase equitable access to public bicycle share and promote more widespread uptake. This approach involves the use of marketing concepts and strategies to influence behaviour change, and has commonly been used in public health to influence a number of behaviours including physical activity, drinking and driving, and smoking. Social marketing has also been used for other transportation modes, such as electric vehicles, car share programs, and public

1 A version of this chapter has been submitted for publication.
A key aspect of social marketing is tailoring marketing and outreach strategies to segments of the population that share similar desires, attitudes, or behaviours. In the case of public bicycle share programs, this requires an understanding of who the users and non-users are, their attitudes towards such programs, and specific motivators and deterrents to program use.

A number of previous studies focus on understanding users of public bicycle share programs and motivators and deterrents to use. Investigations of non-users of public bicycle share programs are less common, and often focus on understanding specific segments of the population (e.g., low income residents) or have small sample sizes that are not representative of the general population. Moreover, studies rarely stratify non-users based on their interest in using public bicycle share. Better understanding of the potential and unlikely users of public bicycle share along with their motivators and deterrents can provide evidence for demand across socio-demographic groups and can serve as valuable data for social marketing efforts of public bicycle share operators and cities with the goal of increasing bicycle share uptake at the population level.

To better understand the market for public bicycle share, this study examined the socio-demographic and transportation characteristics of current, potential, and unlikely users of the Vancouver public bicycle share program and identified specific motivators and deterrents to program use.

2.2. Methods

2.2.1. Context

The City of Vancouver implemented their public bicycle share program, Mobi by Shaw Go, in July 2016. Two years into operation, the program has been used by over 45,000 users for 900,000 trips.

2.2.2. Data

We used data from two cross-sectional surveys. For current bicycle share users (required to be ≥18 years), we used an online Mobi member survey distributed to all
annual and monthly members enrolled as of September 9, 2017 (survey dates: September 22-October 6, 2017, n=1400, 29.4% cooperation rate). To characterize the potential market for public bicycle share (potential users and unlikely users), we used a population-based survey of Vancouver residents (≥18 years) recruited through an online panel using age and sex quotas (October 13-31 2017, n=966, 15.6% cooperate rate). The survey was described as exploring transportation choices in Vancouver and did not mention the ‘Vancouver public bicycle share program’ to avoid biasing participation. Both surveys included questions on individual and household demographics, transportation access, transportation behaviour, public bicycle share use or likelihood of use, and motivators and deterrents to public bicycle share use. The Simon Fraser University Research Ethics Board approved all study procedures and respondents provided informed consent.

2.2.3. Measures

We considered all respondents from the Mobi member survey that had used the program at least once to be “current users”. We used a question from the Vancouver population survey to categorize respondents as either potential or unlikely users based on their response to the question, “How likely would you be to use public bicycle share in Vancouver at some point in the next year, given that station locations are accessible to you?” We categorized respondents who selected “very likely” or “somewhat likely” as potential bicycle share users, and respondents who selected “not likely” or “not at all likely” as unlikely users.

We examined socio-demographic and travel characteristics that are potentially related to public bicycle share use, and were available in both the Mobi member and Vancouver population survey datasets. Variables included: individual demographics (sex, age, education, employment status, place of birth); household demographics (household income, having children at home); transportation access and behaviour (car access, car share membership, bicycle access, primary mode of transportation, bicycled in the past year, perceived safety of bicycling in Vancouver); and location (living and/or working within 500 meters of a Mobi by Shaw Go docking station).

We identified motivators and deterrents to using public bicycle share from two Vancouver population survey questions. We asked “potential users” of the bicycle share
program to select all the reasons that would influence their decision to use the program from a 14-item list. Similarly, we asked “unlikely users” to select all the reasons that would influence their decision to not use the program from an 18-item list. The items listed were based on motivators and barriers to public bicycle share use identified in previous studies and input from Mobi by Shaw Go and the City of Vancouver.63,65,69

2.2.4. Analysis

We applied weights to the Vancouver population survey respondent age and sex strata to match those of the 2016 Canadian census data for the city. In the first part of the analysis, we used descriptive statistics from the member and population surveys to contrast the socio-demographic and travel characteristics of current public bicycle share users with non-users of the program. We focused on percentage differences of at least 5% and trends across categories. In the second part of the analysis, we used logistic regression to identify variables that are associated with being a potential user of bicycle share compared to an unlikely user, using data from the population survey. For the multivariable model, we used backward stepwise regression and selected the model with the lowest Akaike Information Criterion value. The final multivariable model included age, employment status, place of birth, household income, car share membership, primary mode of transportation, bicycled in the past year, and perceived safety of bicycling. Finally, we present potential motivators to using the program among potential users and potential deterrents among unlikely users from the population survey, ranked by the percentage of respondents that selected the motivator or deterrent. All statistical analyses were conducted in R version 3.4.3.

2.3. Results

In total, 1400 respondents completed the Mobi member survey and 966 respondents completed the Vancouver population survey. Of the 1400 Mobi member survey respondents, we excluded 34 that had not yet used the program and 94 with missing demographic data. Of the 966 population survey respondents, we excluded 53 who lived outside of the City of Vancouver (the study area), 35 with missing demographic data, 57 who used the public bicycle share program previously, and 29 who did not indicate a likelihood of using the program (i.e., responded “Don’t know” or “I
prefer not to answer"). Our final analytic sample included 1272 current users and 792 non-users, of whom 182 were potential users (23%) and 610 were unlikely users (77%).

2.3.1. Current users compared to non-users

Table 1 presents characteristics of current, potential, and unlikely users of the Vancouver public bicycle share program. Current users were disproportionately male (58.3%) and between the ages of 25-54 (85.6%), and more likely to be employed (90.5%) and have a graduate degree (34.8%). Current users were more likely to have household incomes >$150,000 compared to potential and unlikely users (27.2% compared to 10.0% and 11.2%, respectively), and potential users had lower incomes compared to the other two groups. Responses across transportation variables indicate that current users are the most oriented towards active modes of transportation. Current users were more likely to have a car share membership (67.7%) and a personal bicycle (69.8%), report walking or bicycling as their primary mode of transportation (45.2%), and perceive bicycling to be safe (79.3%). Most current users either lived or worked inside the bicycle share service area (92.0%), compared to 58.2% of potential users and 49.7% of unlikely users.

2.3.2. Potential users compared to unlikely users

Table 2 shows the results of the logistic regression models for demographic and transportation characteristics associated with being a potential user, compared to an unlikely user of the public bicycle share program. In the adjusted model, potential users were more likely to be employed (OR: 2.04, 95% CI: 1.14, 3.67), and less likely to be aged 65+ compared to respondents aged 18-24 (OR: 0.18, 95% CI: 0.06, 0.53). Respondents with incomes less than $35,000 had four times the odds of being a potential user compared to respondents with incomes over $150,000. Transportation characteristics positively associated with being a potential user were having a car share membership (OR:1.78, 95% CI: 1.17, 2.68), having bicycled in the past year (OR: 2.15, 95% CI: 1.30, 3.54), and using transit as a primary mode of transportation compared to walking (OR: 1.90, 95% CI: 1.05, 3.42). Importantly, potential users were less likely to own a personal bicycle than unlikely users (OR: 0.48, 95% CI: 0.29, 0.79), which suggests that there is interest for public bicycle share use among those who may not bicycle regularly because they do not have easy or immediate access to a bicycle.
2.3.3. Motivators and deterrents

Motivators for potential users and deterrents for unlikely users are shown in Table 3. Among potential users, health was the most commonly selected motivator to using the public bicycle share program (selected by 47.0% of potential users). This was followed by motivators related to convenience, such as having docking stations near one’s home (45.5%) or destination (35.3%) and not owning a personal bicycle (41.0%). Motivators less commonly selected related to bicycle features and design.

Among those unlikely to use the program, the most common deterrents to using the program were preferring to ride a personal bicycle (46.9%) and the convenience of other transportation options (36.4%). This was followed by barriers that pertain to bicycling in general, such as weather (35.8%), traffic (35.1%), and fear of injury from crashes or falls (23.2%). Cost was a deterrent to one-fifth of unlikely users. Other less common deterrents specific to the bicycle share program were not having stations near their destination, lack of knowledge about how to use public bicycle share, the weight of the bicycles, and not having enough bicycles at docking stations.

