Policies to Encourage Commuting by Electric Bicycle in Metro Vancouver

by

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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:

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Abstract

Metro Vancouver currently has very low rates of cycling due to hilly terrain, wet winters, and an auto-centric urban design. Metro Vancouverites instead travel primarily by gasoline powered motor vehicles, creating traffic congestion and air pollution. For many commuters electric bicycles present a feasible alternative to vehicle commuting, including those living in hilly areas. If enough people started commuting by electric bicycles the societal benefits could be significant. Four policies that would encourage more people to commute by electric bicycle on a regular basis are considered. A provincial e-bike to work tax incentive and loan program is recommended as the policy most likely to increase rates of bicycle commuting while being cost-efficient for government and providing affordable access to e-bikes for most vehicle commuters.

Keywords: electric bicycle; e-bike; transportation policy; climate change policy

Dedication

I dedicate this project to my learned professors at the SFU School of Public Policy.

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I wish to thank my supervisor Professor Maureen Maloney for her wise guidance on this project, and Professor Nancy Olewiler for her constructive critiques. I also wish to thank all of the interview participants for their enthusiastic interest in the project and generous donation of their time.

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Glossary

Metro Vancouver	A Regional District of the Province of British Columbia that includes the City of Vancouver, the City of Richmond, the City of Surrey, the City of Langley, the District of Langley, the City of North Vancouver, the District of North Vancouver, the District of West Vancouver, the City of Burnaby, the City of Coquitlam, the City of Port Coquitlam, the City of New Westminster, the City of Maple Ridge, the City of Pitt Meadows, the City of Delta, the University of British Columbia, and Electoral District "A".
E-Bike	A bicycle with an electric motor and battery that provides additional power while cycling.

Executive Summary

High rates of vehicle use in Metro Vancouver, especially for commuting, creates traffic congestion, air pollution and greenhouse gas emissions, and negative health effects. Increasing rates of cycling would ameliorate these negative effects of driving. Metro Vancouver currently has very low rates of cycling due to the hilly terrain, winter weather, and an auto-centric urban design. Electric bicycles represent a more feasible replacement for commuting by car than regular bicycles due to an electric-assist motor making cycling much easier, especially for people living in hilly areas. If large numbers of people started commuting by electric bicycles in place of their vehicles on a regular basis the societal benefits would be significant: reducing traffic congestion and the economic loss that results; reducing air pollution and greenhouse gas emissions; and, improving public health through increased exercise.

The primary barrier to Metro Vancouverites using electric bicycles to commute is the cost of the bikes. At $1,700 for an entry level model, the purchase price for an e-bike is unaffordable for lower income Metro Vancouverites. Public policies that reduce the cost of electric bikes – by reducing the purchase price, amortizing the purchase price, or by way of low pay-per-use fees – would likely increase the rates of electric bicycle commuting.

This report considers four policies that would encourage more people in Metro Vancouver to commute by electric bicycle in place of their cars on a regular basis: a region-wide docking station bikeshare program, a region-wide dockless bikeshare program, a provincial subsidy for new electric bike purchases, and a bike-to-work "E-Cyclescheme" tax incentive and loan program. Each policy is considered in light of the potential effectiveness of the policies at getting large numbers of people to commute by electric bicycle in place of vehicles, the affordability of electric bicycles to lower income employees and students, the feasibility of implementation, and the cost effectiveness of public funds invested in the programs over time.

The result of this analysis is to recommended that an E-Cyclescheme be implemented. It is the policy most likely to achieve the highest rates of electric bicycle commuting in place of vehicles (179,200 trips per week) at a low cost to government ($0.49 per e-bike commute trip in place of a vehicle), and it does not pose significant implementation challenges. In addition, by amortizing the purchase price of electric bikes through an employer loan and reducing overall costs by providing tax incentives, an E-Cyclescheme makes electric bicycles significantly more affordable for all commuters.

The other policies are not recommended for a variety of reasons. Both bikeshare programs have low expected rates of vehicle replacement, in part due to most vehicle commuters living in low density suburbs where operating an economically feasible bikeshare system is most challenging, and in part due to bikeshare being most popular with transit users and other non-vehicle commuters. Another critical factor is that different bikeshare systems are likely to be adopted by municipalities independent of new policy action, and to become integrated through new technology in the next few years. As for a subsidy program, it will likely result in an unacceptable waste of an estimated $28 million of public money on electric bikes that would have been purchased without the subsidy.

After seven years of implementation the societal benefits of an E-Cyclescheme are likely to be significant but modest, with electric bikes purchased through the program predicted to replace 5.1% of vehicle commute trips in Metro Vancouver under 8km, reduce traffic congestion during rush hour on congested routes with bike lanes by up to 5%, and reduce greenhouse gas emissions emitted from vehicles while used for commuting by approximately 1.2%. An E-Cyclescheme could produce higher rates of commuting by electric bicycle in place of vehicles if the region builds substantially more separated bike lanes and implements additional complementary policies that make cycling more attractive or dis-incentivize commuting by vehicle.

Chapter 1. Introduction

The invention of motor vehicles fundamentally improved human land transportation: they are the fastest, most practical and comfortable way to travel. However, the use of gasoline or diesel powered motor vehicles also creates a number of societal problems. These include traffic congestion, air pollution, greenhouse gas (“GHG”) emissions, costly transformation of usable land into roads and parking, and increased sedentary lifestyles harmful to human health. Like most large North American cities, the majority of people in Metro Vancouver use motor vehicles for their daily transportation needs. With an expected additional one million residents living in the region by 2040, the number of motor vehicles on the same roads will increase, as will the attendant problems.

While replacing gasoline and diesel powered motor vehicles (“vehicles”) with electric powered motor vehicles (“electric vehicles”) will reduce air pollution and GHG emissions, it will not reduce traffic congestion, urban sprawl or result in higher rates of exercise. A better alternative is to replace vehicles with active, sustainable and space-efficient transportation options like transit, walking and cycling, when feasible to do so. The relatively new technology of electric bicycles (“e-bikes”) has potential to significantly contribute to reducing the negative effects of driving, especially during rush hour commutes when most vehicle driving occurs. This report considers the potential for pedal-assist e-bikes, which require human power and thus provide exercise, as a new form of active and sustainable transportation that could be attractive to current vehicle commuters. E-bikes make cycling easier, faster and more practical than conventional bicycles, significantly expanding the number of people potentially willing and able to cycle on a regular basis. Accordingly, e-bikes hold greater promise as an alternative to travel by vehicle than conventional bicycles.

Using e-bikes in place of vehicles would help ease traffic congestion, saving people time and benefitting the economy. Studies of traffic congestion in Metro Vancouver estimate the direct cost of traffic congestion at $1.4 billion per year, and the indirect costs at $500 million to $1.2 billion per year (Canada’s Ecofiscal Commission, 2015). Even a small reduction of time lost to traffic congestion would result in cost savings in the tens of millions of dollars.

Greater use of e-bikes would reduce pollution and GHG emissions, especially during the decades it will take to transition to electric vehicles. The British Columbia ("BC") provincial government ("the Province") has legislated GHG reduction targets of 80% below 2007 levels by 2050 to help combat climate change. Passenger vehicles are responsible for 14% of BC's GHG emissions, and in Metro Vancouver, BC's most populated urban area and the focus of this report, that proportion increases to 31% of GHG emissions (Metro Vancouver, 2018, p. 5). One Swedish study estimates that the reduction in vehicle use by e-bike owners results in a reduction of 14 to 20% of the average CO2 per person from transportation each year (Hiselius & Svensson, 2017). Thus, high rates of e-bike cycling in place of gas powered vehicles would significantly contribute to achieving BC's GHG reduction targets.

Bicycle commuting, including by e-bike, improves public health by reducing air pollution and by getting people exercising on a consistent basis. A recent British study of 263,450 commuters found that participants who regularly cycle to work had lower rates of cardiovascular disease, cancer and all-mortality outcomes than non-active commuters and walking commuters, especially for long-distance cycle commuters, and concluded that policies designed to encourage cycle commuting presented "major opportunities for the improvement of public health" (Celis-Morales et al., 2017, p. 5). One estimate of the economic value of the reduced risk of premature death created by regular cycling for the United Kingdom put the health care savings in the billions of pounds (Department for Transport, UK, 2015). High rates of e-bike commuting would therefore improve public health and reduce health care costs.

Affordability is another important concern in a city experiencing an affordability crisis. Commuting by e-bike is inexpensive compared to commuting by vehicle, costing just a few cents per day. For vehicle commuters, using e-bikes for commuting, even some of the time, would reduce their financial burden.

The main barrier to people using e-bikes is the purchase price, starting at $1,700 plus sales tax, with most commuter models ranging between $2,000 and $3,000. The median income in Metro Vancouver is $36,000 per year and the average income is $44,000 per year (Statistics Canada, 2017; Statistics Canada, 2019a). For many Metro Vancouverites with median or average incomes spending an additional $1,700 to $3,000 on a e-bike is not affordable. Public policies that reduce the cost of e-bikes – by reducing or amortizing the purchase price, or by way of low pay-per-use fees for publicly shared e-bikes – would likely increase the rates of e-bike commuting.

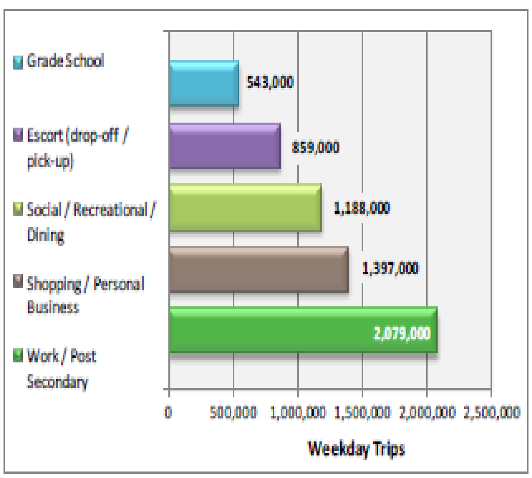
This report evaluates different e-bike policies that have been employed elsewhere in the world for the purpose of recommending a policy that would reduce the financial barriers to e-bike use for Metro Vancouverites, and therefore likely substantially increase the use of e-bikes in place of vehicles to commute in Metro Vancouver. In Chapter 2, patterns of commuting in Metro Vancouver will be reviewed, as will current bicycle policies, the safety and health aspects of cycling, and the nature of e-bike technology and its current regulation in BC. Chapter 3 will explain the study's methodology. Chapter 4 consists of a review of the available social science literature on e-bikes. Chapter 5 presents four e-bike policy options that will be analyzed later in the report. Chapter 6 summarizes data gathered during interviews with transportation planners and bicycle policy experts, and a Vancouver-based e-bike manufacturer and retailer. Chapter 7 explains the criteria and measures that will be employed during the policy analysis. Chapter 8 presents the analysis of the policy options, Chapter 9 explains the reasons for recommending an "E-bike to Work" tax incentive and loan scheme, and Chapter 10 addresses limitations of this research project, and Chapter 11 provides some concluding comments on the likely impact of the recommended policy and the need for additional policies to further increase rates of cycling in Metro Vancouver.

Chapter 2. Background

2.a. Commuting In Metro Vancouver

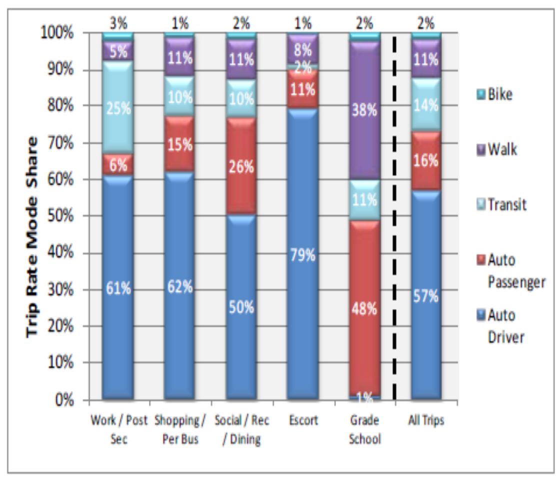
The regional transit authority, TransLink, provides a detailed analysis of travel patterns in Metro Vancouver in its report, *2011 Metro Vancouver Regional Trip Diary Survey – Analysis Report* (TransLink, 2013a). In comparison to other types of trips, commuting accounts for the greatest number (approximately 2.1 million) and greatest share (34%) of daily week day trips in Metro Vancouver (TransLink, 2013a, Figure 2.1.1, reproduced below). Commuting by vehicle is the norm in Metro Vancouver, accounting for 67% of all commute trips (approximately 1.4 million per day), with a low of 50% in the City of Vancouver to a high of 91% in Langley. (TransLink, 2013a, pp. v-vi, 10-11, 30-73, and Figure ES8, reproduced below). In addition, according to 2016 census data, 85% of vehicle commute trips are by single occupancy vehicles (Statistics Canada, 2019b).

Figure 2.1.1 - Weekday Trips by Purpose



Source: TransLink, 2013a, p. 10

Figure ES8 - Mode Share by Trip Purpose

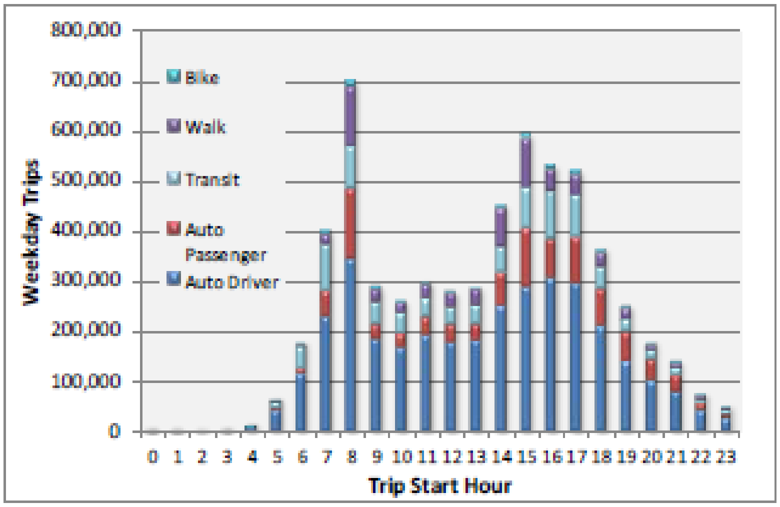


Source: TranslLink, 2013a, p. vi

All Figures reproduced with permission from TransLink.

Rush hour is when most commuting trips occur. Vehicle trip volume peaks during the morning rush hour with 340,000 trips between 8 and 9 a.m., while the afternoon rush hour peak is less pronounced but lasts longer, from 2pm to 6pm (TransLink, 2013a, pp. iii-vi, 15, and Figure 2.1.10, reproduced below).

Figure 2.1.10 - Trips by Mode by Hour-of-Day



Source: TransLink, 2013a, p. 15

The majority of vehicle trips occur within municipalities, ranging from about 60% (Burnaby) to 90% (Langley). More than half of commute trips happen within municipalities, ranging from about 35% (Burnaby) to 65% (Vancouver). Commuting to neighbouring municipalities follows in prevalence, while a relatively small percentage of commute trips are longer cross-regional trips (approximately 10-15%), primarily from the suburbs to Vancouver and Burnaby. In addition, a significant proportion of the cross-regional commute trips are by transit users (TransLink, 2013a, pp. 36-74). For example, in Surrey approximately 180,000 commuting trips occur within Surrey and South Delta (52% of total commuting trips), of which about 82% are by vehicle, while 46,500 commuting trips are to Vancouver (14% of total commute trips) with close to half of the Vancouver commute trips by transit (TransLink, 2013a, p. 61, and Figure 3.6.5a, reproduced below).