<table>
<thead>
<tr>
<th>Table 2.1</th>
<th>Characteristics of current users and non-users of the Mobi by Shaw Go public bicycle share program in Vancouver, from a sub-sample of the 2017 Mobi member survey (n=1272) and 2017 Vancouver population survey (n=792).</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Current Users n=1272</td>
</tr>
<tr>
<td>n (%)</td>
<td>Weighted n (%)</td>
</tr>
<tr>
<td>Demographics</td>
<td></td>
</tr>
<tr>
<td>Sex, Female</td>
<td>Sex, Female</td>
</tr>
<tr>
<td>Age</td>
<td>Age</td>
</tr>
<tr>
<td>18-24</td>
<td>42 (3.3)</td>
</tr>
<tr>
<td>25-34</td>
<td>463 (36.4)</td>
</tr>
<tr>
<td>35-44</td>
<td>376 (29.6)</td>
</tr>
<tr>
<td>45-54</td>
<td>249 (19.6)</td>
</tr>
<tr>
<td>55-64</td>
<td>101 (7.9)</td>
</tr>
<tr>
<td>65+</td>
<td>41 (3.2)</td>
</tr>
<tr>
<td>Demographics, continued</td>
<td>Current Users n=1272</td>
</tr>
<tr>
<td>-------------------------</td>
<td>----------------------</td>
</tr>
<tr>
<td></td>
<td>n (%)</td>
</tr>
<tr>
<td><strong>Education</strong></td>
<td></td>
</tr>
<tr>
<td>High school or less</td>
<td>38 (3.0)</td>
</tr>
<tr>
<td>Post-secondary</td>
<td>791 (62.2)</td>
</tr>
<tr>
<td>Graduate post-secondary</td>
<td>443 (34.8)</td>
</tr>
<tr>
<td><strong>Employment status</strong></td>
<td></td>
</tr>
<tr>
<td>Employed</td>
<td>1151 (90.5)</td>
</tr>
<tr>
<td>Unemployed</td>
<td>30 (2.4)</td>
</tr>
<tr>
<td>Student</td>
<td>43 (3.4)</td>
</tr>
<tr>
<td>Retired</td>
<td>48 (3.8)</td>
</tr>
<tr>
<td><strong>Born in Canada (yes)</strong></td>
<td>805 (63.3)</td>
</tr>
<tr>
<td><strong>Household income</strong></td>
<td></td>
</tr>
<tr>
<td>&lt;$35,000</td>
<td>61 (4.8)</td>
</tr>
<tr>
<td>$35,000 - $74,999</td>
<td>228 (17.9)</td>
</tr>
<tr>
<td>$75,000 - $149,999</td>
<td>465 (36.6)</td>
</tr>
<tr>
<td>$150,000+</td>
<td>346 (27.2)</td>
</tr>
<tr>
<td>No response</td>
<td>172 (13.5)</td>
</tr>
<tr>
<td><strong>Has children living at home (yes)</strong></td>
<td>289 (22.7)</td>
</tr>
<tr>
<td><strong>Transportation Access and Behaviour</strong></td>
<td></td>
</tr>
<tr>
<td>Car share member (yes)</td>
<td>861 (67.7)</td>
</tr>
<tr>
<td>Access to personal car (yes)</td>
<td>817 (64.2)</td>
</tr>
<tr>
<td>Access to personal bicycle (yes)</td>
<td>888 (69.8)</td>
</tr>
<tr>
<td><strong>Primary mode of transportation</strong></td>
<td></td>
</tr>
<tr>
<td>Drive</td>
<td>316 (24.8)</td>
</tr>
<tr>
<td>Transit</td>
<td>380 (29.9)</td>
</tr>
<tr>
<td>Walk</td>
<td>302 (23.7)</td>
</tr>
<tr>
<td>Bicycle</td>
<td>274 (21.5)</td>
</tr>
<tr>
<td>Bicycled in the past year (yes)</td>
<td>–</td>
</tr>
<tr>
<td>Perceived safety of bicycling (Safe)</td>
<td>1009 (79.3)</td>
</tr>
<tr>
<td>Perception of bicycle share in Vancouver (Good idea)</td>
<td>–</td>
</tr>
<tr>
<td><strong>Home and work location relative to Mobi by Shaw Go service area</strong></td>
<td></td>
</tr>
<tr>
<td>Home and work outside</td>
<td>78 (8.0)</td>
</tr>
<tr>
<td>Home inside</td>
<td>240 (24.8)</td>
</tr>
<tr>
<td>Work inside</td>
<td>145 (15.0)</td>
</tr>
<tr>
<td>Home and work inside</td>
<td>506 (52.2)</td>
</tr>
</tbody>
</table>

* Number of respondents with valid home and work locations: current users (n=969), potential users (n=173), unlikely users (n=592)
| Table 2.2 | Demographic and transportation characteristics associated with being a ‘potential user’ of the Vancouver public bicycle share program compared to a ‘unlikely user’, from a sub-sample of the 2017 Vancouver population survey (n=792). |
|-----------|-------------------------------------------------------------------------------------------------|---|---|
|           | Unadjusted OR (95% CI)                                                                          | Adjusted OR† (95% CI) |
| Sex (ref: Female) |                                                                                                   |                           |
| Male      | 1.05 (0.75, 1.47)                                                                               |                           |
| Age (ref: 18-24 years) |                                                                                                   |                           |
| 25-34     | 1.64 (0.87, 3.08)                                                                               | 1.31 (0.66, 2.61)        |
| 35-44     | 0.98 (0.51, 1.90)                                                                               | 0.96 (0.46, 1.98)        |
| 45-54     | 0.53 (0.26, 1.06)                                                                               | 0.61 (0.29, 1.30)        |
| 55-64     | 0.52 (0.25, 1.06)                                                                               | 0.68 (0.32, 1.45)        |
| 65+       | 0.10 (0.04, 0.28)                                                                               | 0.18 (0.06, 0.53)        |
| Education (ref: High school or less) |                                                                                                   |                           |
| Post-secondary | 0.99 (0.56, 1.75)                                                                                   |
| Graduate post-secondary | 1.12 (0.59, 2.14)                                                                                   |
| Employment status (ref: Unemployed/Other*) |                                                                                                   |                           |
| Employed  | 2.99 (1.96, 4.56)                                                                               | 2.04 (1.14, 3.67)        |
| Born in Canada (ref=No) |                                                                                                   |                           |
| Yes       | 0.73 (0.52, 1.04)                                                                               | 0.69 (0.47, 1.01)        |
| Household Income (ref: >$150,000) |                                                                                                   |                           |
| $75,000 - $149,999 | 1.04 (0.57, 1.87)                                                                               | 1.12 (0.58, 2.14)        |
| $35,000 - $74,999 | 1.20 (0.66, 2.17)                                                                               | 1.39 (0.72, 2.67)        |
| <$35,000  | 1.83 (0.95, 3.50)                                                                               | 4.08 (1.92, 8.68)        |
| No response | 0.74 (0.37, 1.48)                                                                               | 1.16 (0.53, 2.55)        |
| Has children living at home (ref: No) |                                                                                                   |                           |
| Yes       | 1.18 (0.74, 1.87)                                                                               |                           |
| Carshare member (ref: No) |                                                                                                   |                           |
| Yes       | 2.36 (1.66, 3.36)                                                                               | 1.78 (1.17, 2.68)        |
| Access to a personal car (ref: No) |                                                                                                   |                           |
| Yes       | 0.65 (0.44, 0.94)                                                                               |                           |
| Access to a personal bicycle (ref: No) |                                                                                                   |                           |
| Yes       | 0.85 (0.61, 1.19)                                                                               | 0.48 (0.29, 0.79)        |
| Primary mode of transportation (ref: Walk) |                                                                                                   |                           |
| Transit   | 2.21 (1.32, 3.69)                                                                               | 1.90 (1.05, 3.42)        |
| Bicycle   | 1.13 (0.38, 3.30)                                                                               | 0.59 (0.19, 1.82)        |
| Car       | 1.23 (0.75, 2.03)                                                                               | 1.69 (0.96, 2.99)        |
| Cycled in the past year (ref: No) |                                                                                                   |                           |
| Yes       | 1.99 (1.42, 2.78)                                                                               | 2.15 (1.30, 3.54)        |
| Perceived safety of cycling (ref: Unsafe) |                                                                                                   |                           |
| Neither safe nor unsafe | 0.68 (0.38, 1.19)                                                                               | 0.62 (0.32, 1.18)        |
| Safe      | 2.00 (1.36, 2.94)                                                                               | 1.71 (1.11, 2.64)        |
| Home and work relative to Mobi service area (ref: Home and work outside) |                                                                                                   |                           |
| Home inside | 1.27 (0.82, 1.95)                                                                               |                           |
| Work inside | 1.44 (0.83, 2.47)                                                                               |                           |
| Home and work inside | 1.61 (1.01, 2.56)                                                                               |                           |
| Missing address | 2.06 (0.89, 4.78)                                                                               |                           |

†Adjusted OR includes variables retained in multiple logistic regression
*Other includes students and retired respondents
Table 2.3  Motivators to bicycle share use among potential users (n=182), ranked by the number of respondents that selected each item.

<table>
<thead>
<tr>
<th>Rank</th>
<th>Motivators</th>
<th>n (weighted)</th>
<th>% of total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>For my health</td>
<td>86</td>
<td>47.0</td>
</tr>
<tr>
<td>2</td>
<td>Stations near home</td>
<td>83</td>
<td>45.5</td>
</tr>
<tr>
<td>3</td>
<td>I don’t have my own bicycle</td>
<td>75</td>
<td>41.0</td>
</tr>
<tr>
<td>4</td>
<td>Stations near destination</td>
<td>64</td>
<td>35.3</td>
</tr>
<tr>
<td>5</td>
<td>Cost is inexpensive</td>
<td>53</td>
<td>29.1</td>
</tr>
<tr>
<td>6</td>
<td>For fun</td>
<td>47</td>
<td>25.9</td>
</tr>
<tr>
<td>7</td>
<td>Helmets are provided</td>
<td>45</td>
<td>24.7</td>
</tr>
<tr>
<td>8</td>
<td>Convenience over other modes of transportation</td>
<td>35</td>
<td>19.5</td>
</tr>
<tr>
<td>9</td>
<td>Bicycles have a basket</td>
<td>34</td>
<td>18.6</td>
</tr>
<tr>
<td>10</td>
<td>System is easy to use</td>
<td>33</td>
<td>17.9</td>
</tr>
<tr>
<td>11</td>
<td>Bicycles have lights</td>
<td>33</td>
<td>17.9</td>
</tr>
<tr>
<td>12</td>
<td>Get to ride for free after paying membership fee</td>
<td>32</td>
<td>17.7</td>
</tr>
<tr>
<td>13</td>
<td>Bicycles have gears to help with hills</td>
<td>23</td>
<td>12.7</td>
</tr>
<tr>
<td>14</td>
<td>I like the appearance</td>
<td>9</td>
<td>4.8</td>
</tr>
</tbody>
</table>

Table 2.4  Deterrents to bicycle share use among unlikely users (n=610), ranked by the number of respondents that selected each item.

<table>
<thead>
<tr>
<th>Rank</th>
<th>Deterrents</th>
<th>n (weighted)</th>
<th>% of total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Prefer own bicycle</td>
<td>286</td>
<td>46.9</td>
</tr>
<tr>
<td>2</td>
<td>Less convenient than other types of transportation</td>
<td>222</td>
<td>36.4</td>
</tr>
<tr>
<td>3</td>
<td>Rain and bad weather</td>
<td>218</td>
<td>35.8</td>
</tr>
<tr>
<td>4</td>
<td>Traffic</td>
<td>214</td>
<td>35.1</td>
</tr>
<tr>
<td>5</td>
<td>Not interested in bicycling</td>
<td>192</td>
<td>31.4</td>
</tr>
<tr>
<td>6</td>
<td>Fear injury from crashes or falls</td>
<td>141</td>
<td>23.2</td>
</tr>
<tr>
<td>7</td>
<td>Cost is too expensive</td>
<td>122</td>
<td>20.1</td>
</tr>
<tr>
<td>8</td>
<td>No stations near home</td>
<td>118</td>
<td>19.3</td>
</tr>
<tr>
<td>9</td>
<td>Health concerns</td>
<td>106</td>
<td>17.3</td>
</tr>
<tr>
<td>10</td>
<td>Destinations are too far to bicycle</td>
<td>96</td>
<td>15.7</td>
</tr>
<tr>
<td>11</td>
<td>Time limits</td>
<td>92</td>
<td>15.1</td>
</tr>
<tr>
<td>12</td>
<td>Steep hills along my route</td>
<td>67</td>
<td>11.0</td>
</tr>
<tr>
<td>13</td>
<td>No stations near destination</td>
<td>58</td>
<td>9.5</td>
</tr>
<tr>
<td>14</td>
<td>I don’t know how to use the system</td>
<td>52</td>
<td>8.5</td>
</tr>
<tr>
<td>15</td>
<td>I don’t like having to wear a helmet</td>
<td>51</td>
<td>8.3</td>
</tr>
<tr>
<td>16</td>
<td>Bicycles are too heavy</td>
<td>35</td>
<td>5.8</td>
</tr>
<tr>
<td>17</td>
<td>No bicycle lanes along my route</td>
<td>30</td>
<td>4.8</td>
</tr>
<tr>
<td>18</td>
<td>Not enough public bicycles at docking stations</td>
<td>15</td>
<td>2.4</td>
</tr>
</tbody>
</table>
2.4. Discussion

This study examined the demographic and transportation characteristics of current, potential, and unlikely users of the public bicycle share program in Vancouver, Canada, as well as potential motivators and deterrents to public bicycle share use. Similar to trends observed in other cities, current public bicycle share users in Vancouver tended to be male, employed, and have higher educations and incomes as compared to non-users, and were more likely to use of active modes of transportation. Of the non-users, 23% were potential users and 77% were unlikely users. Potential users tended to be younger, have lower incomes, and were more likely to use public transit for their main mode of transportation, as compared to current and unlikely users.

As of fall 2017, estimates suggest the proportion of the population that had used the public bicycle share program is 6.2%. Among those who have not used the program, the majority (74%) think that a public bicycle share is a good idea for Vancouver, and nearly one in four indicate they are likely to use public bicycle share within the next year. This suggests that there is considerable opportunity to increase population level uptake of public bicycle share.

The challenge for public bicycle share operators is translating intention into action. People may intend to use public bicycle share, but similar to other intentions such as eating healthier foods or exercising more, intention does not always translate into action. Results from our previous population survey of Vancouver residents in 2016 suggest that the conversation rate from intending to use the public bicycle share program to actual use of the program is low. The 2016 and 2017 Vancouver population surveys were repeat cross-sectional surveys of Vancouver residents, and therefore did not track the same individuals over time, but provide estimates for use and potential use of the program at a population level. In 2016, 26.1% of respondents indicated they were likely to use public bicycle share within the next year, however, according to the 2017 survey conducted one year later, only 6.2% have used it.

Social marketing is one approach that may help increase the conversation rate from intention to action. The marketing mix, also known as the 4 Ps, are considered the core elements of a social marketing strategy, and include product, price, place, and promotion. We describe each of these elements below and provide examples of
corresponding strategies based on the findings from this study that may increase uptake of public bicycle share, particularly among the potential user group (Table 5).

**Product**

The product refers to the object or service being offered, and the benefits associated with the product. In the case of public bicycle share, the product is a service which allows users to rent and return bicycles at designated docking stations throughout a city. The benefits for users of public bicycle share programs could include expanded transportation networks, reduced travel times, one-way bicycle trips, and increased physical activity. Among the potential user group, health benefits and the convenience of stations were the most commonly cited motivators to using the public bicycle share program.

**Price**

Price refers to the perceived costs of the product or service being offered. Costs can include both monetary costs and non-monetary costs, such as time and effort. Our findings showed that potential users were much more likely to have lower incomes compared to current users, and that cost was cited as a barrier among 20% of unlikely users. Currently, standard annual memberships for Mobi by Shaw Go cost $129, and daily passes are $9.75. In spring 2018, Mobi by Shaw Go announced a one year pilot to offer discounted memberships ($20) to low income residents. Continuing this pilot, reducing the cost of regular memberships, and offering a cheaper single trip rate and free trial days could reduce the barrier for non-users to try public bicycle share. In addition, given that potential users were more likely to use transit and belong to car share programs compared to unlikely users, integrating public bicycle share payment with transit passes and car share memberships could reduce the time and effort it takes to try the public bicycle share program.

Marketing initiatives related to price are likely important contributors to the increase in public bicycle share use observed in Montréal during the 2017 season. At the end of the 2017 season, a total of 258,000 users had made a total of 4.8 million trips, which was a 10% increase in individual users and 16% increase in trips from the previous year. Two initiatives that may have contributed to increased uptake, among other factors, were the integration of transit passes, which allowed commuters to use
their transit pass to purchase single BIXI trips, and Free BIXI Sundays, which offered free 30-minute trips on the last Sunday of each month from May to November. A total of 172,935 trips were made on these trial days and the initiative was successful in attracting members, with 28% of those who tried the program for free later purchasing BIXI memberships.72

**Place**

Place refers to where and when the consumer can access the product or service.71 Previous studies have shown that those who live and work in close proximity to a bicycle share docking station are more likely to use the program,38,39,63,73 and amongst the potential group in our study, stations being located near one’s home and destination were among the most commonly cited motivators to program use. Public bicycle share service areas in many cities tend to disproportionately serve higher socioeconomic status neighbourhoods,29,30 and Vancouver is no exception.28 This may explain, in part, why current public bicycle share users in Vancouver were more likely to be of higher socioeconomic status compared to non-users. Mobi by Shaw Go recently expanded their program east to provide better access to lower income neighbourhoods. Continued expansion of the program, particularly to lower income neighbourhoods, may help to increase public bicycle share uptake and improve the equity of spatial access to the program.

In addition to station distribution, public bicycle share uptake is dependent on a city’s efforts in providing cycling infrastructure in the areas where the public bicycle share service area is located.37 Other than cost, station distribution, and preference for one’s own bicycle, the common deterrents to public bicycle share use related to barriers to bicycling more generally, such as rain and bad weather, traffic, lack of interest in bicycling, and fear of injury from crashes or falls. This emphasizes that a city’s efforts to provide safe bicycle infrastructure and promote bicycling as a transportation option are important for public bicycle share uptake.

**Promotion**

Promotion refers to the communication and advertising strategies used to promote the product or service.74 Messages are often crafted to highlight the costs and benefits of the product or service, and can be delivered through a variety of mediums
including print materials, media outlets, social media, and in person. The profile of the potential user group identified in this study and their motivators can help inform the development of advertising strategies. For example, potential users are more likely to use transit compared to unlikely users, and value having stations near their home or work. Potential strategies could include advertising on buses and at transit stations, having pop-up booths at busy transit stations to show people how to use system, and marketing messages that highlight that public bicycle share can save time and serve as the last mile linkage to destinations.

Table 2.5 The four “Ps” of social marketing applied to a public bicycle share program.

| Product | Public bicycle share service, which allows users to rent and return bicycles at designated docking stations throughout a city |
| Price | Reduce cost of memberships  
Offer a single trip pass option  
Free trial days  
Integrate payment with transit and car share programs |
| Place | Expand service area  
Provide safe bicycle infrastructure in areas where public bicycle share stations are located |
| Promotion | Pop-up booths at transit stations  
Advertising on public transit |

2.5. Strengths and Limitations

This study used data from a public bicycle share member survey and a population-based survey to better understand the profiles of current, potential, and unlikely users of a public bicycle share program in Vancouver, Canada. The use of a population-based survey allowed us to identify demand for public bicycle share among non-users at the population level, providing valuable information about who is in the ‘near market’ for the program and who is unlikely to use it. Our findings can help inform public bicycle share operators about the importance of station distribution, cost, and marketing and outreach efforts for the success of their program.

There are several limitations worth noting. We obtained a reasonably high cooperation rate in the Mobi member survey (29.4%), however, the demographic
characteristics of current users reflects those of survey respondents, rather than all members of the public bicycle share program. Moreover, the Mobi member survey only included members of the program, and not casual users (i.e., day pass users). The survey sample in the Vancouver population survey was representative of the Vancouver population based on age and sex, but underrepresented immigrants, and residents with lower incomes and educations. This is a common challenge in surveys.

In addition, we did not consider frequency of public bicycle share usage. Usage for public bicycle share members surveyed ranged from 0.1 to 92.7 trips per month, with a mean of 10.3. Future studies could stratify users based on their frequency of use, or intended frequency of use for potential users.

We asked respondents to select all the reasons that would influence their decision to use or not use public bicycle share, but did not ask them to weight their relative influence. Thus, the most commonly selected factors presented here should not necessarily be conflated with the most important factors to influence behavior change. For example, health was the most commonly selected motivator among potential users. Although health may be a desired benefit, health on its own is likely a poor motivator for influencing travel behavior change. There could also be important motivators and deterrents missing from this list, given that not one motivator or deterrent was selected by over 50% of respondents. Also, respondents may not have had sufficient knowledge about the program to assess all motivators and deterrents accurately, such as program cost or time limits.

Finally, the findings from this study reflect the likelihood of public bicycle share use in the Vancouver population. It is difficult to assess the generalizability of these findings to other cities. However, the demographic profile of current users in Vancouver is similar to the demographic profile identified in other cities, which could suggest that there are also similarities to the profiles of potential and unlikely users identified in this study.