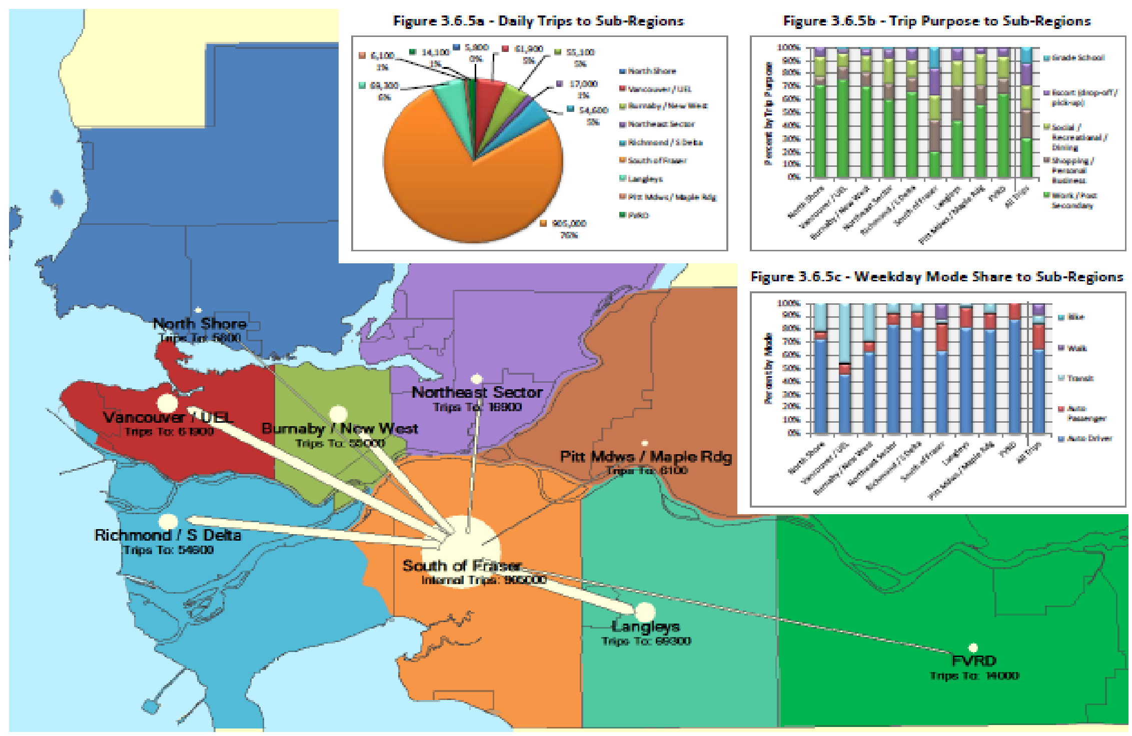
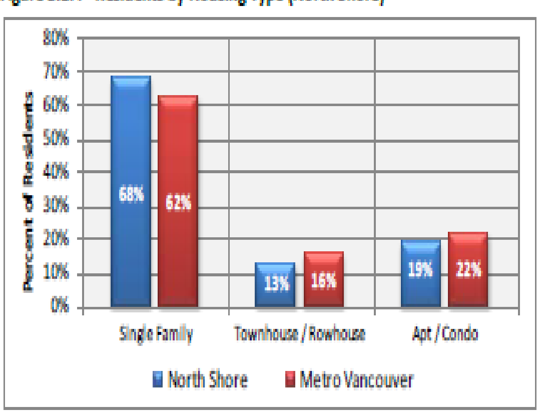


Figure 3.6.5 - Trip Distribution by Sub-Region of Trip Origin (South of Fraser)

Source: TransLink, 2013a, p. 61

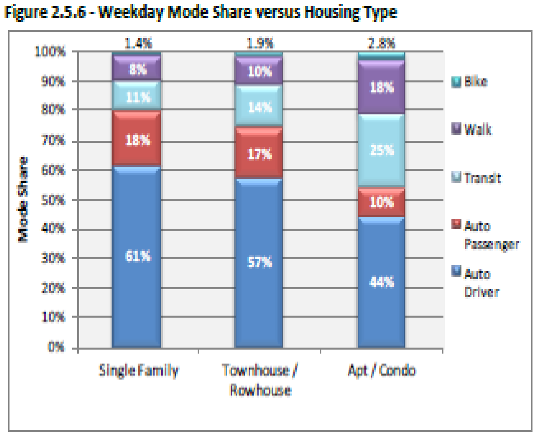
A striking feature of commuting by vehicle is that it primarily occurs in relation to low-density single-family housing, which is where 62% Metro Vancouverites live (TransLink, 2013a, p. 35, and Figure 3.1.4, reproduced below). Overall for the region, 79% of single family residents travel by vehicle for all trips (TransLink, 2013a, Figure 2.5.6, reproduced below). By comparison, residents of apartments use vehicles for 54% of trips (TransLink, 2013a, p. 28). Accordingly, most single occupancy vehicle commuting originates in low-density single family neighbourhoods.

Figure 3.1.4 - Residents by Housing Type (North Shore)



Source: TransLink, 2013a, p. 35

Figure 2.5.6 - Weekday Mode Share versus Housing Type



Source: TransLink, 2013a, p. 28

The average car commute trip distance for the whole region is 14.2 km each way (TransLink, 2013a, Figure 4.1.1), whereas the median distance is 8 km each way (Statistics Canada, 2019c, Table 5). The higher average versus median commute distance reflects the small but significant number of long distance vehicle commuters, who disproportionately impact the average but not the median commute distance (Statistics Canada, 2019c).

Overall, the typical Metro Vancouver commuter is someone who lives in a single family neighbourhood and commutes in a vehicle alone during rush hour. About half of these vehicle commuters travel up to 8 km each way, while the other half travels longer distances – with about 10-15% of those latter commuters travelling very long distances across the region each day. Vehicle commutes of 8 km or less are well suited for commuting by e-bike, as they take half an hour or less for the typical e-bike cyclist, which is time competitive to vehicle commuting in urban areas. As such, it is feasible for a majority of vehicle commute trips to be undertaken by e-bike, including for trips originating in low-density single family housing. Consequently, to achieve the greatest positive impact, policies promoting commuting by e-bike should target single occupancy vehicle commuters who commute within their local municipality and to neighbouring municipalities, with long distance commuting – which would be achieved by commuting by e-bike to transit hubs – a secondary focus.

2.b. Current Policies to Increase Cycling In Metro Vancouver

To address the harms caused by too much vehicle commuting, TransLink has emphasized the need to increase levels of cycling, walking and transit use, setting a long-term regional goal of an increase for these modes of travel of at least 50% by 2040 (TransLink, 2008). This includes setting a target of 15% of all trips less than 8 km by cycling (TransLink, 2011). Compliance with the TransLink 2040 targets by all Metro Vancouver municipalities is required under the *Metro Vancouver 2040 Regional Growth Strategy Bylaw* (GVRD, 2011).

As of 2011, cycling accounted for less than 2% of all trips in Metro Vancouver, with less than 1% in most of the suburban municipalities and a high of 4% in in the City of Vancouver (TransLink, 2013a). Since 2011 cycling rates have increased to 7% in the City of Vancouver, but have remained much the same in the rest of Metro Vancouver (City of Vancouver, 2018).

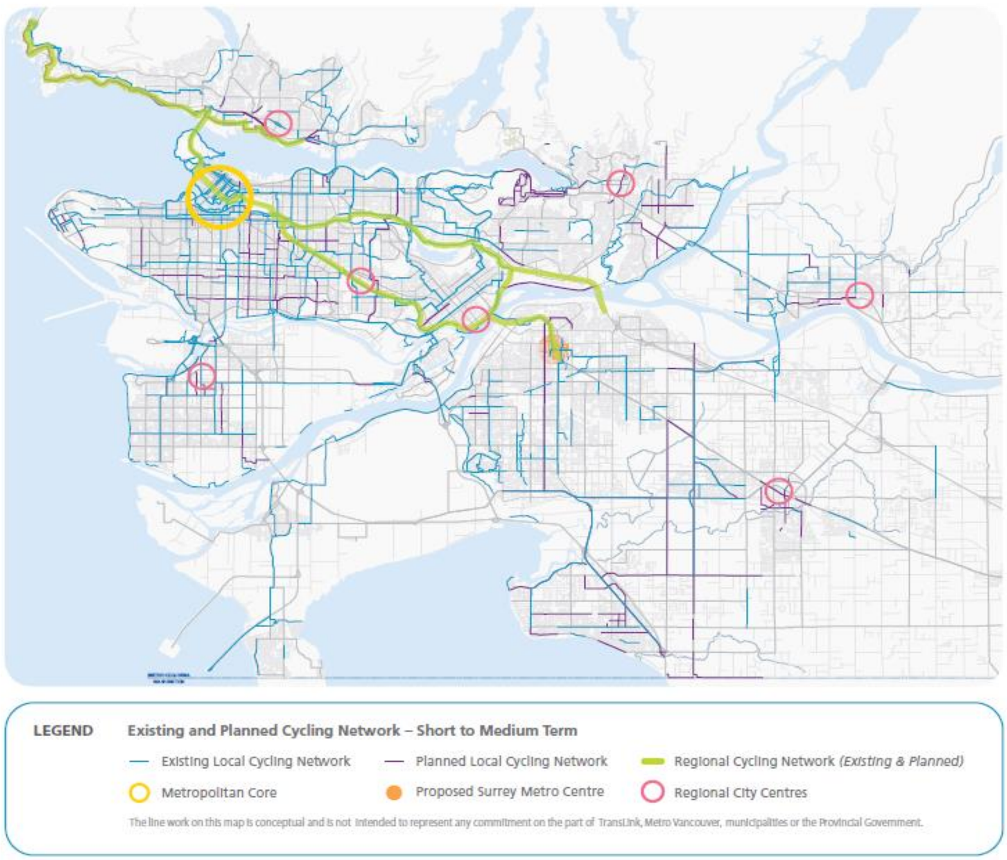
In June 2011, TransLink released *Cycling for Everyone – A Regional Cycling Strategy for Metro Vancouver* ("TransLink Cycling Strategy"), which addresses benefits of and barriers to cycling in the region, and details proposed policies to increase rates of cycling. Some of the noted benefits of cycling in comparison to using vehicles and transit include:

- bicycles produce no emissions of GHGs and other pollutants;
- bicycles are seven times more space efficient than vehicles, reducing the need to convert usable land into roads and parking, and making it possible to transport more people on existing road surfaces;
- investing in bicycle infrastructure is cost effective in comparison to investing in transit or new roads;
- cycling is time competitive to transit and vehicle travel for distances less than 8 km in urban settings.

(TransLink, 2011)

The report further notes that cycling safety is a significant deterrent to increased rates of cycling. TransLink's Cycling Strategy therefore focusses on the construction of many new bike lanes and paths throughout the region. It also recommends investing in more parking facilities at transit hubs, more educational programs, and establishing a public bikeshare system. To these ends, in 2013 TransLink released its *Regional Cycling Strategy – Implementation Plan*, which envisions doubling the designated bicycle routes from 2,400 to 4,200 kilometers and adding 300 km of separated bike lanes (TransLink, 2013c). As for where those bike routes and lanes will be built, TransLink provides the following map:

Map of existing and planned bikeway network



Source: TransLink, 2013c, p. 16

In support of its plans TransLink cites data from Portland and Vancouver that show an exponential increase in bicycle trips corresponding to the increase in bikeway kilometres built (e.g., over 500% increase in Vancouver of both bikeway kilometres and daily trips between 1990 and 2009). Overall TransLink estimates 24% of all vehicle trips in Metro Vancouver are well-suited for bicycles (e-bikes were not considered).

Achieving TransLink's 15% cycling trip target will be challenging. The City of Portland, Oregon and the City of Vancouver have among the highest rates of cycling, after years of building separated bike lanes, at 7% of trips (City of Portland, 2017, percentage of commute trips; City of Vancouver, 2018, percentage of all trips). While several cities in Europe have achieved cycling rates of 15% or higher (e.g., 35% in Copenhagen), these cities differ from Metro Vancouver in important ways: they have historically dense bicycle-friendly urban designs, are relatively flat, and travelling by bicycle is a cultural norm. Policies encouraging e-bike commuting would complement the current cycling policy of building bike lanes and other infrastructure and amenities, making TransLink's 2040 target a more achievable goal.

2.c. E-Bike Technology

There are two categories of electric bicycles: those that have a full-electric power mode, and those that have only pedal assist mode, which require human pedal power to operate. The latter are often called "pedelecs", and are the only type of e-bike considered in this report, since only the use of pedal assist e-bikes results in exercise.

E-bikes are available in all the same styles and models as conventional bicycles. There are also a wide range of innovative cargo e-bikes for both personal and commercial uses. From mountain bikes to road bikes to cruisers, there is an e-bike for everyone.

E-bikes come equipped with small computers that control sophisticated gear changing mechanisms which can automatically adjust the level of power assist needed to maintain a consistent level of effort by the rider. The electric assist can also be set to a specific setting to make the ride easier or harder. The electric assist motor can also be turned off entirely, making the e-bike a regular bike.

As for batteries, they are removable for some models and not removable for others. E-bikes with removable batteries can be charged anywhere there is an electrical outlet, just like a smart phone, whereas fixed battery models require parking next to an outlet. The size of the battery and intensity of e-bike use – the result of, for example, the weight of rider, the number and steepness of hills, and speed – determine the range of an e-bike, with most batteries lasting 50 to 100 km, depending on conditions. Batteries maintain a full charge for 500 recharging cycles, with capacity gradually reducing thereafter. The age of the battery also matters, with gradual reduction of capacity after about five years. Battery lifespan therefore varies depending on the user, from two to ten years. A lifespan of seven years will be assumed in this report, based on the use of an e-bike for commuting purposes only, for five 8 km trips per week.

E-bikes cost more than low to mid quality conventional bicycles, primarily due to the cost of the batteries. An entry level e-bike costs around $1,700 at time of writing, whereas an entry level conventional bike costs around $300, and most quality commuter model e-bikes cost between $2,000 and $3,000. High end conventional bikes and e-bikes are cost comparable, at $3,000 to $15,000. Purchase prices are subject to a federal sales tax of 5% and a BC provincial sales tax of 7%.

Another option is for current bicycle owners to purchase e-bike conversion kits, which cost between $1,200 and $2,000, depending on the size of the motor, the battery capacity, and the quality of the manufacturer. However, low quality and/or old conventional bikes may not have frames or braking systems designed for e-bikes, making such bikes unsafe for conversion. Another factor is that some conversion kits create e-bikes that are not legally compliant due to the motor being too powerful or the top speed too high. To control for these factors, any policy that includes conversion kits should only allow high-quality kits that comply with e-bike regulations, and should require installation by approved bike shops to ensure safety of the converted e-bikes. Accordingly, the cost of a high-quality conversion kit plus installation costs would on average amount to about the same as an entry level e-bike, at approximately $1,700.

2.d. E-Bike Regulations and Policies in BC

In BC, e-bike design is regulated by the *Motor Assisted Cycle Regulation*, B.C. Reg. 56/2018, and by the federal *Vehicle Safety Regulations*, C.R.C., c. 1038. Under these regulations e-bikes are defined as “motor-assisted cycles” or “power-assisted bicycles” that have two or three wheels, a seat, operational pedals, and an electric motor of up to 500 watts. The regulations limit e-bikes to a top speed of 32 km/hr. Once that speed is reached the electric assist must turn off; however the rider could go faster using his or her muscle power, as with a conventional bicycle. The braking system must be capable of bringing an e-bike travelling at 30km/hr to a full stop within 9 metres of application.

E-bike use is regulated by the *Motor Vehicle Act*, [RSBC 1996], c. 318. Pursuant to sections 182.1, 183 and 184, e-bikes riders must be 16 years old, must wear a helmet, and when operating at night require a rear red light and a front white light. Insurance is not required for e-bikes. In addition, e-bike cyclists, like all cyclists, have the same rights and duties as a driver of a vehicle.

Presently the only e-bike-specific policy in BC is the provincial BC SCRAP-IT Program (www.scrapit.ca). Participants of that program agree to scrap their old vehicle for recycling in exchange for a sustainable transportation benefit, one of which is an $850 rebate on the purchase of a new e-bike.

2.e. Cycling Safety and Health Impacts

The comparatively higher risk of accidents for cycling versus driving is well known. One UK report calculates the casualty rate (killed or seriously injured) per billion vehicle miles at 21 for cars and 1,036 for cyclists, which indicates that cycling is 50 times more dangerous than driving a car. The accident rate for e-bikes is similar to the rate for regular bikes (Fishman & Cherry, 2016; Schepers, Wolt & Fishman, 2018).

The main barrier to people cycling more often is the perceived danger of cycling on regular streets in vehicle traffic, especially for the inexperienced (Heinan, van Wee & Maat, 2010; Winters, Davidson, Kao & Teschke, 2011). Cycling on bike lanes separated from traffic is safer than cycling on streets with vehicle traffic, as well as being perceived to be safer by cyclists. Consequently, separated bike lanes are critical to encouraging more people to cycle commute on a regular basis, including by e-bike.

Studies of the impacts of air pollution on cyclists while cycling, as compared to vehicle drivers and transit users, indicate negative health impacts for cyclists. While these impacts can be mitigated by separated bike lanes and using residential non-arterial routes where possible, until vehicles stop burning fossil fuels this health risk will remain. However, studies on the overall benefits and costs of cycling, when balancing the increased risk of injury or death from accidents and the harmful effects of air pollution on cyclists with the increased health benefits of increased activity from cycling, consistently conclude the benefits significantly outweigh the costs, from 9:1 to 96:1, depending on the study (de Hartog, Boogaard & Nijland, 2010; Rabl & de Nazelle, 2012; Rojas-Rueda, Nazelle, Teixido & Nieuwenhuijsen, 2011; Buekers, Dons, Elen & Panis, 2015; Celis-Morales et al., 2017). E-bike cycling provides less exercise than regular cycling but still enough to provide a significant amount of cardiovascular exercise, especially for sedentary people (Bourne et al., 2018). Benefit cost analyses should therefore also be positive for e-bike cycling, though less so than for regular cycling.

Chapter 3. Methodology

The primary research methodology for this project was to conduct a literature review of the social science literature on the potential of e-bikes as a sustainable transportation option that has been produced over the last decade. The resulting detailed understanding of the benefits, barriers and motivators to e-bike use in other contexts formed the foundation for the analysis of the different policies that could be effective in Metro Vancouver. I then conducted a jurisdictional scan to determine what policies have been attempted in other places, how they have been implemented, and whether they have been successful and therefore should be considered as policy options for Metro Vancouver. I also conducted interviews of transportation planners, bicycle policy experts, and an e-bike retailer and manufacturer to assess the likely effectiveness, administrative complexity, feasibility and cost of the proposed policies options.

Chapter 4. Literature Review

E-bike policy serves as an extension of conventional bicycle policy, in that e-bikes make cycling accessible to a greater pool of citizens in a greater number of contexts. Understanding the social science literature regarding commuting by conventional cycling is therefore a necessary pre-requisite for understanding the potential barriers and facilitators to using e-bikes for vehicle commuters.

In an overview of literature on barriers and facilitators of conventional cycling (Heinen et al., 2010), the authors identify the following main factors:

- Commuting long distances is a major barrier, especially for women;
- Cyclists, especially inexperienced cyclists, prefer separated bicycle paths to roads with painted bike lanes due to safety concerns;
- Cities with more cycling infrastructure have higher levels of cycling and better safety records;
- Secure parking facilities at work and at public buildings are important to cyclists, especially those with expensive bikes;
- Showers, changing facilities and lockers at work are also important to bicycle commuters;
- Hills are a deterrent for commuting by bike, especially for the inexperienced and less fit;
- Cold temperatures, rain, snow, and darkness of the winter months in northern countries deter cyclists from commuting.

(Heinan et al., 2016, pp. 61-73)

A survey study of cyclists and potential cyclists in Metro Vancouver had similar findings (Winters et al., 2011), with the main motivators for cycle commuting including bike routes away from traffic and pollution, flat terrain, and secure bike storage. Top deterrents included darkness, rain/snow/ice and, most of all, safety concerns relating to cycling with traffic.

Over the last 15 years researchers in Europe, North America and China have studied e-bikes and e-bike cyclists for the purpose of determining whether e-bikes can realistically increase rates of cycling, in particular in place of vehicles. The bulk of this research is helpfully summarized and analysed by Fishman & Cherry in *E-bikes in the Mainstream: Reviewing a Decade of Research* (Fishman & Cherry, 2016). As noted in that article, the studies consistently find that the main motivators to e-bike use for current and potential e-bike cyclists, particularly in comparison to using conventional bicycles or vehicles, are the following:

- e-bikes require less physical exertion than conventional bikes, resulting in less fatigue, and hilly terrain and wind are much less of a deterrent;
- e-bike users travel at an increased average speed and have longer average trip lengths as compared to conventional bikes, which results in trips taking less time;
- by being easier to use e-bikes mitigate the impacts of high temperatures, poor air quality, and rain;
- e-bikes increase accessibility of cycling for some people with mobility issues, including older people;
- e-bikes have greater potential than conventional bikes to replace or reduce vehicle use for some utilitarian purposes, such as commuting and running errands;
- e-bike ownership results in a significant increase in the number of trips by bicycle as compared to ownership of conventional bikes;
- e-bikes provide sufficient cardiovascular exercise to improve health;
- e-bikes are environmentally friendly, producing 1/40th the $CO2$ of a small gas powered car even when the electricity source is coal, and e-bikes use 1/10th the energy of a small electric car;
- e-bike users feel safer on an e-bike than a conventional bike, though accident rates are similar or slightly higher, depending on the study;
- in most countries women cycle less than men; e-bikes have potential to increase cycling rates for women to a level comparable to men;
- makes cycling more fun.

(Fishman & Cherry, 2016, pp. 80-83)

Recent research since 2015 has focussed on the potential for e-bikes to replace vehicles for different types of transportation trips, particularly commuting, as well as the health benefits, safety, and environmental implications of e-bike use. A summary of some of the main findings of these studies follows. (For a more detailed review of many of the studies summarized below, see Appendix A).

In an American study (Ling, Cherry, MacArthur & Weinert, 2017), the authors determined that e-bike use was generally more utilitarian, used for commuting and running errands, whereas conventional bikes were primarily used for recreation and exercise. E-bike users on average travelled longer distances (14.9 vs. 12.3 miles) and took more trips per week (3.6 vs. 2.7 trips);

In another American study involving an e-bike trial with commuters (MacArthur & Kobel, 2017), the results showed that the number of people commuting by bicycle at least once a week more than doubled from 28% to 59%. In a follow up study (MacArthur, Harpool, Scheppke & Cherry, 2018), a major survey of North American e-bike users produced similar findings. Similar results have been found in Norway (Fyhri & Fearnley, 2015; Fyhri, Heinan, Fearnley & Sundfor, 2017) and the Netherlands (Plazier, Weitkamp, van den Berg, 2017; Lee, Molin, Maat, Sierzschula, 2015; Kroesen, 2017), affirming the attractiveness of e-bikes as an alternative to vehicles for commuting.

In a Norwegian study (Sundfor & Fyhri, 2017), it was concluded e-bikes are more appealing to sedentary people who have little interest in physical activity than for established cyclists. A Belgian study (Cauwenberg et al., 2018) found that e-bikes are particularly attractive to older people, allowing them to cycle when they otherwise would or could not.

A Swedish study focused on the impact of e-bikes on GHG emissions found that significant reductions in CO2 emissions result when e-bikes replace car trips, at an average of 14-20% of CO2 emissions from transportation, amounting to 8.2kg of CO2 per week per e-bike user (394kg/year, or 272 kg/year taking into account bad weather days) (Hiselius & Svensson, 2017). A small-scale UK study found even greater potential GHG reductions (Pierce, Nash & Clouter, 2013). By comparison, the average commuter travelling the median commute distance in the average vehicle in Metro Vancouver produces 906 kg of CO2 emissions per year (See Appendix B for calculations).

A Swiss study (Moser, Blumer & Hille, 2018) and a British study (Cairns et al., 2017) focused on the effect of e-bike trials found high levels of e-bike use during the trials, and high intention to commute by e-bike if one were available after the trials, but low to moderate levels of e-bike use after the trial period, likely due to high e-bike purchase prices.

A German study examined the differences in average speed and acceleration for users of conventional bikes, pedal assist e-bikes and high speed pedal assist e-bikes (Schleinitz et al., 2017). The results found that the average speed for pedal assist e-bikes was about 2 km/hr more than for conventional bikes, and acceleration rates were the same.

A review of recent studies on the health benefits associated with using e-bikes found that e-bikes provide sufficient physical activity to improve cardiorespiratory fitness; using an e-bikes requires more effort than walking but less effort than conventional cycling. (Bourne et al., 2018).

A recent Dutch study of e-bike safety in the Netherlands found that e-bikes and conventional bikes have similar accident rates, and that electric bicycles are not associated with an increased risk of injury once factors such as age of users are taken into consideration (Schepers et al, 2018).

A consistent theme arising from many of the studies covered in the literature review is that the high cost of e-bikes is the main barrier to people using e-bikes, particularly lower income people and students. For example, in a study of university students in the Netherlands provided an e-bike for a multi-week trial period (Plazier et al, 2017b), although 97% percent of participants stated they would like to own an e-bike, 81% reported they were not planning to buy an e-bike due to cost (p. 40). Overall, participants did not view e-bikes as worth the investment in light of the existing low-cost options of commuting by transit or by a regular bike.

Chapter 5. Policy Options

The main barrier to achieving e-bike commuting on a large scale, other than safety issues common to all types of cycling, is the high purchase price of e-bikes. Accordingly, if governments wish to increase rates of e-bike commuting in Metro Vancouver and elsewhere, then they should consider policies that reduce the price of access to e-bikes. In addition, effective policies should focus on making e-bikes accessible to commuters residing in low density residential areas, where most single occupancy vehicle commuters live.

It is important to note some preliminary assumptions and considerations that impact deliberations as to what e-bike policy options should be analysed in this report:

1. A major assumption is that Metro Vancouver municipalities will build the bike lane networks they have planned. Without bike lanes throughout the Metro Vancouver area – especially separated bike lanes – it is unlikely that any e-bike policy will create high levels of cycling for commuting or other purposes, due to the safety concerns of potential e-bike users, especially those who are inexperienced cyclists. The level of bike lane construction is therefore a potentially significant limitation on e-bike policy effectiveness.

2. Another consideration is Metro Vancouver's dark and wet winter, which is likely to limit the effectiveness of e-bike policies from November until March each year, as confirmed by data from Seattle's recent bikeshare pilot and the City of Vancouver's Mobi bikeshare, at least for conventional bicycles used in bikeshare programs (Seattle, 2018, p. 18; Vancouver, 2018, p. 29). However, Copenhagen has among the highest rates of cycling in the world at 35% of all trips, and its winters are similar to Metro Vancouver, which suggests winter may be overcome by better bicycle infrastructure or other factors.

The jurisdictional scan of countries and cities in North America and Europe, supplemented by research of policies recommended by bicycle advocacy organizations, resulted in the selection of four policies that most merit analysis as potentially reducing the cost to access e-bikes for Metro Vancouverites:

1. A region-wide docking station e-bike bikeshare program;
2. A region-wide dockless e-bike bikeshare program;
3. A provincial subsidy of $1,000 for the purchase price of new e-bikes or conversion kits;
4. A provincial “E-Cyclescheme” bike-to-work tax incentive and loan program.

Three policy options were considered and rejected. The first was to make e-bikes exempt from BC’s 7% provincial sales tax, which was rejected because it is unlikely that such a small financial incentive would significantly increase sales of e-bikes. A second rejected option was to fund municipalities holding e-bike demonstration events, with e-bikes made available for people to try for a trial period for the purpose of familiarizing the public with e-bikes, in the hope the participants would then opt to purchase an e-bike. This approach has been employed in many places in Europe, however the literature review suggests there were relatively low rates of e-bike purchases after the trial periods, due to e-bike cost. The other option considered was to increase funding for bike lane network construction, which was rejected since building bike lanes is already the primary policy being implemented.

5.a. Policy Option 1: Docking Station Bikeshare

5.a.1. Background

The objective of all bikeshare programs is to provide affordable access to bikes to everyone in a city in order to increase the rate of cycling. Docking station bikeshare systems (“dock bikeshare”) have docking stations (“docks” or “stations”) placed throughout a city where bikes must be picked up from and returned to at the end of a trip. As of 2016, more than 55 cities in North America had dock bikeshare, including Vancouver, Montreal and Toronto (NACTO, 2017). Vancouver was a relative latecomer to dock bikeshare with its system “Mobi” established in 2016, which as of 2018 has 150 docking stations and 2,000 bikes located in the central core of the city. No other municipality in Metro Vancouver or BC has a dock bikeshare program.

Dock bikeshare users pay a daily, monthly or annual fee, for a certain number of bike rides per day. For example, Mobi offers a 24-hour pass for $9.75, a 90 day pass for $75, and a one year pass for $129, all with unlimited 30 minute rides during those times.

Typically, a “ride” lasts 30 to 60 minutes, with an extra “overage” charge if the user rides for longer.

The primary disadvantage of dock bikeshare is the high capital cost for purchasing and installing the docking stations, and, to a lesser extent, purchasing the bikes. For example, Montreal recently announced an expansion of 60 new docking stations and 1,000 new bikes at a cost of $4.7 million (Montreal Gazette, August 2018), while Toronto announced an expansion of 105 new stations and 1,250 conventional bikes ($1,090 per bike) at a cost of $7.5 million (City of Toronto, 2019). The practical effect of the high capital costs of the docking stations is that it is too expensive to have docks located everywhere in a city, which means lower density parts of cities are often underserviced or not serviced at all. In cities like Vancouver where only a small part of the city has installed docks, only part of the population has access to it and travel is limited to a relatively small area of the city.

Dock bikeshare systems are typically operated by private companies that derive revenues from user fees and advertising, however most are not financially self-sustaining and therefore require some annual funding from cities. For example, Vancouver currently provides Mobi’s operator $0.5 million per year, while Montreal provides $2.9 million per year to Bixi’s operator (Montreal Gazette, June 2018). Capital costs of new bikes and docks are usually borne by cities, regions, or provincial/state governments.

A significant limitation for the potential use of dock bikeshare throughout Metro Vancouver is the predominance of low-density single-family neighbourhoods. Dock bikeshare needs to operate in high density areas where high rates of ridership are most likely to be financially viable without significant public funding.

An advantage of dock bikeshare is that it can solve the “last mile” problem of transit commuting – that is, allowing commuters to use a dock bikeshare bike to get to a transit hub from their home and then from a destination transit hub to a workplace. However, this assumes docking stations are in place near each of these locations. Other important advantages include secure parking at the docks, and storage of large numbers of idle bikes in specific locations – the docks – rather than on sidewalks or streets.

E-bikes are compatible with most dock bikeshare systems. As of 2018, Washington, D.C., San Francisco, New York and Montreal have all introduced small numbers of e-bikes into their fleet of bikes on a pilot trial basis. Mobi's supplier Smoove now offers e-bikes and e-bike compatible docks, which can be used for future Mobi expansions. As for Mobi's existing docks, which are not connected to a power supply to allow charging, some of them could be connected to a power supply and retrofitted or replaced to allow for e-bike charging, where economical to do so.

Dock bikeshare programs have been successful in raising rates of cycling in many cities (e.g., Montreal's Bixi reported 5.3 million trips in 2018 for 6,250 bikes), including significant rates of use during rush hour and in conjunction with transit (NACTO, 2017).

5.a.2. Docking Station Bikeshare Policy Proposal

It is proposed that the current Mobi dock bikeshare system be expanded to high density areas of Metro Vancouver and within 8 km of major transit hubs, such as Sky Train stations, in areas or at destinations where high demand would be expected (e.g., parks, town centres, tourist attractions). Both Montreal's Bixi and Washington, D.C.'s CaBi bikeshare systems provide templates for Metro Vancouver, as they are multi-jurisdictional (operating across several municipalities and states) and spread over long distances and large areas. This policy option assumes Mobi's current operator continuing under contract with TransLink and/or the participating municipalities.

Considering the number of bikes and docks in cities like Montreal and Washington, D.C., it is estimated that at least 300 new e-bike compatible docks and at least 5,000 additional bikes (50% e-bikes) would be required to service the transit hubs and denser areas of Metro Vancouver. All new docks would have charging infrastructure, or e-bikes with removable batteries would be required. The number of e-bikes versus regular bikes at particular stations would be determined based primarily on the hilliness of the terrain.