2.6. Conclusion

Public bicycle share programs are widely touted as having the potential to reduce the public health burden associated with physical inactivity and also reduce air pollution,
greenhouse gas emissions, and motor vehicle traffic. However, public bicycle share programs in many cities, including Vancouver, tend to appeal to a higher socioeconomic status segment of the population that primarily use active modes of transportation for their day to day travel. In order to meaningfully contribute to shifts towards active and sustainable modes of transportation, and to do so equitably, public bicycle share programs need to appeal to a broader population. Our results suggest there is interest in using the public bicycle share program among non-users, particularly among those who are younger, have lower household incomes, and use public transit. To reach currently underrepresented lower income populations, reducing the cost and expanding the service area to lower income neighbourhoods are likely to help. Findings from this study can help inform targeted marketing and outreach to increase public bicycle share uptake in the population.
Chapter 3.

Evaluation of the impact of a public bicycle share program on bicycling in Vancouver, Canada

3.1. Introduction

Public bicycle share programs are an example of a population-based intervention with potential to shift populations towards active transportation. Over the past decade, there has been a marked increase in the popularity and number of public bicycle share programs operating globally, increasing access to bicycling in these cities. Literature on public bicycle share programs covers the demographics of system users, motivators and barriers to use, usage and redistribution patterns, and equity considerations, however, there is limited evidence on the population level impacts of these programs on bicycling. These programs have the potential to increase population-wide bicycling by increasing access to bicycling for those who do not own a personal bicycle, increasing the convenience of bicycling, and by normalizing bicycling as a form of transportation.

For interventions where randomization or experimental control is not possible, natural experiment studies can be used to study potential intervention effects. To date, there is one example of a natural experiment study of a public bicycle share program in Montréal. This study found increases in self-reported bicycling for those who lived close to a bicycle share docking station relative to those who were not in the bicycle share zone at the end of the second season of BIXI Montréal. These findings provide evidence on the impacts of bicycle share on bicycling for those who live near a docking station, but there is limited evidence on the effects for those working in the area. Moreover, public bicycle share programs are implemented at different scales and program uptake varies widely across cities. Assessing the impacts of public bicycle share in different cities can provide decision makers with evidence on potential changes.

2 A version of this chapter has been submitted for publication.

Hosford, K., Fuller D., Lear, A. S., Teschke, K., Gauvin, L., Brauer, M., Winters, M. Evaluation of the impact of a public bicycle share program on population bicycling in Vancouver, BC.
in population bicycling associated with bicycle share programs implemented at different scales and in different contexts.

In July 2016, the City of Vancouver implemented a public bicycle share program, Mobi by Shaw Go, as part of their commitment to make bicycling more accessible to Vancouver residents. The program was implemented in Vancouver’s most densely populated area, and as of October 2017, had over 1200 bicycles at 122 stations covering a land area of 17 km$^2$.$^{52}$ The objective of this study was to examine whether there were increases in bicycling amongst those living or working in close proximity ($\leq$500m) to Vancouver’s public bicycle share program relative to those living and working outside the program’s service area.

3.2. Methods

3.2.1. Context

The City of Vancouver is home to more than 631,000 residents.$^{50}$ With over 320 km of bikeways and a mild climate, bicycling year-round is a viable option.$^{78}$ In 2016, bicycling accounted for approximately 6.1% of all trips made to work, higher than most other Canadian cities.$^{50}$ In the first year of Vancouver’s public bicycle share program, 6,400 memberships were purchased and approximately 436,000 trips were taken on Mobi bicycles.$^{79}$ The cost to use Mobi by Shaw Go for unlimited 30-minute trips is $9.75 (Canadian dollars) for a day pass, $75 for a 3-month pass, and $129 for an annual pass (as of October 2017)$^{16}$

3.2.2. Design

We used a repeated cross-sectional design. Vancouver residents ($\geq$18 years) were recruited through an online panel using age and sex quotas to obtain representative samples. Surveys were conducted prior to the implementation of the public bicycle share program, (T0; October 13-28, 2015); in the early phase of implementation, (T1; October 13-31, 2016); and 15 months post implementation, (T2; October 13-31, 2017). The survey included questions on travel patterns in the past seven days, physical activity, bicycling behaviour, bicycle share knowledge and use (or potential use, pre-implementation), individual and household demographics, and place of
residence and work or school. The number of bicycles and docking stations available during each survey period are shown in Figure 1 (see Appendix C for maps). All study procedures were approved by the Simon Fraser University Research Ethics Board and respondents provided informed consent.

3.2.3. Measures

The outcome was self-reported bicycling in the past week. Respondents were categorized according to whether they reported bicycling for any purpose (transportation or leisure) in the past week (>0 minutes) or not (0 minutes).

The primary independent variables were survey period (i.e. year) and residing or working within the bicycle share service area (i.e., exposure to the bicycle share service area). Survey period was operationalized by using dummy variables to distinguish the three survey periods: T0 (2015), T1 (2016), and T2 (2017). Exposure to the bicycle share service area was based on respondent’s home and work locations, where respondents with one or more Mobi by Shaw Go docking stations within a 500 meter road network buffer of their home, work or school were considered to be within the service area. We picked a distance of 500 meters because previous public bicycle share studies use this distance to define bicycle share service areas, and because living within 500 meters of a docking stations is associated with increased odds of using bicycle share. We asked survey respondents to provide a 6 digit postal code or the
nearest intersection for their home and, if applicable, work or school location. We
geocoded this information and the location of docking stations (provided by Mobi by
Shaw Go) in ArcGIS 10.5. In urban areas, postal codes correspond to approximately one
city block. We assigned respondents to one of four groups: (1) not exposed, (2) exposed
at work, (3) exposed at home, or (4) exposed at work and home. Even though there was
no public bicycle share program in 2015, we categorized 2015 respondents to one of the
four exposure groups based on docking station locations in October 2016. This allows us
to make a reasonable comparison of intervention and control groups over time.

Potential confounders were identified a priori based on individual and
environmental variables that could influence bicycling. Individual variables included sex,
age, education, annual household income, place of birth (Canada or elsewhere), car
ownership, and self-reported health. Environmental variables considered were mean
weekly temperature and total precipitation in the week preceding survey completion, as
differences in weather may affect bicycling rates across survey periods. Data on
temperature and precipitation were obtained from Environment Canada.81

3.2.4. Analysis

We applied post-stratification weights based on age and sex strata in the 2016
Canadian census data to all analyses. We ran unadjusted and adjusted logistic
regression models with difference in differences estimators to assess associations
between bicycling, time, and exposure to the public bicycle share service area. This
approach compares the difference in outcomes (i.e., bicycling) for a population that is
exposed to the intervention (i.e., lives or works within the service area) and for a
population that is not exposed (i.e., lives and works outside the service area) before and
after the intervention.45,47 Difference in differences models include 1) a time variable,
which estimates the average change in the outcome over time, 2) a treatment variable,
which estimates differences between the intervention and control group, and 3) an
interaction term between time and treatment, which estimates the difference in the
average change in outcome over time between the intervention and control group.82 The
interaction term is intended to estimate the effect of the intervention on the outcome over
time and is therefore the primary effect of interest in this analysis. We included
covariates associated with the dependent variable in bivariate analysis at a significance
level of p<0.10 in multiple logistic regression and used backward stepwise regression
using the Akaike Information Criterion (AIC) to construct a model with the lowest AIC value. Independent variables typically associated with bicycling (age, sex, and income) were included in the multiple regression model, even if not statistically significant.

3.3. Results

The pooled sample included 3072 respondents (≥18 years) with 1111 respondents in 2015, 995 in 2016, and 966 in 2017. Cooperation rates were 21.0%, 19.8%, and 15.6%, by year. Of the 3072 respondents, 168 were excluded because they lived outside the study area, and 263 were excluded because of missing postal code (n=176) or sociodemographic data (n=87). Our final sample included 2641 participants (86% of the initial sample).

Weighted demographic characteristics and bicycling rates, by year, are in Table 1. The sample is reflective of the Vancouver population in terms of age and sex, however, respondents in the surveys had higher incomes and education levels and were more likely to be born in Canada compared to census data. The proportion of respondents that had bicycled (on a personal bicycle or Mobi by Shaw Go bicycle) at least once for any purpose in the past 7 days was 17.1% in 2015, 15.6% in 2016, and 17.4% in 2017. A larger proportion of respondents engaged in recreational bicycling as compared to utilitarian bicycling. The proportion that had used a Mobi by Shaw Go bicycle increased from 3.2% in 2016 to 6.2% in 2017. Support for the public bicycle share program increased slightly from 70.0% of respondents reporting that the program was a good idea for Vancouver in 2015 to 74.5% in 2017.

In bivariate analyses, all variables were associated with odds of bicycling at p<0.10 with the exception of education, place of birth, and weather variables. The latter variables were excluded from adjusted models because they did not reach significance in bivariate models. Weighted logistic regression models examining the relationship between exposure to the bicycle share service area, time, and their interaction with bicycling in the past 7 days are shown in Table 2. In the full model, the coefficient for survey period is an estimate of the average change in bicycling over time in the unexposed group. We observed that for people not living or working in the service area, the odds of bicycling was not different at T1 or T2, compared to T0. The coefficient for exposure is an estimate of baseline differences between the exposed (living and/or
working in the service area) and unexposed groups. At baseline, relative to the unexposed group, the odds of bicycling was not different at any level of exposure.