Based on costs reported by Vancouver, Toronto and Montreal, and taking into account a higher cost of $2,500 for e-bikes versus $1,100 for conventional bikes (City of Toronto, 2019), the capital costs are estimated to be $25 million to purchase and install 300 docks, 2,500 conventional bikes and 2,500 e-bikes. In addition, up to $3 million will likely be required annually to cover potential revenue shortfalls. It is also anticipated that, based on costs reported by Seattle for its dockless bikeshare program, Metro Vancouver's municipalities would collectively incur administrative costs of up to $3 million per year in planning, enforcement and other operations necessary to maintain operation of bikeshare systems.

5.b. Policy Option 2: Dockless Bikeshare

5.b.1. Background

Dockless bikeshare is, as the name implies, bikeshare without the docking stations. Bikes can be left anywhere that is permitted within a designated area. It is similar to car share programs like EVO or Car2Go. Users sign up for the dockless bikeshare service by downloading an app onto their smart phone. The app includes a map that shows the locations of bikes, which have GPS locaters installed. Users find a nearby bike and unlock it through the app to begin a “ride”, usually lasting 30 minutes. Dockless bikeshare bikes allow for pay per use, at about $1-2 per ride, as well as monthly or annual passes.

Starting in 2015, dockless bikeshare was an explosive new phenomenon in China, and then spread to western countries. By December 2017 there were five major companies operating in twenty five US cities with 44,000 bikes deployed (NACTO, 2017). In 2018 expansion continued, including on a pilot basis to the Metro Vancouver municipalities of Port Moody, Port Coquitlam and Richmond, as well as UBC. Another development in 2018 was the introduction of e-bike models by several firms, with some using e-bikes exclusively (e.g., JUMP).

Dockless bikeshare systems are operated by private firms. They provide the bikes at no capital cost to cities. The business model requires large capital investment to purchase and distribute large numbers of bikes to achieve profits from user fees on a large scale.

Dockless bikes have an installed locking mechanism, usually on the back wheel. When the ride begins the lock unlatches, and when the ride ends the lock re-engages. Some of the newer models include locking systems that require the e-bike to be attached to a bike rack or other appropriate footing.

The major advantage of dockless bikeshare is it gives users the ability to start and end a trip anywhere in the system’s service area. There is no need to walk to or from the nearest docking station. Another advantage is the cost-savings to governments of not having to purchase expensive docking stations.

However, early adopters of dockless bikeshare had serious issues with dockless bikes being left lying on sidewalks, streets, parks and elsewhere. Some companies have addressed the parking concern with new models of bikes (primarily e-bikes) that use u-locks, which helps ensure that bikes will be attached to bike racks. Other companies have incorporated GPS “geo-fencing”, which designates parking areas on the map in the dockless bikeshare app where the bikes must be parked at the end of a trip or be subject to a fine that is charged to the user’s account.

Another issue with dockless bikeshare systems is that bikes tend to accumulate in certain areas of a city and empty out of others due to patterns of usage. To rectify this problem company staff have to “rebalance” the distribution of bikes in the city by picking up bikes on a flatbed truck in areas of high concentration and moving them to areas of low concentration. This is also done in dock bikeshare systems, but the greater dispersion of bikes in a dockless system means that greater resources must be expended to do the re-balancing.

Results from a 2017 dockless bikeshare pilot in Seattle demonstrates the potential of dockless bikeshare programs: 33% of users reported regularly accessing transit with bikeshare bikes; 54% reported the bikeshare program had made commuting easier; 62 % said they were more likely to use dockless bikeshare to make transit connections; and 73% stated they were more likely to use the bikeshare if e-bikes were available (Seattle, 2018 appendix D). After the pilot, Seattle City Council decided to approve four dockless companies to provide up to 20,000 bikes (both regular and electric) by spring 2019.

With respect to administrative costs, in Seattle they are recouped through licensing fees, at $250,000 USD for each provider. The disadvantage, however, is that while the private firms take on most of the costs they also take on the risks, and if the business does not succeed then the city either has to provide public funding or the bikeshare program fails.

In the last year dockless bikeshare companies have released fleets of e-bikes in many US cities that already have dock bikeshare programs. For these cities the dockless e-bikes are viewed as a complementary extension of the existing dock bikeshare system.

A particular challenge for dockless e-bike systems is battery charging, since there is no home dock to charge the bikes. Some providers have designed their e-bikes to have removable "swappable" batteries, with technology installed on the e-bikes that allow dockless providers' staff to keep track of which batteries are low, so they can replace the batteries as needed throughout the city. Replacing batteries is an added cost to using e-bikes for dockless providers that does not arise for docking station systems that have docks equipped for charging.

An advantage of using e-bikes is that they are more popular with users, resulting in more revenue through more trips per day than conventional bikes, potentially covering or exceeding the additional costs. In January 2018, the City of San Francisco, a very hilly city, implemented an 18-month pilot e-bike program with dockless bikeshare provider JUMP. Data from the pilot indicates very high demand, with usage rates of 8 to 10 trips per day. It was also noted that the e-bikes' installed u-locks effectively addressed parking concerns, but that there was need for additional parking, bike racks and rebalancing of bikes (Barnett, 2018).

5.b.2. Dockless Bikeshare Policy Proposal

A Metro Vancouver-wide dockless bikeshare system that includes at least 50% e-bikes presents significant potential to provide access to e-bikes for commuters. Considering Seattle's determination that 20,000 dockless bikes are required for a city with less than one third of the population of Metro Vancouver living in less than half the area, at least 25,000 bikes (e-bikes and regular bikes) would be required to achieve effective service for the urban areas of Metro Vancouver. And, like in Seattle, there could be more than one provider, but all providers must deliver service throughout the urban areas of the region.

This proposal envisions TransLink facilitating co-operation and co-ordination between municipalities to ensure that the entire Metro Vancouver area is serviced by the same providers, to ensure maximum utility to commuters who commute to neighbouring municipalities and who use dockless bikeshare in conjunction with SkyTrain and other long distance transit throughout the region.

As with the option one, the dockless bikeshare service area would focus on denser regions and areas around major transit hubs, to help ensure user rates are high enough to maintain financially viability. However, the service areas would be significantly larger than for option one, since costly docks are not required, extending into lower density areas adjacent to higher density urban cores and transit hubs.

TransLink and municipal administrative costs would be covered by licence fees from private firm operators. With respect to annual operational costs of the bikeshare system to government, if the system proves to be financially viable then there are no costs, but if not then it is estimated that public funding of up to $5 million per year would be required to cover revenue shortfalls, based on revenue shortfalls for dock bikeshare systems.

The following parameters would apply to dockless bikeshare companies who provide dockless bikeshare service in Metro Vancouver:

1. at least 50% e-bikes are required;

2. all bikes must be e-bikes in hilly areas and must have sufficient power-assist to climb the regions steep hills;

4. all bikes must have u-lock or cable locks that require the bike to be parked and attached to a bike rack or other appropriate infrastructure, and/or must be parked in designated areas with penalties for non-compliance;

6. e-bike batteries must be charged/replaced when needed (e.g., when below 30% charge);

7. bikes must be re-balanced as needed throughout the region to ensure consistent service;

8. costs per 30-minute ride must be no more than $2.

To address the expected increase in demand for bikeshare parking, TransLink and BikeBC would work with and provide funding to municipalities to build new dockless bikeshare parking infrastructure.

5.c. Policy Option 3: E-Bike Subsidy

5.c.1. Background

Consumer subsidies are intended to encourage consumers to buy products that they would not otherwise have bought to achieve public policy objectives, such as increasing energy efficiency. Accordingly, a subsidy toward the purchase of an e-bike or conversion kit would be for the purpose of encouraging people to buy e-bikes for the purpose of using them in place of their vehicles.

The risk inherent in consumer subsidies is that the consumer was going to buy the device anyway. For such consumers the subsidy does not achieve its purpose of changing consumer behaviour and instead results in a waste of public funds. This is known as the "free-rider" phenomenon. In designing a subsidy policy option for e-bikes the free-rider issue must be squarely addressed.

Another issue with subsidies is they can lead to inequity, since wealthy people can take advantage of the subsidy even though they can afford the device, and poorer people may not be able to take advantage of the subsidy because the device, even with the subsidy, is still unaffordable to them. Electric vehicle subsidies are an example of this, especially for the more expensive models. This equity consideration must also be squarely addressed.

Presently, the Province provides a $5,000 subsidy under the CEVforBC Vehicle Incentive Program for the purchase of new battery electric vehicles with purchase prices under $77,000 (www.cevforbc.ca). The Province also provides a subsidy for electric motorcycles under the Specialty-Use Vehicle Incentive Program ("SUVI"), which provides 35% of the purchase price up to a maximum of $2,000 (www.pluginbc.ca/suvi/). There is no similar direct subsidy for e-bikes universally available to BC consumers. However, the $850 incentive available through the BC SCRAP-IT program functions as a form of subsidy for qualifying vehicle owners.

E-bike subsidies have been implemented by several European countries and cities. In February 2018 Sweden introduced a subsidy program that provides a 25% rebate up to a maximum of $1,500, with total funding of $41 million per year, for purchases of new e-bikes or electric motorcycles. France, Spain, and Italy all briefly offered smaller subsidies ($300-$1000) for new e-bikes. Cities have also offered subsidies for e-bikes, such as Oslo ($750) and Paris ($600).

Success of these subsidies is difficult to determine. Perhaps the best measure arises from Sweden's program where demand appears to be exceeding the available funding in the first year, indicating at least 27,000 e-bikes and electric motorcycles will be purchased with the subsidy funds by the end of year. In December 2018, Sweden's e-bike sales were reported to have increased 50% since 2017 (Stenberg, 2018). However, the amount of that 50% increase attributable to the subsidy rather than natural increase in consumer demand is unknown. Similarly the number of those e-bike purchases made by free-riders is similarly unknown, but would appear to be at least 66% assuming the increase in sales increase of 50% year over year was entirely attributable to the subsidy.

5.c.2. E-Bike Subsidy Policy Proposal

This policy option envisions the expansion of the existing SUVI subsidy to include e-bikes and conversion kits, but with a flat $1,000 subsidy toward the purchase of a new e-bike or conversion kit rather than 35% of the purchase price, applicable to a maximum purchase price of $3,000 before tax. The $1,000 subsidy could be applied in combination with the BC SCRAP-IT $850 incentive, which in combination would cover the full cost of a new entry level e-bike, thereby encouraging people to scrap their vehicle in exchange for a "free e-bike".

The $1,000 set amount means that a $1,700 entry level e-bike would cost $700 for purchasers, which is similar to the price of a similar quality conventional bike, thus greatly reducing the barrier to purchasing an e-bike as opposed to a conventional bike. A set amount of $1,000 ensures the same dollar benefit to every consumer, an important component of equity, while the maximum purchase price prevents free-rider high-income employees taking advantage of the program to buy luxury e-bikes, though it is still high enough to allow significant consumer choice.

The amount spent on electric vehicle subsidies provides some guidance as to what funding could be politically feasible for e-bikes. In the fall of 2017 the Province announced $27 million in funding for electric vehicle subsidies for a total of approximately 5,000 EVs sales. These funds were exhausted one year later in September 2018, at which time the Province approved an additional $10 million available until March 2020.

The amount of funding would need to be high enough to ensure that the number of free riders does not unacceptably undermine the effectiveness of the policy. E-bike sales data for BC are not available, however a best guestimate based on US sales of 150,000 e-bikes in 2016 and media reports of sales increasing rapidly produces sales for BC in 2019 in the range of 7,500 e-bikes, and rising by at least 2,000 e-bikes per year thereafter. Therefore, for a subsidy to induce new sales of e-bikes to non-free riders at a level where policy effectiveness could be cost-effective, despite the existence of free-riders, the funding required would need to be at least $15 million per year (15,000 e-bikes). It will be assumed that $15 million per year is the maximum that is feasible considering the electric car subsidy amounts, and that three years is the maximum time period, for a total of $45 million.

5.d. Policy Option 4: E-bike To Work Tax Exemption and Loan Program

5.d.1. Background

A bike to work or "cyclescheme" program combines a government tax incentive benefit with a loan from an employer to make purchasing a new bike more affordable for employees. Different varieties of cyclescheme have been employed in several countries, cities, and universities, including the United Kingdom ("UK") and Ireland. While the details of each cyclescheme program differ, the practical effect is the employer purchases a bike and accessories, as chosen by the employee for the employee to use to bike to work, and then is repaid by the employee through payments from the employee's paycheque over a period of one or more years. The tax incentive arises from the payments being made from the employee's pre-tax income, which amounts to a tax rebate of up to 40%, depending on the employee's tax bracket. The employee also must agree to use the bike at least 50% of the time to commute to work in order to qualify for the program.

In the Irish Cyclescheme employers can purchase one bike and accessories for an employee up to a maximum value of 1,000 euros (www.cyclescheme.ie). The employee registers online with Cyclescheme Ireland, a government affiliate organization responsible for administrating the program, and then the employer purchases the bicycle and accessories chosen by the employee. The employee signs a “Salary Sacrifice Agreement” as part of the application, which sets out the conditions of the repayment plan. Once the bike is in the employee’s possession the employee owns the bike, subject to a contract loan with the employer, and the payroll deductions begin, lasting for 12 months. If the employee quits, retires or is laid off before the end of the payment period, then the employee must repay the employer the outstanding balance.

The UK Cyclescheme program has some significant differences, such as the employer owning the bike and lending it to the employee, that do not appear well suited to the BC context (www.cyclescheme.co.uk). However, it is noteworthy that the UK also has a specialized e-bike cyclescheme run by a non-profit organization called Green Commute Initiative, which has a much higher maximum spending limit of 10,000 pounds, and the loan repayment period can be up to 60 months (www.greencommuterinitiative.uk).

Cycleschemes have several benefits. One benefit is the employee’s promise to use the new bicycle to commute, in most cases in place of a car, which motivates behavioural change. The interest free monthly payment scheme is another significant benefit, as it makes e-bikes more affordable for many current vehicle commuters. A further advantage is a cyclescheme requires little direct government funding, unlike the subsidy under option 3, instead subsidizing the purchase of e-bikes through tax breaks, making the program more financially feasible for governments.

However, a cyclescheme has some negative features: it is somewhat complex, making it more difficult for potential participants to understand; it requires the voluntary participation and agreement of employers; and, it requires a medium to long term commitment by employees.

Cycleschemes are also subject to free rider wastage due to some employees buying a new e-bike who already cycle to work or otherwise do no commute by vehicle. The UK and Irish Cyclescheme data suggests this occurs for 28% to 46% of cyclescheme participants (Clarke, Shires & Laird, 2014). However, there is still some positive impact from current cycle commuters buying e-bikes under the program since those cycle commuters are more likely to commute more often with an e-bike than previously with a conventional bike.

Notwithstanding these issues, studies of cyclescheme in Ireland and the UK indicate positive results:

- as of 2016, the UK cyclescheme had approximately 180,000 new participants per year (Swift et al., 2016);
- cyclescheme has a positive impact on reducing traffic congestion and other externalities of car use (Clarke et al, 2014, p. 16);
- according to several studies employing surveys, rates of cycle commuting increase for cyclescheme participants (Clarke et al., 2014, p. 6):
    - 75% of new cyclists using cyclescheme reported commuting at least twice per week and 31% did so 5 times per week;
    - 92% of all cyclescheme participants reported cycling commuting at least one day per week;
- cyclescheme participants reported reducing their average weekly car mileage by 35 miles per week (Clarke et al., 2014, p. 8);
- approximately 50% of cyclescheme participants reported increased physical activity levels as a result of the scheme (Clarke et al., 2014, p. 8);

While some of these survey results may be overstated, the relative consistency of the various results between studies provides guidance as to what outcomes in BC could be, should an cyclescheme be implemented. Considering the literature review findings with respect to e-bikes increasing rates of commuting as compared to conventional bikes, it is reasonable to expect even better results for a cyclescheme for e-bikes.

In addition, in a recent graduate study employing a benefit cost analysis of a cyclescheme program in Sweden, which considered factors such as GHG emissions and air pollution, infrastructure costs, vehicle ownership costs, impact on health, travel time, and accidents, estimated the benefit to cost ratio at 6.21:1. The author concluded that cyclescheme is a cost efficient way to increase active transportation (Grandin, 2019).