The interaction term (time x exposure), the primary coefficient of interest, estimated the difference in the average change in the outcome over time between the exposed and unexposed groups. Over the study period, there was no evidence that the implementation of the bicycle share program increased the odds of bicycling for those who only work or only live within the service area, relative to those outside the service area. For those who both live and work within the service area, the odds of bicycling was greater at T1 (OR: 2.26, 95% CI: 1.07, 4.80) as compared with those outside the service area, and was also in the positive direction at T2, although the confidence interval crossed 1 (OR: 1.37, 95% CI: 0.67, 2.83). Due to relatively small sample sizes at each exposure level, the confidence intervals were wide for the interaction term.
Table 3.1  Weighted sociodemographic characteristics of survey respondents’ at three time points concurrent with the launch of the Public Bicycle Share Program in Vancouver, Canada (2015-2017).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Pre-implementation T0, Oct 2015 n=939</th>
<th>T1, Oct 2016 n=841</th>
<th>T2, Oct 2017 n=862</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>weighted n (%)</td>
<td>weighted n (%)</td>
<td>weighted n (%)</td>
</tr>
<tr>
<td>Bicycling (any purpose) in the past 7 days</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>160.8 (17.1)</td>
<td>131.6 (15.6)</td>
<td>149.7 (17.4)</td>
</tr>
<tr>
<td>No</td>
<td>778.0 (82.9)</td>
<td>709.8 (84.4)</td>
<td>712.2 (82.6)</td>
</tr>
<tr>
<td>Utilitarian bicycling in the past 7 days</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>104.2 (11.1)</td>
<td>87.9 (10.4)</td>
<td>92.4 (10.7)</td>
</tr>
<tr>
<td>No</td>
<td>834.6 (88.9)</td>
<td>753.5 (86.6)</td>
<td>769.5 (89.3)</td>
</tr>
<tr>
<td>Recreational bicycling in the past 7 days</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>115.9 (12.3)</td>
<td>99.9 (11.9)</td>
<td>117.6 (13.6)</td>
</tr>
<tr>
<td>No</td>
<td>822.9 (87.7)</td>
<td>741.5 (88.1)</td>
<td>744.3 (86.4)</td>
</tr>
<tr>
<td>Bicycle share service area*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Outside</td>
<td>528.6 (56.3)</td>
<td>463.3 (55.1)</td>
<td>413.2 (47.9)</td>
</tr>
<tr>
<td>Work inside</td>
<td>132.1 (14.1)</td>
<td>114.1 (13.6)</td>
<td>94.3 (10.9)</td>
</tr>
<tr>
<td>Home inside</td>
<td>156.4 (16.7)</td>
<td>166.5 (19.8)</td>
<td>206.9 (24.0)</td>
</tr>
<tr>
<td>Home and work inside</td>
<td>121.8 (13.0)</td>
<td>97.6 (11.6)</td>
<td>147.4 (17.1)</td>
</tr>
<tr>
<td>Bicycle share use</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>- -</td>
<td>26.9 (3.2)</td>
<td>53.7 (6.2)</td>
</tr>
<tr>
<td>No</td>
<td>- -</td>
<td>808.7 (96.1)</td>
<td>802.4 (93.1)</td>
</tr>
<tr>
<td>Don’t know</td>
<td>- -</td>
<td>5.8 (0.7)</td>
<td>5.8 (0.7)</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>486.7 (51.8)</td>
<td>435.3 (51.7)</td>
<td>443.6 (51.4)</td>
</tr>
<tr>
<td>Male</td>
<td>453.1 (48.2)</td>
<td>406.1 (48.3)</td>
<td>419.3 (48.6)</td>
</tr>
<tr>
<td>Perception of bicycle share in Vancouver</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Good idea</td>
<td>663.1 (70.0)</td>
<td>606.9 (71.1)</td>
<td>653.1 (74.5)</td>
</tr>
<tr>
<td>Perceived safety of bicycling in Vancouver</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Safe</td>
<td>435.9 (46.0)</td>
<td>391.1 (45.8)</td>
<td>431.6 (49.2)</td>
</tr>
<tr>
<td>Age (years)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18-24</td>
<td>99.2 (10.6)</td>
<td>85.5 (10.2)</td>
<td>86.7 (10.1)</td>
</tr>
<tr>
<td>25-34</td>
<td>210.2 (22.4)</td>
<td>181.0 (21.5)</td>
<td>191.1 (22.2)</td>
</tr>
<tr>
<td>35-44</td>
<td>161.5 (17.2)</td>
<td>142.1 (16.9)</td>
<td>146.7 (17.0)</td>
</tr>
<tr>
<td>45-54</td>
<td>152.7 (16.3)</td>
<td>145.8 (17.3)</td>
<td>147.2 (17.1)</td>
</tr>
<tr>
<td>55-64</td>
<td>136.5 (14.5)</td>
<td>126.0 (15.0)</td>
<td>128.9 (15.0)</td>
</tr>
<tr>
<td>65+</td>
<td>178.7 (19.0)</td>
<td>161.0 (19.1)</td>
<td>161.3 (18.7)</td>
</tr>
<tr>
<td>Annual household income</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;$50,000</td>
<td>228.8 (24.4)</td>
<td>207.7 (24.7)</td>
<td>216.3 (25.1)</td>
</tr>
<tr>
<td>$50,000 - $150,000</td>
<td>427.9 (45.6)</td>
<td>395.2 (47.0)</td>
<td>403.9 (46.9)</td>
</tr>
<tr>
<td>$&gt;150,000</td>
<td>79.8 (8.5)</td>
<td>84.6 (10.1)</td>
<td>96.4 (11.2)</td>
</tr>
<tr>
<td>No response</td>
<td>202.3 (21.5)</td>
<td>153.9 (18.3)</td>
<td>145.3 (16.9)</td>
</tr>
<tr>
<td>Car ownership</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>749.6 (79.8)</td>
<td>665.1 (79.0)</td>
<td>645.0 (74.8)</td>
</tr>
<tr>
<td>No</td>
<td>189.2 (20.2)</td>
<td>176.3 (21.0)</td>
<td>217.0 (25.2)</td>
</tr>
<tr>
<td>Self-reported health</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Poor/Fair</td>
<td>135.1 (14.4)</td>
<td>121.5 (14.4)</td>
<td>96.0 (11.1)</td>
</tr>
<tr>
<td>Good</td>
<td>292.9 (31.2)</td>
<td>279.4 (33.2)</td>
<td>267.3 (31.0)</td>
</tr>
<tr>
<td>Very Good/Excellent</td>
<td>510.8 (54.4)</td>
<td>440.6 (52.4)</td>
<td>498.6 (57.8)</td>
</tr>
<tr>
<td>Mean temperature</td>
<td>13.1 °C</td>
<td>11.5 °C</td>
<td>10.4 °C</td>
</tr>
<tr>
<td>Mean daily rainfall</td>
<td>2.5 mm</td>
<td>8.1 mm</td>
<td>11.3 mm</td>
</tr>
</tbody>
</table>

*The bicycle share service area is defined as the area within 500 meters of a public bicycle share docking station.
Table 3.2  Results of weighted logistic regression analyses examining associations between bicycling and survey period, exposure to the public bicycle share service area, and their interactions at three time points concurrent with the 2016 launch of the public bicycle share program in Vancouver, BC (2015-2017).

<table>
<thead>
<tr>
<th></th>
<th>Bicycling</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Unadjusted OR (95% CI)</td>
<td>Adjusted† OR (95% CI)</td>
<td></td>
</tr>
<tr>
<td><strong>Survey Period</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>October 2015, T0 (Ref)</td>
<td>1.00</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>October 2016, T1</td>
<td>0.88 (0.62, 1.26)</td>
<td>0.90 (0.62, 1.29)</td>
<td></td>
</tr>
<tr>
<td>October 2017, T2</td>
<td>1.09 (0.77, 1.56)</td>
<td>1.04 (0.73, 1.50)</td>
<td></td>
</tr>
<tr>
<td><strong>Exposure to bicycle share service area</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No exposure (Ref)</td>
<td>1.00</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>Work only</td>
<td>1.28 (0.78, 2.10)</td>
<td>1.07 (0.63, 1.81)</td>
<td></td>
</tr>
<tr>
<td>Home only</td>
<td>1.53 (0.98, 2.40)</td>
<td>1.52 (0.96, 2.43)</td>
<td></td>
</tr>
<tr>
<td>Home and work</td>
<td>1.08 (0.64, 1.84)</td>
<td>0.77 (0.44, 1.33)</td>
<td></td>
</tr>
<tr>
<td><strong>Survey x Exposure</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T0 x no exposure (Ref)</td>
<td>1.00</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>T1 x work</td>
<td>0.84 (0.39, 1.81)</td>
<td>0.82 (0.37, 1.81)</td>
<td></td>
</tr>
<tr>
<td>T2 x work</td>
<td>0.90 (0.42, 1.94)</td>
<td>0.94 (0.42, 2.08)</td>
<td></td>
</tr>
<tr>
<td>T1 x home</td>
<td>0.66 (0.33, 1.31)</td>
<td>0.59 (0.29, 1.20)</td>
<td></td>
</tr>
<tr>
<td>T2 x home</td>
<td>0.55 (0.29, 1.05)</td>
<td>0.48 (0.25, 0.94)</td>
<td></td>
</tr>
<tr>
<td>T1 x home and work</td>
<td>2.17 (1.04, 4.55)</td>
<td>2.26 (1.07, 4.80)</td>
<td></td>
</tr>
<tr>
<td>T2 x home and work</td>
<td>1.37 (0.68, 2.77)</td>
<td>1.37 (0.67, 2.83)</td>
<td></td>
</tr>
</tbody>
</table>

† Model controls for age, sex, annual household income, car ownership, and self-reported health.

3.4. Discussion

This study assessed whether there were greater increases in bicycling amongst those living or working in close proximity to Vancouver’s public bicycle share program relative to those living and working outside the program’s service area. The results show that over time, those only living or only working within the service area were not more likely to bicycle compared to those outside the service area. For those both living and working within the service area, we observed an increase in bicycling at three months following the implementation of the bicycle share program (T1), however this increase was not sustained at fifteen months following implementation (T2). This could be explained by an initial excitement surrounding program implementation that subsided over time.
Public bicycle share programs can directly increase population bicycling from the use of the program itself, and also indirectly, through increases from personal bicycle use. The second pathway, increases from personal bicycles, could arise if the use of public bicycle share motivates users to also ride their personal bicycles more frequently, or if having a public bicycle share program as part of the city normalizes bicycling and influences non-users to bicycle more frequently. It is plausible that residents who live and work within the service area might increase their bicycling more than those outside the service area, as they are exposed to bicycle share on a regular basis, and therefore, may be more likely to use the program (pathway 1) or be influenced to ride their own personal bicycle (pathway 2).