5.d.2. Policy Proposal: E-Bike to Work Tax Exemption and Loan Program

It is proposed that the Irish cyclescheme model be adapted for application in BC for the purchase of e-bikes specifically, and renamed “E-Cyclescheme” or “E-bike-to-Work”. Like the Irish cyclescheme it is proposed that E-Cyclescheme participants have ownership of the e-bike from the time of purchase, with the loan secured by a contract with the employer, as owning the e-bike enables employees to purchase insurance.

In light of the differences between the tax systems in Ireland and BC, it is proposed that the BC E-Cyclescheme include a provincial income tax credit for the total amount paid by the employee toward the e-bike under the E-Cyclescheme program in a given year, applied on the employee’s annual income tax return. The benefit received would depend on income level, since BC’s income tax rates range from 5.06% to 16.8%, with 7.7% applied to income earned between $40,000 and $81,000, the tax bracket that includes the average income for Metro Vancouverites. Since a rebate of 7.7% rebate is relatively low as compared to 25% or more in Ireland and the UK, and thus may not sufficiently encourage program participation, it is further proposed that e-bikes purchased through E-Cyclescheme be exempt from BC’s 7% provincial sales tax. Thus, in total, E-Cyclescheme participants would receive a benefit of 12.05% to 23.8%, depending on the tax bracket, or 14.7% for the average participant.

This policy proposal envisions the Province overseeing a non-profit organization that is tasked with establishing and administering the program. The E-Cyclescheme body would be responsible for:

- designing and operating a website for the E-Cyclescheme;
- determining what e-bikes and accessories are available or purchase, and which e-bike retailers are authorized retailers, under the scheme;
- negotiating with retailers to get discounts for program participants;
- preparing easy to understand information packages and promotional materials for employers and employees;

- preparing easy to understand application forms and informational materials, to be made available on the website;

- marketing the scheme to public and private employers, and to the public at large, to encourage participation in the E-Cyclescheme, including providing information sessions at employer offices;

- other administrative tasks as necessary to operate the E-Cyclescheme.

As with the Irish E-Cyclescheme, employees would submit a simple online application form on the E-Cyclescheme website to register with the Province as an E-Cyclescheme participant. Once approved, the employee would be able to receive the tax benefits. Participants would then select the e-bike and accessories they wish to purchase from an approved retailer. The employer would pay for the e-bike and accessories, with the employee’s paycheque deductions beginning immediately thereafter.

To secure the loan employees would be required to enter into a “E-Cyclescheme Agreement”, which would set out the terms of the loan in a simple to understand standard form contract. The E-Cyclescheme agreement would include the following key terms:

- the scheme allows for purchases of e-bikes, conversion kits, or e-bike batteries, plus accessories (e.g., helmet, lock, lights), but not conventional bikes;

- a maximum total for the purchase price and loan of $3,000 for an e-bike and accessories;

- participants can purchase a new e-bike or conversion kit every seven years, and a replacement e-bike battery every 3 years;

- registration with an anti-theft registry is required, where available;

- employees are required to have insurance during the pay period, if not already covered by a home insurance plan;

- salary sacrifice payment period of up to 36 months, to be agreed upon by the employee and employer;

- in consideration for benefits provided by the program, employees commit to use the e-bike primarily for commuting purposes;

- in the event an employee's employment ends prior to the end of the payment period, the entire remainder of the amount outstanding will be deducted from the remaining paycheques. If the remainder outstanding exceeds the total funds owing in the remaining paycheques, then the employee must pay the additional outstanding or forfeit ownership of the e-bike to the employer.

The E-Cyclescheme is limited to e-bikes because the literature indicates a much higher likelihood of participants commuting by e-bike than in place of a vehicle than by a conventional bike. The provision for purchasing a new e-bike every seven years or a battery every three years is designed to encourage E-Cyclescheme participants to continue commuting by e-bike once their battery needs replacing (every 3 to 10 years depending on frequency of use) or in the event their e-bike has reached the end of its lifespan.

The higher maximum 36 month pay period, as compared to the Irish cyclescheme payment period for conventional bikes, takes into account the higher purchase price of e-bikes. Consequently, the amortized monthly payments are made more affordable, thereby encouraging participation, especially by lower income employees. The limit of $3,000 is designed to prevent high income free-rider employees from purchasing expensive e-bikes at the public's expense, while preserving significant consumer choice to encourage participation.

It is further proposed that the E-Cyclescheme be made available to post-secondary students through post-secondary institutions, with the same terms applying, except that the e-bike payments would be added to student fees owing each term over a 2 or more year period (depending on the length of the degree program), rather than being deducted from a paycheque. Students who transfer from or cease attending the post-secondary institution prior to the end of the payment period would similarly be required to pay the remainder outstanding or forfeit ownership to the institution.

Chapter 6. Interview Results

The purpose of conducting interviews with transportation planners and bicycle policy experts was to gather information as to what bicycle policies are presently being planned or implemented in Metro Vancouver, and to acquire informed opinions as to whether the proposed policy options would be feasible, equitable, and effective.

Interviews were conducted with the individuals from the following government bodies:

- City of Burnaby
- City of Vancouver, Bikeshare Program
- City of Richmond
- City of Coquitlam
- City of Surrey
- District of North Vancouver
- University of British Columbia
- Ministry of Transportation, BikeBC Program
- TransLink, New Mobility Group

Interviews were conducted with experts from the following non-profit organizations:

- Better Environmentally Sound Transportation
- The British Columbia Cycling Coalition

An interview was also conducted with the Steve Miloshev, owner and CEO of e-bike manufacturer and retailer Motorino, to gather information on industry trends.

The following constitutes a summary of results from all the interviews:

<u>Recent trends in e-bike industry</u>

- Sales in e-bikes have been rising year over year.
- Younger people are buying e-bikes more than older people.

- New e-bikes and batteries are much better quality than before, the weight of some models is now comparable to regular bikes.

- Purchase prices are expected to continue to fall, perhaps as much as 25% in the near term.

Bike lanes and other bicycle policies

- Bike lane construction is progressing in accordance with municipal plans, especially where there is new road construction. Adding bike lanes to existing roads is more difficult and progressing more slowly.

- In some municipalities, adding painted bike lanes to city streets has not resulted in increased cycling mode share. Separated bike lanes are needed to attract more cyclists.

- Several municipalities are currently investing in more bike racks, secure bike parking and storage facilities, way-finding signage, and educational programs for schools.

- Several municipalities have implemented or are working on bylaw amendments to require improved parking for bikes in new and existing buildings, including access to electrical outlets for e-bikes.

- TransLink is in the process of installing secure bike storage (for 40+ bikes) at major SkyTrain stations, with user fees of $1 per day.

Dock and dockless bikeshare

- Dock bikeshare systems are more expensive because of capital costs for the docks, which is a barrier for some municipalities, but if there is enough density and usage rates are high then revenues can justify the capital costs. Furthermore, TransLink may be able to fund some or all of the capital costs, as it did with the recent Mobi expansion in the City of Vancouver.

- Municipalities have jurisdiction over bikeshare. TransLink currently lacks legislative authority to administer a region-wide system.

- Consistent access to bikeshare across municipalities would be ideal, but at this point municipalities are pursuing their own programs with different bikeshare providers.

- TransLink is working on regional guidelines for electric personal mobility devices, including e-bikes, and for bikeshare, which municipalities can implement to create consistent region-wide rules.

- In the future TransLink or a market provider may be able to provide a region-wide “mobility as service app” that integrates the different bikeshare, car share, and transit systems for all users across the region in one smartphone app or updated Compass Card.

- The difference between dockless and docking station systems is lessened by use of “geofenced” virtual parking spots called “havens” in dockless bikeshare systems, where users are required to park the bikes or be subject to a fine. Also, a docked system can be integrated with dockless bikeshare to create a hybrid system, with dockless bikes serving areas where docks are not installed.

- Public transit is the backbone of bikeshare systems. If a docked or a dockless system were to be implemented across Metro Vancouver it would need to be focussed on transit hubs in higher density areas.

- If spread to other regions there may not be enough ridership because bikeshare users are typically not experienced cyclists and need bike lanes to feel safe, and there are few separated bike lanes outside the City of Vancouver.

- Adding e-bikes to Mobi’s current docking stations presents challenges because they are solar powered and not connected to electric outlets. Some docking stations will be more easily and cheaply electrified than others. Future stations can be required to be electric. Swappable battery e-bikes present another option.

- Managing bikeshare systems requires having enough staff assigned to site new parking zones or docking stations, deal with citizen input, and ensure compliance with rules.

- Docking station bikeshare allows for careful management of where bikes are parked to prevent safety and pedestrian traffic flow issues that would be created by bikes being left on sidewalks.

- New data suggests that lower income people prefer dockless systems because of the inexpensive pay per use fees. Daily, monthly or annual fees present a barrier to some low income users.

- It is an open question whether dockless providers will prove to be financially viable. Municipalities and/or TransLink may or may not provide public funds to subsidize dockless bikeshare providers if they are not financially viable.

- Providing bikeshare in low density areas is very challenging because of lower usage rates, which decreases economic viability, and because it is difficult to ensure a consistent and reliable supply of e-bikes for daily commuting. Bikeshare would work best within 2 or 3 km of transit hubs and in higher density areas.

- Some municipalities are sceptical that dockless bikeshare would benefit their communities, primarily due to concerns about bikes cluttering streets, sidewalks and other public spaces.

E-bike commuting

- E-bikes are critical to achieving higher rates of cycle commuting in hilly areas. They are not necessarily critical for flat regions like Richmond.

- Leaving an e-bike (or regular bike) at a transit hub is problematic for may cyclists due to fear of theft or damage. Bike parkades are being built at transit hubs, though not enough for hundreds of e-bike commuters, and it is not yet clear if commuters with expensive e-bikes (or regular bikes) will trust the parkades enough use them.

- Owning e-bikes is a more practical solution than the bikeshare systems for people living in low density single family neighbourhoods.

Subsidies

- A subsidy could be a good idea in the short term, but costs of e-bikes will eventually hit a tipping point at which time wide scale adoption occurs without subsidies.

- Implementing an e-bike subsidy program would not be administratively difficult.

- A subsidy does not make an e-bike affordable for all people since the remaining purchase price remains too large for many lower income people, and thus benefits high income earners more.

- Placing a limit on the e-bike purchase price permitted for the subsidy could negatively impact people with disabilities who need a higher end e-bike or e-tricycle. This could be addressed with a separate higher subsidy for qualifying disabled people.

E-Cyclescheme

- There should be a cap on purchase prices for both a subsidy and for a cyclescheme, as the public should not be subsidizing purchases of luxury e-bikes.

- An E-Cyclescheme could reach a lot of participants just with public service employees. For example, Vancouver has approximately 7000 employees, and Burnaby has approximately 4000 employees.

- E-Cyclescheme administrators could adopt corporate procurement strategies to acquire discounts on e-bikes for participants.

- While the loan aspect of the program makes it more accessible to lower income employees, the program will likely benefit longer-term higher-income employees more than low income employees, especially those in short term or unstable jobs.

- For both the E-Cyclescheme and the subsidy options theft is a serious issue, especially for lower income people since if their e-bike is stolen they cannot afford to buy another one. Requiring insurance and/or registration with an anti-theft program would help ameliorate this problem, but insurance would increase costs and anti-theft programs are not available in all areas of Metro Vancouver.

Chapter 7. Criteria and Measures

Commuting by e-bike simultaneously creates environmental, economic and public health benefits that are commensurate to the number of e-bikes being used to commute in place of vehicles. Policies that result in high numbers of e-bikes being used to commute are therefore going to be the most effective at achieving the desired societal benefits. Accordingly, the first criteria is “policy effectiveness”, measured by the estimated number of e-bikes deployed and the estimated number of commute trips by e-bike in the place of vehicle commuting that will likely result upon full implementation. A measure of “low”, “medium” or “high” will be assigned, with “low” attributed to policies that are likely result in weekly e-bike commute trips in place of cars of under 50,000 per week, “medium” for between 50,000 to 100,000 trips per week, and “high” for more than 100,000 trips per week.

The second criterion for consideration is “affordability”, which addresses the issues of equitable access to e-bikes. This criterion will be measured by the anticipated cost to access e-bikes for lower income employees and students. “Lower income” is defined for the purposes of this report as commuters who earn less than the median individual income of $36,000 per year. A measure of “low” indicates e-bike access is likely too expensive to provide any meaningful access, “medium” indicates access without significantly impacting disposable income, and “high” indicates e-bike use will likely reduce overall transportation costs for lower income commuters.

The third criterion for consideration is “implementation feasibility”, which takes into consideration the administrative and political complexity for local and/or provincial government bodies to implement the policies, as well as technical challenges. A measure of “low” means implementation is complex and difficult, “medium” means implementation poses some challenges but is not highly complex or difficult, and “high” means that implementation is not complex or difficult.

The fourth criterion for consideration is “governmental cost”, as informed by the anticipated level of public funding required to set up and maintain the policy programs, and the cost-effectiveness of the programs at producing e-bike trips in place of vehicle commute trips. These costs will be measured after seven years of implementation. A measure of “low” means the anticipated costs in light of the e-bike trips produced are prohibitive to implementation, “medium” indicates annual funding requirements are feasible but not low in light of the cost per e-bike trips produced, and “high” means the anticipated program costs and costs per e-bike trip are low.

Chapter 8. Analysis of Policy Options

8.a. Policy Effectiveness

Ultimately the level of policy effectiveness will be determined by the number of trips by e-bike in place of vehicle commute trips that are likely to result, as all policy benefits flow therefrom. The total number of e-bikes deployed is one factor to consider, but most important is the likely number of commute trips per week per e-bike that result. Other important factors include: the likelihood of the e-bikes serving low density suburbs where most car commuters live; the ability of the e-bikes to be used in conjunction with transit for long distance commutes; and reliability of access to the e-bikes during commuting times. What follows are best estimates that quantify the potential for each option to result in e-bike commute trips in place of vehicles.

<u>Option 1: Dock Bikeshare</u>

Expansion of the Mobi dock bikeshare system would well serve short distance commuters within the service areas, as well as long distance commuters within service areas who use transit with the e-bikes providing the “last mile” of their commutes.

Data from dock bikeshare e-bike pilots indicate e-bikes are used for between 7 and 10 trips per day (8 will be assumed). With deployment of 2,500 e-bikes in Metro Vancouver the number of trips could be as high as 20,000 per day. However, conventional bikeshare data from Seattle indicates only about 40% of trips are for commuting. E-bikes would likely increase commuting trips, so 50% will be assumed. In addition, data from several bikeshare programs indicates that only about 20% of bikeshare users would normally travel by car as most bikeshare users usually take transit or walk (Fishman, 2015, p. 104, Figure 6). Accordingly, the likely number of commute trips per day in place of a vehicle are reduced to 2,000. (See Appendix B for calculations.)

With respect to servicing low density areas, to install enough docks to allow large numbers of potential users to walk less than 5 minutes to a docking station would be very expensive, as would rebalancing bikes to these more distant locations, and the low usage rates would likely ensure those costs are not recouped. It is therefore unlikely service would be provided in many low-density areas of Metro Vancouver, a serious limitation for his option.

The estimated total commute trips in place of vehicles is 2,000 per day, or 10,000 per week. This option therefore scores a rating of “low”.

Option 2: Dockless Bikeshare

This option envisions 12,500 e-bikes conventional bikes and 12,500 e-bikes deployed at full implementation. Similar rates of use in place of vehicle commuting can be assumed as for e-bikes under option one for similar reasons, with two significant differences.

First, the lower capital costs of dockless bikeshare, due to not needing docks, means that it is more economically feasible for dockless providers to serve more lower density areas than a docking station system. Therefore, the total area and total number of potential car commuters potentially served by dockless bikeshare is likely higher. While the higher rates of use are accounted for in part by the much greater number of bikes in the dockless bikeshare fleet, the higher proportion of vehicle commuters expected to use the system merits an adjustment to 40% of trips replacing vehicle commuters rather than 20%.

Second, dockless bikeshare systems result in more dispersed placement of e-bikes since they can be parked in more locations than docking station systems. This means more re-balancing of e-bikes would be needed to reliably serve commuters than in a dock bikeshare system. This is especially the case for low density areas. Consequently, it is more likely that regular users of a dockless system who live in single family residences will not always have an e-bike nearby ready for use. Not having reliable access to an e-bike for commuting purposes would be a serious deterrent to regular use by commuters who need to be able to get to work on time every day. Thus, these greater reliability concerns in lower density areas merit a discount of 10% from that of the docking station option.

Altogether, 12,500 dockless e-bikes are likely to produce 90,000 trips per week in place of vehicle commutes, a number that remains constant over time assuming no new e-bikes are added to the system. Accordingly this option merits a score of “medium”.

Option 3: $1,000 Subsidy

In light of the Swedish subsidy results and expected increases in e-bike sales each year due to their growing popularity, it would be expected that at least 50% of e-bikes purchased with the $15 million per year subsidy would be free riders in year one (7,500), rising to 63% in year two (9,500), and to 77% in year three (11,500). The $45 million subsidy program can therefore be expected to produce 28,500 free-rider e-bikes and 16,500 non-free rider e-bikes. As the subsidy would be a province-wide program, these numbers must be decreased 50% to account only for Metro Vancouver (50% of BC's population), amounting to 8,250 non free-rider e-bikes.

As for the likelihood of the number of e-bike commuting trips per week in place of vehicle, the literature review suggests an average of 50% of commute trips (5 trips) could be expected, however, because many purchasers may not be employed or students, the number of commute trips will be reduced to an average of 3 trips per e-bike per week.

With respect to access to commuters in low density areas, the subsidized bikes are equally available to all Metro Vancouverites. However, lack of secure parking at transit hubs, and inability to take e-bikes on SkyTrain during rush hour, makes it unlikely that many of the subsidized e-bikes will be used in conjunction with transit for long commutes. Accordingly, this limitation merits a further reduction of 15%, reflecting the approximate average number of car commuters who travel long distances to work each weekday.

The 8,250 non free rider e-bikes purchased in Metro Vancouver over the lifetime of the subsidy are expected to produce 4,200 trips per day in place of vehicle commutes, or 21,000 weekly trips, and therefore merits a score of "low".

Option 4: E-bike to Work Tax Incentive and Loan Program

The UK cyclescheme had 164,000 participants purchase new bikes in 2014. Since BC in 2019 has about 7.8% of the population of the UK, once fully implemented the E-Cyclescheme is expected to produce 12,800 participants per year if applied to the whole province, which amounts to 6,400 participants per year for Metro Vancouver.

According to the cyclescheme survey studies, about 30% of participants can be expected to be current cycle commuter, transit users or walkers. The data also indicates that participants who already cycle to work increase the frequency of commute trips per week with their cyclescheme bike – this is even more likely to occur if the participant purchased an e-bike purchased through E-Cyclescheme rather than a conventional bike. Therefore, a lower 20% discount (instead of 30%) will be applied to take into account the likely higher rates commuting by existing cycle commuters due to their use of e-bikes.

The UK data indicates the cyclescheme commuters can be expected to cycle to work on average of 2-3 times per week (4-6 commute trips per week). Assuming the lower rate of 4 trips per week is the most accurate, but taking into account higher expected rates when using an e-bike, 5 trips per week will be assumed.

Like with the subsidy option, the E-Cyclescheme is available to all Metro Vancouver residents. However, unlike the subsidy option, it is unlikely that long distance commuters would purchase an e-bike if they are unwilling to park at transit hubs as part of their commute to work, since the purpose of the program is for employees to commute to work. Accordingly, no discount will be applied to take into account long distance vehicle commuters.

In the first year E-Cyclescheme is expected to produce 25,600 commute trips per week in place of a vehicle, and after 7 years it is expected to produce an estimated 179,200 trips per week, or 35,840 trips per day. Accordingly, this option merits a score of "high".

8.b. Affordability

The overriding consideration under this criterion is the affordability and therefore level of access to e-bikes for low income vehicle commuters under each policy option.

Option 1: Dock Bikeshare

For those who opt for the $129 annual pass (unlimited 30 minute rides), the cost per day of commuting by a Mobi bikeshare bike 5 days per week amounts to $0.50 per weekday. A 90-day pass costs $75, or $1.15 per weekday. While these daily rates are highly affordable for most users, the interview results indicated that low income users prefer to pay per ride because they may not have additional money to purchase an annual or monthly pass. Mobi does not currently allow for single rides; the lowest cost option is a day-pass for $9.75

However, it is unlikely that very low income people who cannot afford the up front cost of a $75 or $129 pass are vehicle commuters, in light of the much higher costs of vehicle ownership and commuting. Accordingly, despite the current unavailability of an inexpensive pay per use, this option merits a score of “high”.

<u>Option 2: Dockless Bikeshare</u>

The dockless provider for Richmond, U-bicycle, charges $150 for an annual pass ($0.58 per weekday), $15 for a day pass, and has a pay as you go option of $1 for 30 minutes (https://www.u-bicycle.ca/ubicyclepage). The additional availability off a pay per use option makes the dockless bikeshare option even more affordable for low income vehicle commuters than option one. Accordingly, this option also merits a score of “high”.

<u>Option 3: $1,000 Subsidy</u>

While the $1,000 subsidy decreases the cost of an entry level e-bike from $1,700 to $700, a major increase in affordability, the cost of $700 (plus sale tax) is still high for low income vehicle commuters struggling to make ends meet.

If the low income vehicle commuter were to sell his or her vehicle, or scrap it with the BC SCRAP-IT program, then the e-bike purchase price should not pose a barrier. However, it cannot be assumed that low income vehicle commuters are likely to sell or scrap their vehicles to buy an e-bike, since if it is their only vehicle (which can be assumed due to low income) then they would then have no vehicle for other transportation needs, such as driving children to school or visiting relatives in Chilliwack.

For many low-income vehicle commuters the cost of purchasing a new e-bike for $700 would amount to a unaffordable additional cost. Accordingly, the subsidy option receives a score of “low”.

<u>Option 4: E-Bike to Work Tax Incentive and Loan Program</u>

On the one hand, an E-Cyclescheme appears to most benefit higher income employees due to their being able to afford deductions to their paycheques to pay for the e-bike. On the other hand, the relatively small monthly payments made possible by the loan scheme makes purchasing an e-bike much more affordable for low-income employees who cannot afford the high upfront cost of purchasing an e-bike.

Ultimately the analysis is determined by the affordability of the monthly payments for low-income participants. Assuming a $2,000 E-Cyclescheme loan, the monthly payments for a 36 month period would be $55 per month (some of which is refunded through the year end income tax credit). According to a recent poll, 41% of British Columbians are $200 or less from being able to pay their bills (MNP, 2019). An additional expense of $55 per month is therefore likely cost-prohibitive for many low income vehicle commuters. However, the savings from commuting by e-bike in place of a vehicle would make up for some or all of the monthly payment – the savings in gasoline costs alone would amount to $55 or more in a month for many vehicle commuters, depending on the length of the commute and how often the person uses the e-bike.

The loan aspect of the E-Cyclescheme significantly increase affordability to low income car commuters once savings in driving costs are considered. However, for those with very short commutes or who will not use the e-bike often, the savings may not fully cover the monthly cost of the e-bike. Balancing the various factors this option merits a score of “medium”.

8.c. Implementation Feasibility

Policy options that are very complex or politically difficult to implement should not be recommended barring some special consideration. The interview results are most important for this consideration.

<u>Option 1 and Option 2: Dock and Dockless Bikeshare</u>

These two options are considered together as very similar issues arise for both.

The fact that several municipalities have recently decided to pursue dockless bikeshare systems while some municipalities are sceptical of their value, and Vancouver is currently committed to its docking station system, indicates that acquiring agreement from all municipalities to implement a region-wide integrated system – docked or dockless – would be very difficult at this time. In addition, TransLink’s lack of legislative authority to mandate an integrated system amongst the various municipalities similarly impedes implementing a region-wide system.

In addition, a technological solution may arise that will enable an integrated bikeshare system for the region, without the need for creating a co-ordinated system. The interview results indicated the real possibility for a "mobility as service" app or updated Compass card to be available in the next few years, which would allow people to use any of the docked and dockless bikeshare systems then operating in Metro Vancouver with the single app or updated Compass card. Such a technology would effectively eliminate the need to develop an integrated system; each municipality can choose its own bikeshare system and integration would happen later when the technology is ready for deployment.

While this "mobility as service" technological solution will likely not be available for two or more years, its transformative potential indicates that attempting to implement an integrated system at this time, a highly complex and politically difficult task, may be unnecessary and undesirable. Accordingly, both options merit a score of "low" on this criterion.

Option 3: $1,000 Subsidy

The interview results indicated implementation would be relatively simple considering the SUVI program is already in place. Another positive factor is that this option does not require municipal involvement to operate. This option therefore merits a score of "high".

Option 4: E-Bike To Work Tax Incentive and Loan Program

The Irish cyclescheme program provides a model for implementation, making the program highly feasible. Assuming the E-Cyclescheme is operated by a private non-profit agency under Provincial government regulatory oversight, there would be an initial period requiring greater resources to establish the regulatory framework and to collaborate with the non-profit in establishing the system, followed by a period of consistent and relatively minimal expenditure of resources for program oversight. Like the subsidy option, an E-Cyclescheme imposes no administrative responsibility for municipalities. While the E-Cyclescheme option will be more complex than the subsidy option, it is not expected to be difficult to implement, and therefore merits a score of "high".

8.d. Governmental Cost

It is important to directly compare costs of creating and implementing the different options over time, as the amount of funding required impacts on the political feasibility of funding the policies, and the cost per e-bike commute trip in place of a vehicle illuminates the cost-effectiveness of the policies. In this section the four policy options will be separately analysed with scores provided after a comparative analysis at the end.

Seven years has been chosen for the cost-comparison analysis to allow time to fully implement all the policy options, to amortize costs for the options that involve high spending at the beginning of the program, and to allow a better assessment of cost per e-bike commute trip in place of a vehicle over time. It also reflects the estimated average life of an e-bike battery, after which time additional cost considerations arise that are too unpredictable to calculate at this time.

Option 1: Dock Bikeshare

This option envisions deployment of 5,000 additional bikes (2,500 e-bikes) and 300 new docking stations to an expanded Mobi system at a capital cost of $25 million, plus up to $3 million per year to cover shortfalls in operational revenues, plus an additional cost of $3 million in indirect municipal costs.

Over a seven year period the total program cost (including regular and e-bikes) amounts to $67 million, or $9.57 million per year. On a cost per trip basis, only the costs pertaining to e-bikes are considered, which amounts to $9.20 per e-bike commute trip in place of a vehicle. Over longer periods of time the cost per year would improve through further amortization of the capital cost for the docking stations.

Option 2: Dockless Bikeshare

On this criterion dockless bikeshare differs significantly from the docking station expansion. Since dockless bikeshare capital costs are borne entirely by the private providers, the only cost to government arises in the indirect costs to municipalities and/or TransLink for administering the program, which can be recouped by licencing fees. Consequently, a Metro Vancouver-wide dockless system should be cost-neutral to government, assuming the private dockless providers are economically viable. However, if the private providers are not economically viable, then TransLink, the Province and/or municipalities would need to either subsidize the private operators at an estimated cost of $5 million per year or abandon dockless bikeshare services for the region.

Total costs of the program are estimated at $0 or $25 million and cost per e-bike commute trip in place of a vehicle amounts to $0 or $0.53, depending whether public funding is required.

Option 3: $1,000 Subsidy

This option envisions a $15 million per year subsidy for three years for a total of $45 million. In addition, the provincial government would incur costs to administer the program and liaise with e-bike retailers, guesstimated at $100,000 per year, or $300,000 total. Applied to Metro Vancouver only, these costs are 50% less, at $22.5 million and $150,000, which amounts to an annual amortized cost of $3.2 million per year over seven years. The cost per e-bike trip in place of a vehicle amounts to $3.95.

Option 4: E-Bike to Work Tax Incentive and Loan Program

The cost to government of an E-Cyclescheme depends on the popularity of the program. Assuming an average purchase/loan of $2,500, and an average tax rebate of 14.7% (PST plus income tax rebates), the loss of provincial tax revenues attributable to 6,400 e-bikes (for Metro Vancouver only), plus $250,000 in estimated annual administrative costs, amounts to $2.6 million per year, or $18.20 million after seven years. The cost per e-bike commute trip in place of a vehicle amounts to $0.48. After seven years the costs per e-bike commuter trip would likely continue to fall due to the increased time that bikes purchased in previous trips are continuing to be used for commuting.

Cost comparison of the policy options

Table 1 presents the findings with respect to estimated program costs and cost effectiveness of the four policy options after seven years of implementation. A detailed accounting of the calculations supporting these findings is provided at Appendix “B”.

Table 1: Estimated Governmental Costs and Cost-Effectiveness of Policy Options After Seven Years

	Estimated total program cost and annual average cost to governments over 7 years	Estimated number of non-free rider e-bikes deployed over 7 years	Cost per non-free rider e-bike deployed (all costs) over 7 years	Estimated number of total commute trips in place of a vehicle over 7 years	Cost per e-bike commuter trip in place of a vehicle
Dock Bikeshare	$33.5 million for e-bikes only / $67 million including regular bikes $4.78 million for e-bikes only / $9.57 million including regular bikes	2,500 e-bikes (deployed in 1 year)	$13,400	3.64 million trips	$9.20
Dockless Bikeshare	0 / $17.5 million for e-bikes only / 0 / $35 million total including regular bikes* 0 / $2.5 million for e-bikes only / 0 / $5 million per year including regular bikes*	12,500 e-bikes (deployed in 1 year)	0 / $1,400*	32.76 million	0 / $0.53*
$1,000 Subsidy	$22.65 million total for Metro Vancouver / $45.30 million total for BC** $3.24 million per year for Metro Vancouver / $6.47 million per year for BC	8,250 e-bikes (deployed over first 3 years)	$2,745	5.73 million	$3.95
E-Cyclescheme	$18.21 million total for Metro Vancouver / $31.8 million total for BC $2.60 million per year for Metro Vancouver / 5.20 million per year for BC	44,800 e-bikes (deployed equally over 7 years)	$406	37.27 million	$0.49

* The two amounts are provided due to risk of needing subsidies to maintain system in the even private operators prove not to be financially viable.
** Program cost of $15 million distributed over first three years, with $0 for remaining 4 years.

The dock bikeshare option is cost prohibitive as a policy to replace car commuting on all measures, with average annual costs at over $8 million and cost per e-bike trip in place of a vehicle at $7.82, thus meriting a score of “low”.

The dockless bikeshare option performs best on overall costs if it does not require public funding (since the cost is $0), but only moderately well if it does require public funding at $5 million per year. On a cost per trip basis the dockless bikeshare performs either extremely well with no public funding required, at $0 per trip, or very well even if public funding is required, at $0.53 per trip, and therefore overall it merits a score of “high”.

The subsidy option’s total program costs are moderate at $3.24 million per year when averaged over 7 years, while the cost per trip in place of a car commute at $3.95 is very high, even after 7 years of amortizing the initial funds expended in the first three years. Factoring in the very high costs in the first three years and the wastage of public money on free-riders, the very high cost per e-bike trip outweighs the moderate program costs, thus this option merits a score of “low”.

The E-Cyclescheme option performs very well on both the program cost at $2.6 million per year and cost per e-bike trip in place of a vehicle commute trip at $0.49, thus meriting a score of “high”.

Chapter 9. Recommendation

It is recommended that the Province implement an E-Cyclescheme. Table 2 summarizes the policy analysis determinations that support this recommendation.