The current findings differ from a similar study in Montréal that showed increases in overall bicycling for those who lived close to a docking station relative to those outside the service area, at the end of the second season of BIXI Montréal. In the current study, we did observe a positive association for those who both lived and worked within the service area in the first season, but not for those who only lived in the area. Further, the observed confidence intervals of the effect estimate crossed 1 in the second season. Differences in scale and implementation timeline may be one explanation for differing results. Vancouver’s program started modestly with 250 bicycles at 23 stations located in Vancouver’s downtown core, and slowly built over the two years to 1200 bicycles at 122 stations. In comparison, the Montréal program launched with 5000 bicycles at 450 stations in the first year. In addition, only a small proportion of Vancouver residents had used bicycle share (3.2% of survey respondents in 2016, 6.2% in 2017), lower than the estimated 8.2% of Montréal residents that used bicycle share in the first season of the program’s operation (May-Nov 2010).

Moreover, trips made on bicycle share bicycles were only a small fraction of overall bicycling trips in Vancouver, which are estimated at 46 million trips per year based on daily estimates of 128,000 trips per day. In Mobi by Shaw Go’s first year of operation, approximately 436,000 trips were made on Mobi bicycles, and at the point of our 2017 survey (15 months of operation, including two summers), a total of over 680,000. It is also worth noting that not all trips made by bicycle share are new trips because some trips would have been made by personal bicycle previously. Surveys with Mobi by Shaw Go members suggest that approximately 6-8% of bicycle share trips replace trips previously made by personal bicycles.
Attributing increases in bicycling to a bicycle share program is difficult because the implementation of these programs often coincides with secular trends of increased bicycling, as cities typically make upgrades to bicycle infrastructure concurrently. Difference in differences analysis can partly, but not completely, account for some of these other factors. For example, between our baseline survey at T0 and follow-up survey at T2, although a modest 16 km of bicycle routes were added, a greater density of routes were added inside the bicycle share service area (0.44 km/km²) compared to outside (0.09 km/km²). In addition, there are two crucial assumptions of the difference in differences method that should be met in order to obtain unbiased estimates of the intervention effect. First, the parallel trend assumption, which assumes that in the absence of the intervention the average outcomes for the intervention group and control group would follow parallel trends over time. This assumption is difficult to test because it would require multiple data points prior to the intervention and spatially resolved longitudinal data on overall cycling is not available. Second, difference in differences assumes no changes in relevant aspects of the population demographic structure over time. In our case, there are two possible ways this assumption could be violated: changes in the sociodemographic structure of the study area overall, or changes in the sociodemographic structure in the exposed and non-exposed groups due to the expansion of the bicycle share service area over time. We did not see any other major differences in the composition of our sample over time, with the exception of car access. The proportion of respondents with access to a car decreased over time from 79.8% (95% CI: 77.1-82.3) at T0 to 74.8% (95% CI: 71.8-77.7) at T2, and access decreased slightly more in the unexposed group compared to the exposed groups. This reflects an overall shift to sustainable modes of transportation among Vancouver residents, and could also influence bicycling over time.

Public bicycle share programs are just one example of an intervention that cities are employing to increase bicycling. Other interventions to increase bicycling include bicycle infrastructure development (i.e., protected bicycle lanes, traffic signals, bicycle parking at transit stations), marketing and educational programs (e.g., Bicycle to Work Week), and traffic calming. Studies examining specific bicycling interventions often show modest impacts on bicycling, however, Pucher et al. notes that that the combined effect of all bicycling infrastructure in a city (e.g., bicycle lanes, traffic signals, bicycle share programs, etc.) may have a greater impact on bicycling than the sum of its
Public bicycle share programs contribute to the overall efforts of a city to improve bicycling, and in time, may help shift a population towards bicycling.

3.5. Strengths and Limitations

We employed rigorous methods to assess population-level impacts and are one of only two studies to use repeated cross-sectional surveys with independent samples, before and after the implementation of a public bicycle share program. In addition to considering exposure to the bicycle share service area based on home locations, we also consider exposure based on work locations, which is often not considered in evaluations of bicycling interventions.

Our study faces limitations common to natural experiment studies including bias from residual and unmeasured confounding, and selection bias. This analysis does not control explicitly for changes to the built environment (e.g., addition of bicycling infrastructure). A greater density of bikeways was added inside the bike share service area (0.44 km/km²) compared to outside (0.09 km/km²), which could positively bias the intervention effect. However, we do not believe that the slight differential increase in bicycle route length had a substantial impact on the results because additional infrastructure was only a 5% increase in route length (+16km, compared to the overall length of bicycle infrastructure at baseline of ~306km). Second, our surveys were matched in time of year, but weather did vary by survey year. The weather during the 2015 survey period was somewhat warmer and dryer than in 2016 and 2017. In bivariate analyses temperature and rainfall were not associated with bicycling in the past week, and these were not included in final models. Third, selection bias could occur as respondents in our surveys had higher incomes and educations, and underrepresented immigrants as compared to the Vancouver population. This is common for both telephone and online surveys, but suggests that the estimates of bicycling in the general population may be overestimates as income, education status, and immigrant status are predictors of bicycling.

We assigned respondents to one of four exposure levels, to go beyond past work and consider exposures at both home and work. With this more nuanced consideration, confidence intervals are wide and in some cases some caution is warranted when interpreting the results. Additionally, within the service area, changes in bicycling may
vary across neighbourhoods. Future work could consider assessing whether public bicycle share programs impact bicycling differently for neighbourhoods within the service area.

The cost and pricing structure for Mobi by Shaw Go use changed from 2016 to 2017, which could affect usage of the program. At T1, there were two pass options: a day pass ($7.50) and a monthly pass ($10-20 depending on plan). At T2, the cost for the day pass increased ($9.75), the monthly pass was replaced by a 3-month pass ($75), and there was an additional annual pass option ($129-159).

Finally, we used self-reported bicycling in the past week as our outcome measure, where respondents who reported at least one trip by bicycle were categorized as bicycling. Other metrics such as number of bicycle trips, % bicycling to work, and minutes of bicycling are also common in the literature.\textsuperscript{44} In our survey we did collect minutes of bicycling in the past week. Descriptive results for minutes of bicycling over time showed a similar trend to the results observed in this analysis. Future analyses could also consider evaluating the impact of a public bicycle share programs on changes in people’s attitudes towards bicyclists and bicycling.

3.6. Conclusion

Using a natural experiment study design, we observed that the implementation of the public bicycle share program in Vancouver was associated with greater increases in bicycling for those living and working inside the bicycle share service area relative to those outside the service area in the early phase of implementation, but this effect did not sustain over time. We did not find an association between increased bicycling over time and only living or only working within the service area, relative to those outside the service area. It may be that the program is either too early in its implementation or was implemented at too small a scale to have a measurable effect over our study period for those exposed to the program at only home or work. These findings can be complemented by other natural experiment studies that examine the impact of bicycle share programs implemented at different scales in other cities.
Chapter 4.

Conclusion

4.1. Summary & Policy Implications

This thesis sought to understand demand for a public bicycle share program among Vancouver residents as well as the impact of the program on population bicycling levels. Findings from this thesis have policy relevance for program operators looking to increase bicycle share uptake and for cities considering whether to implement a bicycle share program. Below I summarize the main findings and policy implications of the two research chapters in this thesis.

In Chapter 2, I examined the sociodemographic and transportation characteristics of current, potential, and unlikely users of the public bicycle share program and identified motivators and deterrents to program use. Similar to trends in other cities, current users of the Vancouver public bicycle share program tended to be male, employed, and have higher educations and incomes as compared to non-users, and were more likely to use active modes of transportation. Amongst non-users of public bicycle share, nearly one in four were identified as potential users. Importantly, this chapter provided direction on marketing and outreach efforts to increase uptake, particularly among potential users. Key messages were:

- There is opportunity to increase equitable uptake of public bicycle share, as lower income residents are currently underrepresented among current users of public bicycle share but are interested in using the program.

- The motivators among potential users related to health benefits, not owning a bicycle, and stations near their home or destination.

- The deterrents among unlikely users related to a preference for other modes of transportation, and barriers to bicycling more generally, such as rain and bad weather, traffic, and fear of injury from crashes or falls. Approximately one fifth identified cost as a barrier.
• Social marketing strategies that may encourage uptake in the potential user group include:

  o **Price:** Reducing cost of memberships, offering a single trip rate, free trial days, and integrated payment with transit passes and car share memberships.

  o **Place:** Expanding the service area to lower income neighbourhoods.

  o **Promotion:** Advertising on transit and pop-up booths at transit stations.

In Chapter 3, I used difference in difference estimation to assess the impact of the public bicycle share program on bicycling for those living or working inside the bicycle share service area, relative to those outside the service area. Key messages were:

• While those living and working inside the public bicycle share service area had initial increases in bicycling in the early phase of program implementation relative to those outside the service area, this increase did not sustain at 15 months post program implementation. No increases in bicycling for those who were only living or working inside the service area were observed.

• The approximately 436,000 trips made on public bicycle share bicycles in the first year of program operation constituted less than 1% of bicycling trips in the city.

• The public bicycle share program may have been too early in its implementation or implemented at too small a scale to have a measurable effect on bicycling two seasons into program operation.

Taken together, these two chapters suggest greater uptake of the public bicycle share program in Vancouver is likely needed to have an appreciable impact on population bicycling, and by extension, population health and environmental outcomes. The program is still in the early stages of implementation, and in time, may have a greater impact on bicycling. Findings from Chapter 2 are encouraging as they suggest there is considerable opportunity to increase public bicycle share uptake in Vancouver,
with nearly one in four non-users indicating interest in using the program within the next year. However, this chapter also highlights that other complementary initiatives, especially safety related investments such as separated bicycle lanes are also needed to encourage bicycle share uptake. Thus, cities with limited budgets for cycling infrastructure should carefully consider the value that public bicycle share programs may offer relative to other investments.

In contrast to the results in this thesis, an increase in bicycling was observed for Montréal residents who lived within the bicycle share service area in the second season of implementation. Differences in program size may be one explanation for differing results. As of the second season of operation, Vancouver’s program had 1200 bicycles at 122 stations and Montréal’s had approximately 5000 bicycles at 450 stations. Thus, programs implemented at a larger scales may be more successful at increasing bicycling.

4.2. Contributions

This thesis contributes to our understanding of population-level demand for a public bicycle share program and program impacts on bicycling. The second objective in particular, impacts on bicycling, helps address the evidence gap identified in Bauman et al.’s recent review as to whether public bicycle share programs can influence population physical activity through increased bicycling. Moreover, the methodology used in this thesis addressed the three methodological gaps of public bicycle share research described in the introductory chapter of this thesis:

1. Study population: We used population-based surveys to capture demand for public bicycle share in the general population and changes in bicycling behaviour over time. This allowed us to identify those in the near market for public bicycle share, and generate tailored recommendations for increasing public bicycle share uptake in this group. Moreover, the repeat cross-sectional population surveys allowed us to evaluate the impact the public bicycle share program had in the general population over time, including for users and non-users of the program.
2. **Natural experiment study design.** We used appropriate natural experiment methodology to evaluate the impacts of a real-world intervention on bicycling. To our knowledge, we are the second study, after the study of BIXI in Montréal,\(^{45}\) to conduct a pre-post evaluation of a public bicycle program with a representative sample of the population. The differing results between Vancouver and Montréal suggest that context is important, and there is value in evaluating programs implemented at different scales and in different contexts.

3. **Intervention exposure.** In addition to considering the impact of the public bicycle share program on bicycling for those living within the service area, we also considered the impact for those working in the area. We included four levels of exposure to the public bicycle share program in our analysis: (1) not exposed, (2) exposed at work, (3) exposed at home, and (4) exposed at work and home. Three months into program implementation, we found that those exposed at both home and work had a two-fold increase in bicycling, relative to those outside the service area. However, we did not observe an increase for those who only lived or only worked within the service area. Work location is often not considered in public bicycle share evaluations; however, our results suggest that including work exposure is important as the impact of the program differed for those who both lived and work within the service area.

### 4.3. Limitations and Future Work

Specific limitations of each study are detailed in the research chapters, however, below I present the broader limitations of this thesis and highlight areas for future work.

The population based cross sectional surveys included a sample of approximately 1,000 residents at three timepoints. Though this is a sufficiently large sample compared to other public bicycle share studies of users and non-users,\(^{39,40,66}\) the sample was broken into smaller sub-groups in each of the research chapters. Chapter 2 only considered non-users of public bicycle share in the 2017 survey (n=792), and further categorized the sample into potential users (n=182) and unlikely users (n=610) of public bicycle share. Chapter 3 used data from all three surveys, however assigned respondents to one of four exposure categories. Of the total analysis sample (n=2641), 1405 respondents were not exposed to the bicycle share service area, 341
were exposed at work only, 530 were exposed at home only, 367 were exposed at both home and work. The small sample sizes for populations exposed to the intervention may have limited my ability to detect small changes in bicycling. The proportion of our survey sample that resided inside the public bicycle share service area (32%) reflects very closely to that of the Vancouver population (33%) as of Fall 2017. However, future studies could consider oversampling residents residing within the public bicycle share service area, as was done in the Montréal study,45 to ensure sufficient power to detect small changes in bicycling.

Effects from built environment interventions often take time to materialize. The follow-up population surveys in this study were conducted at 3 months post bicycle share implementation and 15 months post bicycle share implementation, which may have been too early to detect intervention effects. However, it was reasonable to assume that intervention effects might be observed at 15 months because an increase in bicycling was observed in the second season of Montréal’s public bicycle share program.46 The different results between the two cities could be explained by a smaller scale program in Vancouver that was implemented on a much slower timeline than anticipated. Mobi by Shaw Go launched in June 2016 with 250 bicycles at 23 stations with the intention of having a total of 1,500 bicycles at 150 stations by the end summer 2016, however this phase of implementation was not completed until May 2018. Program expansion is currently underway to expand to 2,000 bicycles at 200 stations by the end of summer 2018. The City of Vancouver has provided additional funding to Dr. Winter’s study of the Vancouver Public Bike Share Program for a third follow up population survey of Vancouver residents in October 2018. I plan to add this follow up point to the analysis to assess whether changes in bicycling are observed in the third season of program operation, as well as changes in attitudes and uptake of the program.

A key challenge for natural experiment studies is selecting an appropriate control group. The control group should ideally be similar to the intervention group prior to the intervention, and in the difference in difference approach it is assumed that the outcome would have changed in a similar way for both groups in the absence of the intervention.77 In our sample of Vancouver residents, we assigned respondents who lived and/or worked within 500 meters of a public bicycle share docking station to the intervention group, and all others to the control group. The advantage of using respondents from the same city for the control group is that they experience the same
climate and share a similar political and social context to the intervention group. However, there is a risk of exposure misclassification because Vancouver residents who do not live or work inside the bicycle share service area can also take advantage of the public bicycle share program. Particularly because the public bicycle share program is located in and around Downtown Vancouver, which is Metro Vancouver’s primary business and entertainment district and an area frequented by residents who do not live or work in the area. Presumably any impacts on bicycling will be stronger for those who are exposed to the public bicycle share program on a regular basis, however, the effect could be biased towards the null if bicycling in the control group was also impacted by the public bicycle share program. An alternative approach could be to select a comparison city that shares similar characteristics to the study city but did not implement a public bicycle share program.89

An important caveat to interpreting the results from Chapter 3 is the measure of bicycling used. We used self-reported bicycling in the past seven days as our outcome measure of bicycling. This was the same measure used in the Montréal study, which allowed for comparisons to be made between results in the two cities. However, this measure gives an indication for the proportion of residents bicycling but does not provide information about frequency or duration of bicycling trips. Information about frequency and duration of bicycling trips, as well as mode substitution for new bicycling trips, are necessary for determining the contributions of public bicycle share programs to total physical activity levels and downstream health outcomes. Determining the downstream health impacts of public bicycle share programs is an important area for future research.

4.4. Knowledge Translation

This thesis is part of a larger study on the health, transportation, and equity impacts of the Vancouver public bicycle share program. Beyond the work described in this thesis, my role in the larger study of Vancouver’s public bicycle share program has been to analyze the repeat cross-sectional surveys of Vancouver residents (2015, 2016, & 2017) and the Mobi member surveys (2016 & 2017). These results have been shared with our partners at the City of Vancouver and Mobi by Shaw Go through various reports and presentations. In June 2018, I presented the survey results at ‘Bike Sharing in the Metro Region’, an event co-hosted by the Planning Institute of British Columbia’s South Coast Chapter and TransLink to discuss progress, challenges, and opportunities for
expanding bicycle share to Metro Vancouver. In November 2018, I will present the findings from this thesis at the Annual American Public Health Association Meeting.

In addition to the two research papers in this thesis, I led a study evaluating the spatial equity of public bicycle share service areas in Canadian cities. As of 2017, four of the five major Canadian bicycle share programs, including Vancouver’s, provided better access to higher socioeconomic status areas. This study was presented at the Annual Transportation Research Board Meeting in January 2018, and published in the Transportation Research Record.

4.5. Conclusion

Public bicycle share programs are a new mobility option that can offer users many benefits including expanded transportation networks, reduced travel times, and the ability to make one-way bicycle trips. This thesis aimed to understand demand for the Vancouver public bicycle share program and the impacts of the program on population bicycling. We found that there is opportunity to increase public bicycle share use, with nearly one in four non-users indicating they were likely to use the program within the next year. However, we did not observe an increase in bicycling for those living and/or working inside the bicycle share service area relative to those outside the service area in the second season of program operation. Greater uptake of the public bicycle share program in Vancouver is likely needed to have an appreciable impact on population bicycling, and by extension population health and environmental outcomes.
References


Appendix A.

Mobi Member Online Survey Questions

TRAVEL BEHAVIOUR
1. Overall, which mode of transportation do you use most often to get around?
2. Overall, how safe do you think cycling is in Vancouver?
3. In the past 3 MONTHS, how often did you typically travel using a Mobi bicycle?
4. In the past 3 MONTHS, how often did you typically travel using your own bike?
5. In the past 7 DAYS, did you do any of the following? (Please don't count any activity twice)

MOBI USE
6. How did you first learn about Mobi?
7. In your opinion, what impact has the implementation of Mobi had on... (Note: asked in 2016 only)
   a. the image of the City of Vancouver
   b. road safety in Vancouver
   c. the ease of travelling within Vancouver
   d. the promotion of active transportation in Vancouver
   e. the health of the population in Vancouver
   f. the ease of connecting with public transit in Vancouver
8. As a result of your use of Mobi, do you use each of the following types of travel options more often, less often, or about the same as before you joined Mobi?
9. Which of the following best describes your TYPICAL helmet use when riding a Mobi bicycle?
10. What is your main reason for not typically using a helmet when riding a Mobi bicycle?

MOBI TRIPS
11. Since joining Mobi, how many trips have you made on a Mobi bike? (Note: This question is primarily an administrative question used for branching in the survey to set up participants for question 12 (survey would only present fields to fill out for up to 3 trips…but fewer if fewer taken)
12. Please think about your most recent trip on Mobi. We shall call this "Trip A". (Repeat for TRIP B, C)
   i. What was the trip purpose?
   ii. Would you have made this trip if Mobi was not available?
   iii. If YES, what mode would you have used?
   iv. What other modes of transportation did you combine with Mobi on this trip?
MOTIVATORS & BARRIERS

13. In general, which of the following reasons motivated your decision to use Mobi? Select all that apply.
14. In general, which of the following reasons prevent you from using Mobi more often? Select all that apply.
15a. Please share how strongly you agree or disagree with each statement relating to the Mobi service area and supply. (Note: asked in 2016 only)
15b. Where specifically would you like Mobi to install another station (e.g. street, neighbourhood, landmark)?