Table 2: Matrix Summary of Policy Analysis Results

	Option 1: Dock Bikeshare	**Option 2: Dockless Bikeshare**	**Option 3: $1,000 Subsidy**	**Option 4: E-Cyclescheme**
Criterion 1: Policy Effectiveness	**Low**: 10,000 e-bike trips per week in place of a vehicle	**Medium**: 90,000 e-trips per week in place of a vehicle	**Low:** 21,000 e-bike trips per week in place of a vehicle	**High:** 179,200 e-bike trip per week in place of a vehicle
Criterion 2: Affordability	**High:** low cost monthly and annual passes	**High:** low cost passes and low pay-per-use fees	**Low:** $700+ purchase price after subsidy still too expensive	**Medium:** monthly payments of $50+ per month feasible for many but not all
Criterion 3: Implementation Feasibility	**Low:** politically and technically complex due to multiple jurisdictions	**Low:** politically and technically complex due to multiple jurisdictions	**High:** low technical difficulty, low complexity	**High:** low technical difficulty, moderate complexity initially, then low complexity
Criterion 4: Governmental Cost	**Low:** $9.20 per e-bike commute trip in place of a vehicle	**High:** $0 / $0.53 per e-bike commute trip in place of a vehicle, depending on need for subsidy	**Low:** $3.95 per e-bike commute trip in place of a vehicle	**High:** $0.49 per e-bike commute trip in place of a vehicle

Score range of “Low”, “Medium” or “High”: low is the most negative score and high the most positive score for all criteria.

The expansion of dock bikeshare across Metro Vancouver does not present an cost-effective option for encouraging large numbers of car commuters to instead commute by e-bike. The dockless bikeshare option performs much better on both effectiveness and in terms of government cost than dock bikeshare. However, for both bikeshare options, the difficulty of implementing a region-wide system across over multiple independent municipalities, and the expectation that an integrated bikeshare system will likely develop through technological innovation without further government intervention, weigh heavily against recommending either option.

While relatively simple to implement, the subsidy option performs poorly on all other criteria. In particular, the approximately $28 million wasted on free-riders and the low number of expected commuter trips militate strongly against recommending that option.

Instead the scales tip in favour of recommending the E-Cyclescheme option, as it will likely produce the greatest amount of e-bike trips in place of car commutes – thus producing the highest levels of reduced pollution and GHG emissions, reduced traffic congestion, and improved public health – and at a low cost to government. Furthermore, the program would not be difficult to implement and would be affordable to most car commuters, including many low income employees and students.

It is further recommended that initial efforts to recruit employers be focussed on large public sector employers – e.g., public service employees, municipalities, universities, crown corporations – followed by large private sector employers, to access the greatest number of potential participants in the shortest possible time, thereby maximizing societal benefits in the short and long term.

The benefits of the E-Cyclescheme program would apply equally to all other urban areas of the province and, with the possible exception of traffic reduction, to rural parts of the province as well. It is therefore recommended that the E-Cyclescheme be employed in Metro Vancouver as well as across the province, starting with the urban regions with the most car commuters – such as Greater Victoria, Kelowna, Nanaimo and Prince George – if resources require a staggered implementation.

Chapter 10. Limitations

The above analysis has some limitations. In particular, while the trips per e-bike estimates for all the policy options considered are grounded in real data from other contexts where possible, they may turn out to be too high or too low when applied in Metro Vancouver. The local factors weighing against successful implementation include the many days per year with rain, the long hours of darkness in the winter months, and the small amount of separated bike lanes outside the City of Vancouver at the present time. On the other had, the gradual building of separated bike lanes throughout the region, the local popularity of outdoor physical activities, and the ever-increasing costs of driving in a highly unaffordable city, could result in e-bikes becoming more popular with car commuters than anticipated in this report, especially in the dry summer months.

Another limitation is the focus on using e-bikes for commuting and not for other purposes. If other non-recreational trips – e.g., errands, social activities – made in place of vehicles were included, the benefits and cost-effectiveness of all the policy options would likely increase, probably more for the bikeshare programs than the other options due to higher usage rates per e-bike. Another factor not considered are the benefits that e-bikes may have on reducing demand for transit, thereby reducing the costs of future transit expansions and potentially reducing overcrowding on current transit routes. A study that takes into account these factors would provide further guidance to policy makers as to the potential overall effectiveness of the policies considered in his report at increasing overall rates of cycling, and the benefits and costs that arise considering the wider considerations involved.

Chapter 11. Conclusion

Although none of the policy options considered in this report are likely to achieve TransLink's target of 15% of *all* trips under 8km by bicycle, the rate of cycling is expected to increased significantly upon full implementation of an E-Cyclescheme, especially for commuting during rush hour, amounting to replacement of 5.1% of vehicle commute trips under 8km, 3.4% of all commute trips under 8km, and 1.2% of all trips under 8km. Considering the current cycling rate of less than 2% for all trips for the region, these figures represent major increases in rates of cycling for Metro Vancouver. In addition, if a combined docked and dockless bikeshare regional system evolves at the scale considered in this report, then all these figures would be considerably higher, likely doubling current cycling rates, if not more.

The societal benefits likely to result from an E-Cyclescheme will be moderate in overall effect, due to the relatively small number of vehicle trips replaced compared to the total for all purposes. With respect to GHG emissions, by year seven the E-Cyclescheme should result in a reduction of 18,640 tonnes of CO2 per year, which amounts to about 1.2% of GHG emissions from vehicle commuting (0.04% of annual emissions from all personal transportation) in Metro Vancouver (see Appendix B for calculations). As for health care savings, while the literature strongly indicates high benefit to cost ratios for public money spent on regular cycling, the level of increased physical activity for e-bike cyclists produced by E-Cyclescheme is too uncertain to provide a financial estimate of the value of the resulting benefits to e-cyclists and government, other than to say it is likely positive on a benefit to cost basis. As for traffic congestion, decreases in travel time for vehicle commuters are most likely to occur during rush hour on highly congested local routes near separated bike lanes (FLOW, 2016). A reduction of up to 5% of the time lost to traffic congestion can reasonably be expected to occur on congested routes where high numbers of e-bike cyclists previously commuted by vehicle, which should result in savings to the economy in the tens of millions of dollars per year (FLOW, 2016; Hamilton et al., 2018).

To achieve TransLink's target for cycling of 15% of all trips under 8km, which amounts to approximately 457,000 trips per weekday, many more e-bikes than expected under the proposed E-Cyclescheme would need to be in active use in place of vehicles on a regular basis – at least an additional 400,000 e-bikes, assuming cyclists use the e-bikes to replace on average five vehicle trips per work week. Recent research indicates that combining policies that dis-incentivize driving vehicles with policies that promote using bicycles produce greater cumulative results than any one policy on is own (FLOW, 2016). Accordingly, achieving TransLink's targets will require implementing policies that make driving less attractive, such as congestion charges, in combination with policies that make cycling more attractive, such as building large-scale secure bicycle parking at transit hubs or increasing the number of vehicle-free streets or areas. Most of all there needs to be the political will to provide additional funding to build the many separated bike lanes needed throughout the region. Without separated bike lanes providing access to all the urban areas of Metro Vancouver, safety and convenience concerns will continue to limit growth in rates of cycling in the region, even with the widespread adoption of e-bikes.

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Appendix A – Literature Review

A large Chinese study of e-bike use patterns over a 6 year period in the city of Kunming, China, explored how the demographics and use characteristics of e-bike users changed over time, and considered whether e-bikes could dispute the traditional motorized road system (Cherry et al., 2016). Like many cities in China, Kunming has experienced a massive increase in e-bike use, from 0 in 2000, to 200,000 in 2005, to more than 1 million in 2012. E-bikes constitute 75% of all bicycles, and account for 19% of all trips in the city. The dominant purpose of e-bike trips was commuting to and from work (68%). The study found that e-bike users would otherwise be predominantly bus users (>50%), though there was also a significant displacement of car and taxi trips with 10-13% of e-bike users being previous car/taxi users, and with 24% current e-bike users stating they if they did not have an e-bike they would otherwise use car/taxi. While caution should be taken in extrapolating these findings to a western urban context, they are still informative of dynamics in a context where e-bike usage is very high.

In an American study that explored differences in experiences and perceptions between conventional and electric bicycle users (Ling et al., 2017), the authors determined that e-bike use was generally more utilitarian, used for commuting and running errands, whereas conventional bikes were primarily used for recreation and exercise. Enjoyment and health benefits were equally high for both types of bikes. Survey respondents were mostly male (83%), predominantly older (61% were 50 to 69, 11 % over 69), reported widely varying income levels, and most also owned a regular gasoline vehicle (71%). E-bike users on average travelled longer distances (14.9 vs. 12.3 miles) and took more trips per week (3.6 vs. 2.7 trips). E-bike users, especially older users, reported highly valuing e-bikes for riding up hills, against the wind, and in keeping up with other cyclists. Older respondents used e-bikes more for recreation while younger respondents used them more for commuting. Participants identified expensive purchase price at the primary barrier to purchasing an e-bike. Anti-theft devices were also identified as very important. The study's authors concluded that the results indicated that e-bikes increase rates of cycling.

A 2013 American study of the effect of e-bikes at three employment campuses in Portland, Oregon, focussed on the effects of owning an e-bike on commuters (MacArthur et al., 2017). Prior to participating in the study participants identified several barriers to conventional bicycle use: bad weather, hills, perspiration, trip length, and time constraints. Participants were provided e-bikes for a 10-week trial period. After the trial period participants were again surveyed. The results showed that e-bikes had a substantial impact on reducing certain barriers, in particular perspiration (47% to 10%), trip length (44% to 23%), time constraints (18% to 10%), and hills (38% to 0%). Barriers that remained constant or increased were bad weather, carrying capacity, safety concerns, and secure parking. The number of people commuting by bicycle at least once a week more than doubled from 28% to 59%, and use for all purposes similarly at least doubled. Participants reported very high levels of agreement that e-bikes were comfortable, fun, easy to use, and safe, and reported feeling more comfortable riding in traffic than on a conventional bike. Another significant finding was that about 42% cyclists who were not actively cycling prior to receiving an e-bike started commuting to work at least once per week with the e-bike.

In a follow up study also headed by MacArthur, a major survey of North American e-bike owners (including Canadians) was conducted to determine if the Portland study's findings were reflected across North America, (MacArthur et al., 2018). The survey confirmed the Portland study's findings. Hills, distance, perspiration, and speed/time were the top concerns. 49% of participants reported using their e-bikes daily, and 34% of all participants reported using their e-bike as their primary mode of transport for commuting, with that number increasing to 45.9% for those under the age of 55. Furthermore, of those who commuted by e-bike, 46% said they would otherwise have used a vehicle for their commute. 96.4% agreed or strongly agreed that they enjoyed riding an e-bike, and the vast majority of participants agreed that riding an e-bike was more fun than a regular bike and that they would rather cycle than drive a car. The survey results also demonstrated that there were important demographic differences to e-bike use, both in motivations for use and manner of use. Older e-bike users and those with physical limitations were most interested in reducing the effort of cycling, less concerned about speed or perspiration, and more interested in using e-bikes for exercise, health improvement, and recreation. Female e-bike users were more concerned about hills, less concerned about speed or perspiration, and were more motivated by the ability to carry cargo and/or children. Younger e-bike users had a more utilitarian approach, caring more about speed, perspiration, and carrying cargo/kids, and using e-bikes to make commuting easier, cheaper, and less time consuming.

A qualitative study of e-bike owners in Sacramento, California, came to similar findings (Popovich et al., 2014). Common themes from the participant interviews about the positive aspects of using an e-bike included: mitigating issues of age, injury or disability; better acceleration and higher speeds; longer distances travelled; not being fatigued or sweaty; going up hills easily; being able to bike in very hot weather; and, being able to use the car less and spend less on gas. Several participants emphasized that the e-bike was a lot of fun to use, and that this reason was a primary motivator for using their e-bike. As one 59-year-old female participant stated: "You can get places fast and carry a lot of stuff. It's as fast as driving. It gives you exercise but doesn't exhaust you. It takes all the drudgery out of bicycling and puts the joy back in."

In a Norwegian study of the effects of e-bikes use on conventional bicycle and other transport mode use (Fyhri, 2015), the authors' research quantitatively tests the hypothesis that e-bike use increases the total amount of cycling. Participants were provided an e-bike for 2 or 4 weeks, tracked by a GPS, and their results were compared to a control group. The study concluded that e-bikes resulted in considerable increases in cycling in terms of number of trips and distance cycled, and as a share of total transport trips. E-bikes affected both commuting and non-commuting purposes, though the distance travelled was most impacted for commuting. The impact of e-bikes was greater for women. There was no difference between different age groups. It was also found that e-bike use increased over time.

In a subsequent Norwegian study also headed by Fyhri, 5500 car owners were surveyed to determine their perceptions of e-bikes and their willingness to pay ("WTP") for one (Fyhri et al., 2017). A sample of survey participants were then given access to an e-bike for 2 to 4 weeks, after which they were again given the same survey. The results showed that there was a significant increase in WTP for an e-bike after the trial period, indicating a high level of satisfaction with their e-bike experience. The results also showed that participants favoured benefits of the e-bike were the ability to ride fast uphill and to travel farther and faster with less exertion and sweating. It was also found that current cyclists were least interested in e-bikes, suggesting that new e-bike users would be commuters substituting away from vehicles. The authors conclude that in countries where e-bikes are still a niche product, e-bike trials can be effective at spreading awareness.

In another Norwegian study (Sundfor et al., 2017) it was concluded that current conventional cyclists are less interested in purchasing an e-bike than non-cyclists, and e-bikes are more appealing to sedentary people who have little interest in physical activity. Sedentary e-bike users in the study increased the amount of cycling they did, and reported an increase in total levels of physical activity, suggesting e-bikes could have a positive impact on public health generally.

A recent study of Dutch e-bike users who commute from small villages to the city of Groningen explores the motives, travel behaviour and experiences of those commuters (Plazier et al., 2017). The study participants were all current e-bike owners and regular users, who also owned conventional bicycles but who did not consider conventional bikes as serious alternative to their cars for commuting due to long travel times and excessive exercise causing sweatiness and fatigue. Their reasons for purchasing an e-bike varied, with some motivated by a subsidy, others motivated by health reasons, and some who just did not like driving or taking transit. The participants wore GPS trackers for two weeks and were then interviewed. The GPS data showed that participants used e-bikes for 72.6% of all commuter trips, more than cars (22%) or bus (6.2%); commute distance was an average of 14.1 km as compared to 24 km for cars and 20.5 km for bus; and travel time was longer than by car but similar to taking the bus. The main reasons provided for not using the e-bike were weather (i.e., heavy rain, but participants noted that wind was no longer a factor with an e-bike) and daily agenda (i.e., days when needing to make multiple trips). The primary motivators for using the e-bike for commuting were enjoying being outside, physical exercise, freedom from transit schedules, and disconnecting from work. Overall, commuting by e-bike had the benefits of conventional cycling without the disadvantages. The study's authors conclude that enjoyability of commuting by e-bike may be a key factor in e-bikes being an effective substitute for vehicles.

Another study from the Netherlands (Lee et al., 2015) focuses on the issue of whether electric bike trips replace motor vehicle trips. The average age of e-bike owner respondents was 60 years old, reflecting purchase patterns in that country. It was found that e-bike trips replace both the conventional bicycle (41%) and motor vehicles trips (40%), but are more likely to replace automobiles for commuting.

Yet another study from the Netherlands study (Kroesen, 2017) came to similar conclusions using different methods, finding that e-bikes replaced conventional bikes and to a lesser extent vehicles. That study also found that car owners are more willing to use e-bikes as an alternative compared to the conventional bicycle or public transport.

A study of Swedish e-bike users focussed on the potential for CO2 reductions by e-bike use and on differences between urban/suburban and urban e-bike use (Hiselius & Svensson, 2017). The authors found that large reductions in CO2 emissions result when e-bikes replace car trips, at an average of 8.2kg of CO2 per week per e-bike user (394kg/year). The mode of transport replaced by e-bike depends on where the person lives, and on the purpose of the trip. Urban e-bike riders tend to replace conventional bike trips more than rural users (11-15% vs. 19-37%, depending on type of trip), and rural users tend to replace more vehicle trips (42-60% vs. 71-86%, depending on type of trip). An e-bike is more likely to replace a vehicle for people commuting to work from a rural area than for someone living in the city (75% vs. 52%), however less rural e-bike owners use their e-bike to commute than urban e-bike owners (52% vs. 66%). The average number of days per week an e-bike trip substituted a vehicle trip for commuting to work/school was over 3 for urban e-cyclists and 2.5 for rural e-cyclists. Overall these findings suggest a higher potential for car substitution for commuting, and consequently higher reductions in GHG emissions, for rural/suburban residents using e-bikes.