MOBI CUSTOMER SERVICE

16a. How satisfied are you with your Mobi by Shaw Go membership? (Note: asked in 2017 only)
16. Please rate how easy or difficult it was for you to understand the following when using Mobi:
   a. Finding a bicycle or station
   b. Locking a bicycle
   c. Plan options and pricing information
   d. Overage fees
   e. Unlocking a bicycle (Note: asked 2016 only)
   f. Contacting customer service (Note: asked 2016 only)

Please rate the following questions 18-19 on a scale of 1 to 5, where 1 is Excellent and 5 is Poor. (Select one option)
17. Features of Mobi bikes and stations:
   a. Condition and cleanliness of bikes
   b. The way to report problems with bikes
   c. The appearance of bikes
   d. Condition of stations
   e. Docking a bike
   f. Cleanliness of equipment
   g. Map at station
   h. Lighting at stations
18a. Website and App:
   a. Website general functionality
   b. Registration process through website
   c. Station map on Website
18b. Have you ever used the Mobi by Shaw Go App? (Note: asked in 2017 only)
   Please rate:
   a. App general functionality
   b. Registration process through app
   c. Station map on app
19. Registration and the call center:
   a. Online registration
b. Obtaining your membership fob  
c. Fob activation  
d. Call centre wait time  
e. Customer service representative’s ability to solve issues

SAFETY & CYCLING INCIDENTS

20. How many times in the past 3 months have you been involved in a crash or fall (for any reason) while riding your own bike in the city?  
21. How many times in the past 3 months have you been involved in a crash or fall (for any reason) while riding a Mobi bicycle in the city?  
22. Please think about your most recent crash or fall. We shall call this "Crash/Fall A".  
   a. What was the month of the crash or fall?  
   b. Did your crash or fall involve any of the following?  
   c. Were you on a Mobi bike at the time of the crash or fall?  
   d. Did any of the following result from your crash or fall?  
   e. e. Was the crash reported to any of the following? …. (repeat for CRASH/FALL B, C etc.)

DEMOGRAPHIC INFORMATION

23. Do you have a driver's licence?  
24. What car share services do you belong to?  
25. How many of the following are kept in your household?  
26. How many people, including yourself, live in your household?  
27. Are you...? male or female?  
28. What year were you born?  
29. What is the highest level of education you have completed?  
30. What is your postal code of your home?  
31. What best describes your current employment status?  
32a. What is the postal code of your main place of work or study?  
32b. If you do not know the postal code, please give the name of your workplace or school and nearby cross-streets of your place of work or study  
33. Were you born in Canada?  
34. Vancouver residents come from many different backgrounds. How would you describe yourself?  
35. In general for someone your age, would you say that your health is:  
36. Which of the following best describes your total annual household income before taxes?  
37. Finally, do you have any suggestions to improve Mobi?
Appendix B.

Vancouver Population Online Survey Questions

SCREENING QUESTIONS
S0. Where in British Columbia do you live?
S1. What neighbourhood do you live in?
S2. What year were you born?

TRAVEL BEHAVIOUR
Q1. Overall, which mode of transportation do you use most often to get around?
   a. How often did you make such a journey over the last 7 days? AND
   b. How much time in total over the last 7 days did you spend travelling … by:
      Q2. to and from work. (e.g. travel to and from your place of work, accompanying
           your spouse to and from their work).
      Q3. For business, by which we mean any journeys in the course of your work or
           on employer’s business (e.g. travel to and from meetings, making deliveries, etc.)
      Q4. to and from a place of study (e.g. travel to and from your university or
           college) or to and from school (e.g. if you accompany a child to and from school).
      Q5. for shopping and personal business (e.g. food shopping, non-food shopping,
           window-shopping, visiting a doctor, bank, solicitor or estate agents, visiting a
           relative in hospital, or accompanying someone else to a doctor, hospital etc.).
      Q6. to visit friends and relatives and for other social activities. (e.g. a journey to
           and from the cinema or other entertainment facilities).
Q7. In the last 7 days, did you do any walking for recreation, health, fitness (including
    walking dog)? How many times? Please estimate the total time.
Q8. In the last 7 days, did you do any cycling for recreation, health or fitness? How many
    times? Please estimate the total time.
Q9. In the last 7 days, did you do any moderate to vigorous intensity physical activities in
    your leisure time? This could be any activity that made you sweat, such as jogging,
    playing sports, or the gym. How many times? Please estimate the total time.
Q10. In the last 7 days, did you do any moderate to vigorous intensity physical activities
     as part of your job? This could be any activity that made you sweat, such as jogging,
         playing sports, or the gym. How many times? Please estimate the total time.

CYCLING BEHAVIOUR
Q11. Overall, how safe do you think cycling is in Vancouver?
Q12. In the previous 12 months, have you used a bicycle?
Q12a. How often do you typically travel by bicycle?
Q12b. On your last trip by bicycle, did you wear a helmet?
Q13a. Would you consider using a bicycle in future? (Note: Only for those who have not
         used bicycle in past year.)
Q44. On a 4-point scale, with 1 being strongly disagree and 4 being strongly agree, how much would you agree with the following statement: “I would like to travel by bicycle more than I do now.” (Note: asked in 2017 only)
Q45a. Have you walked or bicycled on the new Arbutus Greenway in the past 12 months? (Note: asked in 2017 only)
Q45b. Have you walked or bicycled on the Point Grey Road Seaside Greenway in the past 12 months? (Note: asked in 2017 only)

PERCEPTIONS OF VANCOUVER’S PUBLIC BICYCLE SHARE (called “MOBI by Shaw Go”)

Q14. Have you ever heard of a public bike share program?
Q15. Do you think that a public bike share program is a good or bad idea for Vancouver?
Q34. Have you seen a public bike share station in Vancouver? (Note: asked in 2016 and 2017 only)
Q35. Have you seen anyone riding a public bike share bicycle in Vancouver? (Note: asked in 2016 and 2017 only)
Q36. Have you ever ridden a public bike share bicycle in Vancouver? (Note: asked in 2016 and 2017 only)
Q16. How likely would you be to use public bike share in Vancouver at some point in the next year, given that station locations are accessible to you? [If Q16 = 1 or 2 then ask Q17a]
Q17a. Which of the following reasons influence your decision to use the Vancouver public bike share? [check all that apply] [If Q16 = 3 or 4 then ask Q17b]
Q17b. Which of the following reasons influence your decision to not use the Vancouver public bike share? [check all that apply]

PUBLIC BICYCLE SHARE USERS [ONLY THOSE WHERE Q36=1; bike share users]

Q37. On average, how many times per day, week, month or year do you use a public bike share bicycle?
Q38. On average per trip, how many minutes or hours do you use a public bike share bicycle?
Q39. When you use public bike share bicycles, what type of trip does it TYPICALLY involve? [check all that apply]
Q40. When you use public bike share bicycles, which of the following modes of transportation do you TYPICALLY integrate into your travel? [check all that apply]
Q41. What type of transportation would you have used to make these trips if public bike share was not available? [check all that apply]
Q42. Which of the following best describes your TYPICAL helmet use when riding a public bike share bicycle? (Select one answer only)
Q43. What is your main reason for not always using a helmet when riding a public bike share bicycle? (Select one answer only)
SOCIAL PARTICIPATION (THIS SECTION ADDED IN 2017)

Q46. How would you describe your sense of belonging to your local community?
Q47. How often do you… (Enter # of times per week or month or year for each)
   a. … say hello to a neighbour?
   b. … stop and have a chat with a neighbour?
   c. … visit a neighbour, or receive a visit from a neighbour?
   d. … go somewhere (e.g., to a shop; restaurant), together with a neighbour?
   e. … ask help/advice from or do you help/give advice to a neighbour yourself?

Q48. If you lost a wallet or purse that contained two hundred dollars, how likely is it to be returned with the money in it, if it was found by:
   a. someone who lives close by?
   b. a complete stranger?

CYCLING INCIDENTS [ONLY THOSE WHERE Q12=1; cyclists]

Q18. How many times in the past 3 months have you been involved in a crash or fall (for any reason) while riding your bike in the city?
Q19. We would like more information about your crashes or falls in the past 3 months. If you have had more than 3 crashes or falls in the past 3 months, please provide information on the 5 most recent incidents:
   a. Month of crash or fall
   b. Was it reported to ICBC?
   c. Was it reported to police?
   d. Were you injured?
   e. Did you visit a hospital emergency department because you were injured?
   f. Were you admitted to hospital? (overnight stay in a depart. other than emergency)

Did your crash or fall involve any of the following?
   g. Collision with a vehicle door being opened
   h. Other collision with a motor vehicle (including car, SUV, truck, bus, motorcycle)
   i. Collision with another cyclist
   j. Collision with a pedestrian
   k. Hitting a hazard on the route (e.g. train track, post, pothole, curb, slippery surface)
   l. A fall when trying to avoid a collision
   m. You being distracted
   n. A mechanical issue (brakes, gears, pedals)
   o. Did this crash occur while you were riding a Vancouver Public Bikeshare bike?

DEMOGRAPHIC INFORMATION

Q20. Do you have a drivers’ license?
Q21. How many of the following vehicles are kept in your household? Bicycles for adults, Bicycles for children, Cars or vans, Motorcycles
Q22. What car share services are you part of? (Select all the apply)
Q23. How many people, including yourself, live in your household?
   a. Children aged under 5
   b. Children between 5 and 15
   c. Adults aged 16 and over (including yourself)
Q24. How long have you lived in your current home residence?
Q25. What is your postal code of your home? OR If you do not know the postal code, please give the address, or nearby cross-streets of your home.
Q26. Are you …? Male Female Other
Q27. What is the highest level of education you have completed?
Q28. What is your current employment status?
Q29. What is your postal code of your main place of work or study? Or, if you do not know the postal code, please give the address, or nearby cross-streets of your place of work or study.
Q30. Were you born in Canada?
Q31. Vancouver residents come from many different backgrounds. How would you describe yourself? (Select up to 2 options)
Q32. In general, for someone your age, would you say that your health is:
Q33. Which of the following best describes your total annual household income before taxes?
Appendix C.

Bicycle share service areas in the first and second season of program operation, Vancouver, BC

Season 1 (Oct 2016)
Service area*: 13.6km²
Stations: 72
Bicycles: 775

*The service area is defined as the area within a 500 meter road network buffer of a docking station

Season 2 (Oct 2017)
Service area: 17.0km²
Stations: 122
Bicycles: 1200