A UK study (Pierce et al., 2013) of a single National Health Services general practitioner who substituted an e-bike for a vehicle for work commutes (all other types of trips could be made by car), found that this resulted in a reduction of CO2 emissions by 748 kg per year, representing a 35% reduction of CO2 emissions for the participant's overall vehicle use.

A Swiss study (Moser et al., 2018) considered the challenge to e-bike adoption posed by existing habits of vehicle users, that is, the difficulty in convincing habitual car drivers to switch to e-bikes. Switzerland has an annual e-bike promotional programme whereby participant car owners trade their car keys for a e-bike for 2 weeks and at the end of the trial are giving a coupon for 20-25% off the purchase of an e-bike. The effectiveness of this programme was the subject of the study. Programme participants were predominantly educated men, with a mean age of 43.6, all of whom owned one or two cars. One year after the end of the programme, 44% of participants had bought an e-bike, and 17% reported intending to buy one. The study also found that habitual association to car travel had reduced significantly, which the authors state suggests a long-term effect on participants' habitual use cars. For participants who purchased an e-bike, they tended to associate using their e-bike for more types of trips, in addition to having less tendency to associate transport trips with their vehicles than before.

In a Belgian study of the potential for e-bikes to promote active aging for older adults (Cauwenberg et al., 2018), the authors found that being able to bike longer distances than with a conventional bike was the most important benefit to e-bike use for older adults (35%), followed by e-biking allowing continued biking otherwise not possible due to health condition (26%). The weight of the e-bike was cited as the most important disadvantage (33%), followed by "no disadvantage at all" at (29%) and fear of theft (11%). Older e-bike users reported a mean frequency of 12 trips / month in the spring/summer/fall and 2 trips / month in the winter, with median weekly usage at 135 minutes per week. E-bike trips predominantly replaced trips that would have been made by conventional bike (72%) and by car (50%), while participants also reported making trips by e-bike that would not have made at all (22%). Although only noted as a disadvantage by 10% of participants, 27% of participants had an e-bike accident; however, these crash statistics are not dissimilar to those for conventional bikes. The authors' findings also suggest that e-bikes may enable older women to cycle as much as men.

A study conducted in Brighton, England, was designed to evaluate the likely attractiveness of e-bikes to commuters in an urban context in the UK, a country where cycling rates are low and there is scepticism that bikes can replace cars at any significant level. Brighton was selected due to it being hilly and windy, conditions that deter conventional cycling. In the study 80 employees of two firms were provided an e-bike for 6-8 weeks and were told to use the bike as much or as little as they wished. Over 50% of participants used the e-bike 3 or more days per week and commuted to work an average of 2 days per week. 43% reported travelling less by car overall, indicating an overall reduction of car mileage by at least 20%. 59% of participants reported an increase in physical activity, including 21% who reported a major increase. After the trial period, approximately 38% of participants who only owned a conventional bike reported expecting to increase the amount they cycle in the future, with the number increasing to 76% if an e-bike were available (with the majority of those predicting a “major increase”). Furthermore, 73% of participants said they would cycle to work at lease one day a week if they had an e-bike available (compared to 29% for conventional bike), with about 25% reporting the intention to cycle to work by e-bike (if one were available) 5 days a week. In a follow up survey one year later, 35% of the of participants reported increased conventional cycling since the trial, though only 8% had purchased an e-bike. The authors conclude that e-bike trials can result in increased e-bike use. They further conclude that their data indicates a continuum of e-bike use across individuals.

A Netherlands study (Plazier et al., 2017b) considered the potential for e-bike use among the younger population as a substitute for using overly congested public transit. Participants were university students who either used a conventional bike or took transit. They were provided an e-bike for 4-5 weeks, after which they were offered the possibility of buying an e-bike at a reduced price. The reaction to the e-bike experience was overwhelmingly positive: 97% said they would like to own an e-bike; 94% said an e-bike is an appealing alternative to conventional bikes; 100% agree that using an e-bike is easy and fun; 95% said they arrived at school without sweating; 78% said an e-bike was an appealing alternative to transit; and 79% said they felt safe in traffic on an e-bike. Interviewees emphasized the value of increased speed and shorter commute times, as well as being independent from bus and train schedules. However, despite these positive experiences, participants did not view an e-bike as worth the investment due to the cost, as compared to existing free options of public transit and conventional cycling.

Appendix B – Calculations

Commute Trips in Metro Vancouver: Statistics and Calculations

Total trips per weekday, all trip purposes (2011): 6.1 million (TransLink, 2013)

Total weekday commute trips by all trip types (2011): 2.1 million (TransLink, 2013)

Total weekday car commute trips (2.1 million x 67%): 1.4 million

Total weekday commute trips by all trip types per week (2.1 million x 5 days): 10.5 million

Total weekday car commute trips per week (1.4 million x 5 days): 7 million

Average car commute distances, one way (2011): 14.2 km (TransLink, 2013, Figure 4.1.1)

Median car commute distance, one way (2016): 8 km (Statistics Canada, February 2019, Table 5)

TransLink 2040 target for cycling = 15% of all trips under 8 km = 457,500 trips per day by cycling (6.1 million trips per day x 7.5% [8km assumed to be median distance for all trips])

15% of commuting trips under 8km = 2.1 million trips per day x 50% (excluding trips over 8k) x 15% = 157,500 cycling commute trips per day (787,500 per week)

Policy Effectiveness Calculations

Option 1: Expansion of Mobi Docking Station Bikeshare

2,500 e-bikes x 8 trips per day x 50% of trips for commuting purposes x 20% replacing car trips = 2,000 e-bike trips in place of car commute trips per day.

Total commute trips per week, year one and year seven (2,000 daily trips x 5 days) = 10,000 trips

Total commute trips per year (10,000 weekly trips x 52 weeks) = 520,000 trips

Total commute trips over seven years (520,000 trips x 7 years) = 3.64 million trips

Percentage of weekly car commute trips (10,000 commute trips / 7 million weekly car commute trips) = 0.14%

Percentage of weekly car commute trips under 8 km (10,000 / 3.5 million) = 0.28%

Commute trips per e-bike per week (10,000 weekly trips / 2,500 e-bikes) = 4

Commute trips per e-bike per year (4 x 52) = 208

Option 2: Dockless Bikeshare

12,500 e-bikes x 8 trips per day x 50% of trips for commuting purposes x 40% replacing car commute trips x 90% due to reliability concerns = 18,000 e-bike trips in place of car commute trips per day

Total trips per week, year one and year seven (18,000 x 5 days) = 90,000 trips

Total trips per year (90,000 x 52 week) = 4.68 million

Total trips over seven years (4.68 million x 7 years) = 32.76 million trips

Percentage of weekly car commute trips (90,000 / 7 million) = 1.2%

Percentage of weekly car commute trips under 8 km (90,000 / 3.5 million) = 2.4%

Commute trips per e-bike per week (90,000 trips / 12,500 e-bikes) = 7.2

Commute trips per e-bike per year (7.2 x 52) = 374

Option 3: $1,000 subsidy at $45 million funding ($15 million / year for 3 years)

7,500 e-bikes year 1 + 5,500 e-bikes year 2 + 3,500 e-bikes year 3 = 16,500 e-bikes x 0.50 to apply to only Metro Vancouver = 8,250 non-free rider e-bikes after three years

Trips in place of car commutes per week in year one (3,750 e-bikes x 0.85 reduction for low density commuters x 3 trips/week) = 9,562

Trips in place of car commutes per week in years three to seven (8,250 e-bikes x 0.85 reduction for low density commuters x 3 trips/week) = 21,038

Trips in place of car commutes in year one (3,750 e-bikes x 0.85 reduction for low density commuters x 3 trips/week x 52 weeks) = 497,250

Trips in place of car commutes in year two (6,500 e-bikes x 0.85 reduction for low density commuters x 3 trips/week x 52 weeks) = 861,900

Trips in place of car commutes in year three to seven (8,250 e-bikes x 0.85 reduction for low density commuters x 3 trips/week x 52 weeks) = 1,094,000

Total trips in seven years (1,094,00 x 4 years + 861,900 (y2) + 497,224 (y1)) = 5.73 million

Percentage of weekly car commute trips in years three to seven (21,037 / 7,000,000) = 0.3%

Percentage of weekly car commute trips under 8 km (21,037 / 3.5 million) = 0.6%

Option 4: E-Cyclescheme

164,000 e-bikes / year in UK in 2014 (population of 64 million)

Population of BC in 2019 = 5 million = 7.8% of 2014 UK population

164,000 e-bikes x 0.078 = 12,800 e-bikes x 0.5 Metro Vancouver population of BC = 6,400 e-bikes per year

Total e-bikes over seven years (6,400 e-bikes x 7 years) = 44,800

Weekly trips in place of car commutes in year one: 6,400 e-bikes x 0.8 new cycle commuters in place of cars x 5 commute trips per week = 25,600 trips per week in place of car commutes

Trips in place of car commutes for year one (25,600 trips x 52 weeks) = 1.33 million trips

Weekly trips in place of car commutes for year seven (44,800 e-bikes x 0.8 new cycle commuters in place of cars x 5 commute trips per week) = 179,200 per week (35,840 per week day)

Trips per year in place of car commutes in year seven (179,200 trips per week x 52 weeks) = 9.32 million

Calculation of total e-bike commute trips in place of a car over seven years:

Year	Total E-bikes Deployed	Total Trips per Year (x 0.8 [20% discount] x 5 trips / week x 52 weeks / year)
1	6400	1,331,200
2	12800	2,662,400
3	19200	3,993,600
4	25600	5,324,800
5	32000	6,656,000
6	38400	7,987,200
7	44800	9,318,400
Total Trips over 7 years		37,273,600

Percentage of weekday car commute trips at end of year seven (35,840 / 1.4 million) = 2.56%

Percentage of weekday car commute trips under 8 km at end of year seven (35,840 / 700,000 [excluding trips over 8km, assuming 8km median]) = 5.1%

Percentage of weekly weekday commute trips under 8 km of all types at end of year seven (35,840 / 1.05 million [excluding trips over 8km, assuming 8km median]) = 3.4%

Percentage of all weekday trips under 8km at end of year seven = 1.2% (35,840 trips per day / 3.05 million trips per day [excluding trips over 8km, assuming 8km median])

Percentage of all weekday trips at end of year seven = 0.6% (35,840 trips per day / 6.1 million trips per day)

Governmental Cost Calculations

Docking Station Bikeshare

$25 million (capital cost) + $21 million (shortfalls in annual revenue at $3 million per year x 7 years) + $21 million (municipal operation costs of $3 million per year x 7 years) = 67 million / 7 years = 9.57 million / year

E-bike total cost over seven years (capital and operational) = $67 million (5000 e-bikes and regular bikes and docking stations) x 0.50 (e-bikes only) = $33.50 million / 2,500 e-bikes = $13,400 per e-bike

Cost per e-bike commute trip in place of car over seven years = $33.5 million (e-bike only program costs) / 3.64 million trips (total trips over 7 years) = $9.20

Dockless Bikeshare

$0 if private providers economically viable, assuming licence fees cover all indirect governmental administrative costs

Cost over seven years = $5 million / year if dockless providers not financially viable x 7 years = $35 million

E-bike total cost over seven years (capital and operational) = $35 million (25,000 e-bikes and regular bikes) x 0.50 (e-bikes only) = $17.50 million / 12,500 e-bikes = $1,400 per e-bike

Cost per e-bike commute trip in place of car over seven years = $17.5 million (e-bike only program costs at year 7) / 32.76 million trips (total e-bike trips over 7 years) = $0.53

Subsidy

$15 million per year x 3 years = $45 million (all of BC) x 0.50 (applied to Metro Vancouver) = $22.50 million

Implementation costs = $100,000 per year x 3 years = $300,000 (all of BC) x 0.50 (applied to Metro Vancouver) = $150,000

Total cost for Metro Vancouver ($22.50 million + $0.15 million) = $22.65 million

Total costs averaged over 7 years ($22.65 / 7 years) = $3.23 million

Total cost per e-bike ($22.65 million / 8,250 e-bikes) = $2,745

Cost per e-bike commute trip in place of car over 7 years = $22.65 million (total program cost at year 7, Metro Vancouver only) / 5.73 million trips (total trips over 7 years) = $3.95

<u>E-Cyclescheme</u>

Total governmental costs per year (all of BC) = 12,800 e-bikes per year x $2,500 (average loan) x 0.147 (average income tax rebate plus PST exemption) + $500,000 (annual administrative costs) = $5.20 million per year

Total governmental costs per year (Metro Vancouver only) = 6,400 e-bikes per year x $2,500 (average loan) x 0.147 (average income tax rebate plus PST exemption) + $250,000 (annual administrative costs) = $2.60 million

Total costs after 7 year period (assuming constant rates of participation, all of BC) = $36.40 million

Total costs after 7 year period (assuming constant rates of participation, Metro Vancouver only) = $18.21 million

Average cost per year over 7 years (assuming constant rates of participation, Metro Vancouver only) = $2.60 million

Total cost per e-bike ($18.21 million / 44,800 e-bikes) = $406

Cost per e-bike commute trip in place of car over 7 years = $18.21 million (Metro Vancouver program cost at year 7) / 37.27 million trips (total trips over 7 years) = $0.49

<u>E-Cyclescheme : CO2 Reduction Calculations as of Year 7</u>

Calculation using Hiselius & Svensson findings:

272 kg CO2 average reduction for e-bike users in Sweden, taking into account bad weather days (Hiselius & Svensson, 2017)

Hiselius & Svensson calculation: 38,400 e-bikes (44,800 x 0.80 [20% discount]) x 272kg CO2 reduction per e-bike per year = 10,444 tonnes CO2 per year as of year seven

Calculation for e-bike replacing a car for all commute trips:

Average passenger vehicle (USA) emits 404 grams of CO_2 per mile (250g per km) (EPA Green Vehicle Guide: https://www.epa.gov/greenvehicles/greenhouse-gas-emissions-typical-passenger-vehicle)

Metro Vancouver average car commute: 14.2 km (28.4 km round trip).

Metro Vancouver median car commute and assumed median e-bike commute: 8 km (16 km round trip)

CO_2 for median car commuter per year, commuting purposes only, assuming 5 days per week, 49 weeks (assuming 3 weeks vacation) per year (16 km x 5 days x 49 weeks = 3,920km x 250g CO_2/km = 980,000g (980 kg) CO_2/year

CO_2 reduction for E-Cyclescheme e-bike in place of median car commuter: 9.32 million trips (per year in year 7) x 8 km per trip (assumed average e-bike commute trip) = 74.5 million km x 250g CO_2/km = 18.64 billion grams of CO_2 per year = 18.64 million kg CO_2 per year = 18,640 tonnes CO_2 per year

Total BC GHG emissions = 62.3 tonnes CO_2 equivalent (Province of BC. *Trends in GHG Emissions in B.C. (1990-2016).* http://www.env.gov.bc.ca/soe/indicators/sustainability/ghg-emissions.html)

Percentage of BC total GHG emission per year (18,640 / 62.3 million tonnes CO_2) = 0.03%

Percentage of BC GHG emissions from personal use motor vehicles (62.3 million tonnes CO_2 x 0.14 [14% from personal transport] = 8,722,000 tonnes CO_2) = 18,640 / 8,722,000 = 0.2% for BC

Total Metro Vancouver GHG emissions = 15 million tonnes CO_2 equivalent (Metro Vancouver. (2015). *2015 Lower Fraser Valley Air Emission Inventory and Forecast*. http://www.metrovancouver.org/services/air-quality/AirQualityPublications/2015LowerFraserValleyAirEmissionsInventory.pdf)

Percentage reduction of Metro Vancouver GHG emissions (15 million tonnes) = 18,640 / 15 million = 0.1%

Percentage reduction of Metro Vancouver GHG emissions from personal use motor vehicles (15 million tonnes CO_2 x 0.31 [31% from personal transport] = 4.65 million tonnes CO_2) = 18,640 / 4,650,000 = 0.4%

Percentage reduction of Metro Vancouver GHG emissions from personal use motor vehicles for commuting purposes (4.65 tonnes CO_2 x 0.31 [31% from personal transport] = 1.58 million tonnes CO_2) = 18,640 / 1,580,000 = 1.2%